Conference Agenda

20th conference in series of the European Fuel Cell Forum in Lucerne

12th EUROPEAN SOFC & SOE FORUM 2016

5 – 8 July 2016, Kultur und Kongresszentrum Luzern - KKL Lucerne/Switzerland

Conference Chairman:

Prof. Nigel Brandon
Imperial College London

International Solid Oxide Fuel Cell and Electrolyser Conference with Exhibition, Industry Workshops and Tutorial

- Conference – Overview, Schedule and Program
- Abstracts of all Papers
- List of Authors, Participants and Exhibitors

SWISS
Official Carrier

Name:
Address:
Phone:
E-mail:

European Fuel Cell Forum, Olivier Bucheli & Michael Spirig, Obgardihalde 2, 6043 Luzern-Adligenswil/Switzerland
Phone +41 44-586-5644, Fax +41-43-508-0622, forum@efcf.com, www.EFCF.com

International conference on SOLID OXIDE FUEL CELL and ELECTROLYSER

12th EUROPEAN SOFC & SOE FORUM 2016

5 - 8 July 2016

Kultur- und Kongresszentrum Luzern (KKL) Lucerne / Switzerland

Chairman: Prof. Nigel Brandon

Imperial College London

Tutorial

by Dr. Günther G. Scherer ex PSI Villigen, Switzerland
Dr. Jan Van Herle EPF Lausanne, Switzerland

Exhibition

Event organized by European Fuel Cell Forum
Olivier Bucheli & Michael Spirig
Obgardihalde 2, 6043 Luzern-Adligenswil, Switzerland
Tel. +41 44-586-5644 Fax +41-43-508-0622 forum@efcf.com www.EFCF.com

12th EUROPEAN SOFC & SOE FORUM 2016

Table of content

	page
Welcome by the Organisers	I - 4
Conference Session Overview	I - 5
Conference Schedule and Program	I - 6
Poster Session I & II	I - 25
Abstracts of the Oral and Poster Presentations	I - 42
List of Authors	II - 1
List of Participants	II - 11
List of Institutions	II - 25
List of Exhibitors / List of Booths	II - 34/40
Outlook to the next European Fuel Cell Forums	II - 41

SWISS
Official Carrier

The event is endorsed by:

ALPHEA Rue Jacques Callot FR-57600 Forbach/France	**SIA (Berufsgruppe Technik und Industrie)** Selnaustr. 16 8039 Zürich / Switzerland	**UK HFC Association** c/o Synnogy, Church Barn Fullers Close Aldwincle Northants NN14 3UU United Kingdom
Bundesverband Mittelständische Wirtschaft, Landesverband Schweiz Baarerstrasse 135, 6301 Zug /Switzerland	**Swiss Academy of Engineering Sciences** Seidengasse 16 8001 Zürich / Switzerland	**Vätgas Sverige** Drottninggatan 21 SE-411 14 Gothenburg/Sweden
Euresearch Effingerstr. 19 3001 Bern /Switzerland	**Swiss Gas and Water Industry Association** Eschengasse 10 8603 Schwerzenbach / Switzerland	**VDI Verein Deutscher Ingenieure** Graf-Reck-Strasse 84 DE-40239 Düsseldorf / Germany
International Hydrogen Energy Association P.O. Box 248294 Coral Gables, FL 33124 / USA	**TEMONAS** - FCH-JU development consort. TEchnology MONitoring and ASsessment Tool info@temonas.eu	**Wiley – VCH Publishers** Boschstr. 12 DE-69469 Weinheim / Germany

Welcome by the Organisers

Olivier Bucheli & Michael Spirig

European Fuel Cell Forum
Obgardihalde 2
6043 Adligenswil-LUZERN / Switzerland

Welcome to the 12th European SOFC & SOE Forum 2016! The KKL, the beautiful and impressive Culture and Congress Center of Lucerne, Switzerland, provides the frame for this 20th event in series of successful conferences in Fuel Cell and Hydrogen Technologies. Competent staff, smooth technical services and excellent food allow the participants to focus on science, technology and networking in a creative and productive work atmosphere.

Once more we face the challenge to adapt the programme to the evolving needs of the scientific and technical community around high temperature electroceramic technologies. The interest in Power-to-Gas applications is confirmed. Solid Oxide membrane reactors also start to play a key role in other gas conversion applications. Handling electrodes in a generalised manner is therefore meaningful. With the high number of poster contributions, we maintain the extended poster sessions to allow for quality time for direct scientific exchange.

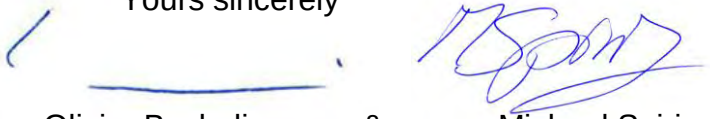
We want to keep one thing constant: The focus on facts and physics. The organisation is independent from public or private financial sponsors and can therefore grant for autonomy. The participants and exhibitors are the base of the event. Your participation made this event possible, please consider those days as your personal reward!

The COP 21 confirms the importance of reducing Greenhouse Gas Emissions and the energy turn-around (Energiewende). Within Europe, we start to see progress in commercialisation of FC based micro-CHP products. For the first time, the technology has an opportunity to provide a pay-back to end-users and society. However, Solid Oxide technology is yet far away from full recognition of its potential and role it can play! Major efforts are still required, from materials and engineering over manufacturing and innovative business models. The European Fuel Cell Forum aspires to provide an exchange platform that those efforts can be carried forward in a targeted manner – and allow for joint progress of the whole industry!

We would like to thank our conference chair Prof. Dr. Nigel Brandon, the Scientific Organising Committee and the Scientific Advisory Committee for their excellent work. Based on 290 contributions, they have composed a sound scientific programme picturing the recent progress in high temperature electroceramics from more than 30 countries and 6 continents – we look forward to seeing this exciting programme of the European SOFC & SOE Forum 2016. Again a Special Issue of “Fuel Cells – From Fundamental to Systems” will be edited from invited papers. We hope that the charming and inspirational atmosphere of Lucerne allows the participants to initiate and deepen partnerships that result in true products and solutions for society, putting together some more pieces in the emerging picture of our future energy system.

Our sincere thanks also go to all the presenters, the session chairs, the exhibitors, the International Board of Advisors, the media, the KKL staff and our co-workers. We thank all of you for your attendance and support. May we all have a wonderful week in Lucerne with fruitful technical debates and personal exchanges!

Yours sincerely



Olivier Bucheli & Michael Spirig

We are looking confident on the 2016 event and the future with:

- ► 6th EUROPEAN PEFC & Electrolyser FORUM 4 - 7 July 2017
- ► 13th EUROPEAN SOFC & SOE FORUM 3 - 6 July 2016

Conference Session Overview

Session	**Luzerner Saal** (ground floor)	Session	**Auditorium** (1st floor)
A01	**P1** - Opening Session		
A02	**P2** - Fuel Cell Market - Korean Industry - EU Overview		
A03	Companies & Major groups development status I	**B03**	State of the art & novel processing routes
A04	Tract A (ground- and first floor)	Poster Session I covering All Oral Session Topics	
A05	Companies & Major groups development status II	**B05**	Lifetime: Materials and cells
A06	R&D at institutions - Overviews and status	**B06**	Electrolytes, interconnects, seals
A07	**P3** - Energy Revolution: Smart innovations & early adopters		
A08	Lifetime: Cells & Stacks	**B08**	Modelling, validation & optimisation: Cell & stack
A09	Cell design and characterisation	**B09**	Metal supported SOFCs
A10	Tract A (ground- and first floor)	Poster Session II covering All Oral Session Topics	
A11	Lifetime: Stacks & systems	**B11**	Modelling, validation & optimisation: System
A12	Stack design and characterisation	**B12**	Advanced characterisation tools and techniques
A13	Development of systems & balance of plant components	**B13**	Anodes: State-of-the-art & novel materials I
A14	Reactors, separators & storage based on solid oxide tech.	**B14**	Anodes: State-of-the-art & novel materials II
A15	Current and future market issues	**B15**	Cathodes: State-of-the-art & novel materials
A16	**P4** - Closing Ceremony, Keynote by the Gold Medal Winner		**Legend:** Px: = Plenary;

Conference Schedule & Programme

Wednesday, July 6, 2016

Luzerner Saal

Morning		Morning
09:00	**P1: Opening Session (A01)** **Nigel Brandon, O. Bucheli, M. Spirig**	**A01**
09:00	**Welcome by the Organizers** Olivier Bucheli, Michael Spirig European Fuel Cell Forum, Luzern/Switzerland	A0101
09:05	**Welcome by the Chair** Nigel Brandon Imperial College London, London/UK	A0102
09:15	**Welcome to Switzerland: FCH Research & Realisation** Stefan Oberholzer, Rolf Schmitz, Walter Steinmann Swiss Federal Office of Energy, Bern/Switzerland	A0103
09:30	**P2: Fuel Cell Market - Korean Industry - European Overview** **Nigel Brandon**	**A02**
09:30	**The Fuel Cell Industry 2015: the most shipments yet** David Hart (1), Franz Lehner (1) E4Tech, Lausanne/Switzerland	A0201
09:50	**Korea: Current status of Fuel Cell Industry** Hae-Weon Lee Korea Institute of Science and Technology (KIST), Seoul/Korea	A0202
10:10	**Europe: Overview on FCH-JU projects & activities in stationary applications** Mirela Atanasiu FCH JU, Busssles/Belgium	A0203
10:30	**Break - Ground Floor in the Exhibition**	

International Board of Advisors

Prof. Joongmyeon Bae, KAIST, Daejeon/Korea
Prof. Frano Barbir, Chair, Unido/Croatia
Dr. Ulf Bossel, ALMUS AG/Switzerland
Dr. Niels Christiansen, NCCI innovation/Danmark
Dr. Olaf Conrad, University of Cape Town/South Africa
Dr. Karl Föger, Ceramic Fuel Cells/Australia
Dr. Nancy L. Garland, Department of Energy, USA
Prof. Hubert A. Gasteiger, TU München/Germany
John Bøgild Hansen, Haldor Topsøe A/S, Denmark
Prof. Angelika Heinzel, ZBT/Germany
Prof. Ellen Ivers-Tiffée, Karlsruhe Institute of Technology/Germany
Prof. Deborah Jones, CNRS/France
Prof. John A. Kilner, Imperial College London/UK
Dr. Jari Kiviaho, VTT/Finland
Dr. Ruey-yi Lee, INER/Taiwan
Dr. Florence Lefebrve-Joud, CEA/France
Prof. Paulo Emilio V. de Miranda, Coppe/Brazil
Prof. Mogens B. Mogensen, Technical University of Denmark
Prof. Vladislav A. Sadykov, Boreskov Institute of catalysis/Russia
Prof. Massimo Santarelli, Politecnico di Torino, Italy
Prof. Kazunari Sasaki, Kyushu University/Japan
Dr. Günther G. Scherer, ex PSI, Villigen/Switzerland
Dr. Günter Schiller, DLR Stuttgart/Germany
Dr. Subhash Singhal, Pacific Northwest National Laboratory/USA
Dr. Martin Smith, Uni St. Andrews/UK
Prof. Robert Steinberger-Wilckens, Chair; Uni Birmingham/UK
Prof. Constantinos Vayenas, University of Patras/Greece
Prof. Wei Guo Wang NIMTE/PR, China
Dr. Christian Wunderlich, IKTS/Germany

	Luzerner Saal		Auditorium	
11:00	**Companies & Major groups development status I** **Florence Lefebvre-Joud, David Hart**	**A03**	**State of the art & novel processing routes** **Yoed Tsur (tbc), Enrique Ruiz-Trejo**	**B03**
11:00	**Advances in Hexis' SOFC development** Andreas Mai, Felix Fleischhauer, J. Andreas Schuler, Roland Denzler, Volker Nerlich, Alexander Schuler Hexis Ltd., Winterthur	A0301	**Development of tubular proton conducting electrolysers** M.-L. Fontaine (1), C. Denonville, R. Strandbakke (2), E. Vøllestad (2), J.M. Serra (3), D.R. Beeaff (4), C. Vigen (4), T. Norby (2) (1) SINTEF Materials and Chemistry, Oslo/Norway, (2) University of Oslo, Oslo/Norway, (3) ITQ UPV-CSIC, Valencia/Spain, (4) CoorsTek Membrane Sciences Norway, Oslo/Norway	B0301
11:15	**Solid Oxide Fuel Cell Development at Versa Power Systems and FuelCell Energy** Brian Borglum (1), Hossein Ghezel-Ayagh (2) (1) Versa Power Systems, Ltd., Calgary/Alberta/Canada, (2) FuelCell Energy, Inc., Danbury/USA	A0302	**Silicon-supported Nano Thin Film Solid Oxide Fuel Cell Array with Superior Mechanical Stability** Jong Dae Baek, Yong-Jin Yoon, Pei-Chen Su School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore/Singapore	B0302
11:30	**Development status of Ceres Power Steel Cell technology: further improvements in manufacturability, durability and performance** Robert Leah, Adam Bone, Mike Lankin, Mahfujur Rahman, Eva Hammer, Ahmet Selcuk, Andy Clare, Subhasish Mukerjee, Mark Selby Ceres Power Ltd., Horsham/UK	A0303	**Anode with Ni-YSZ Nanostructures Infiltrated into YSZ Pillars** Keisuke Nagato (1,2), Lei Wang (1), Takaaki Shimura (3), Masayuki Nakao (1), Naoki Shikazono (3,4) (1) Graduate School of Engineering, The University of Tokyo, Tokyo/Japan, (2) JST PRESTO, Saitama/Japan, (3) Institute of Industrial Science, The University of Tokyo, Tokyo/Japan, (4) JST CREST, Saitama/Japan	B0303
11:45	**High-efficiency cogenerators from SOLIDpower SpA** Massimo Bertoldi (1), Olivier Bucheli (2), Alberto V. Ravagni (1,2) (1) SOLIDpower SpA, Mezzolombardo/Italy, (2) HTceramix SA, Yverdon-les-Bains/Switzerland	A0304	**Influence of Process Parameters on Microstructure and Permeability of Axial Suspension Plasma Sprayed Electrolytes in SOFCs** Mohit Gupta (1), Joel Kuhn (2), Olivera Kesler (2), Nicolaie Markocsan (1) University West, Trollhättan/Sweden	B0304

12:00	**25kW Stack Module Development Status at sunfire** Christian Walter (1), Thomas Strohbach (1), Peter Meisel (1), Kai Herbrig (1), Danilo Schimanke (1), Oliver Posdziech (1) sunfire GmbH, Dresden/Germany	A0305	**Aqueous Tape Casting for Multilayer and Co-sintered Ni/8YSZ Substrates for SOFC** Nor Arifin (1), Robert Steinberger-Wilckens (1), Tim Button (2) (1) Centre of Fuel Cell and Hydrogen Research, Chemical Engineering Department,University of Birmingham, Birmingham/UK, (2) School of Metallurgy and Material, University of Birmingham, Edgbaston/Birmingham/UK	B0305
12:15	**Development and Demonstration of a Novel Reversible SOFC System for Utility and Micro Grid Energy Storage** Joshua Mermelstein (1), Oliver Posdziech (2) (1) Boeing, Huntington Beach/USA, (2) sunfire GmbH, Dresden/Germany	A0306	**On the optimization of (Mn,Co)3O4 suspensions for electrophoretic deposition** Sophie Labonnote-Weber (1), Guttorm Syvertsen-Wiig (1), Hilde Lein (2), Andreas Richter (1) (1) Ceramic Powder Technology AS, Tiller/Norway, (2) Department of Materials Science and Engineering, Norwegian University of Science and Technology, Trondheim/Norway	B0306
12:30	**Lunch - 2nd Floor on the Terrace** **Coffee - Ground Floor in the Exhibition & 1st Floor in the Poster Session**			

Wednesday, July 6, 2016

Afternoon	Tract A (ground- and first floor)			Afternoon
13:15	**Poster Session I** **covering All Oral Session Topics** **Nigel Brandon, Jürgen Rechberger**	**A04**		

15:00	**Companies & Major groups development status II** **Robert Steinberger-Wilckens, Anke Hagen**	**A05**	**Lifetime: Materials and cells** **Viola Birss, Harumi Yokokawa**	**B05**
15:00	**Recent Advances in MSC Stack Technology for Mobile Applications at Plansee** Wolfgang Schafbauer, Christian Bienert, Matthias Rüttinger, Marco Brandner, Lorenz S. Sigl Plansee SE, Reutte/Austria	A0501	**Quantitative review of degradation and lifetime of solid oxide cells and stacks** Theis L. Skafte (1,2), Johan Hjelm (2), Peter Blennow (1), Christopher Graves (2) (1) Haldor Topsoe A/S, Kgs. Lyngby/Denmark, (2) Department of Energy Conversion and Storage, Technical University of Denmark, Roskilde/Denmark	B0501
15:15	**Solid Oxide Fuel Cell APUs for Transport Applications** Juergen Rechberger, Michael Reissig, Jörg Mathe, Bernd Reiter AVL List GmbH, Graz/Austria	A0502	**Electrochemical Analysis of Sulfur Poisoning in Ni/8YSZ Cermet Anodes** Sebastian Dierickx, André Weber, Ellen Ivers-Tiffée Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany	B0502
15:30	**Status of Elcogen unit cell and stack development** Matti Noponen (1), Paul Hallanoro (1), Jukka Göös (1), Enn Õunpuu (2) (1) Elcogen Oy, Vantaa/Finland, (2) Elcogen AS, Tallinn/Estonia	A0503	**Phase decomposition of La2NiO4+δ under Cr- and Si-poisoning conditions** N. Schrödl (1), A. Egger (1), E. Bucher (1), C. Gspan (2), T. Höschen (3), F. Hofer (2), W. Sitte (1) (1) Chair of Physical Chemistry, Montanuniversitaet Leoben, Leoben/Austria, (2) Institute for Electron Microscopy and Nanoanalysis (FELMI), Graz University of Technology & Graz Centre for Electron Microscopy (ZFE), Graz/Austria, (3) Max Planck Institute for Plasma Physics, Garching/Germany	B0503
15:45	**Sylfen: a new energy storage company using solid oxide fuel cell & electrolysis technology** Nicolas Bardi, Caroline Rozain Sylfen, Grenoble/France	A0504	**Experimental and theoretical evaluation of sulfur poisoning of Ni/CGO SOFC anodes** Matthias Riegraf (1), Vitaliy Yurkiv (1), Rémi Costa (1), Günter Schiller (1), Andreas Mai (2), K. A. Friedrich (1) (1) German Aerospace Center (DLR), Stuttgart/Germany, (2) Hexis Limited, Winterthur/Switzerland	B0504
16:00	**Break - Ground Floor in the Exhibition & 1st Floor in the Poster Session**			

Wednesday, July 6, 2016

Afternoon | Luzerner Saal | Auditorium | Afternoon

16:30	R&D at institutions - Overviews and status Subhashish Mukerjee, Pei-Chen Su	A06	Electrolytes, interconnects, seals Prabhaker Singh, Truls Norby	B06
16:30	**Status of SOFC/SOEC Stack and System Development and Commercialization Activities at Fraunhofer IKTS** Mihails Kusnezoff, Stefan Megel, Matthias Jahn, Thomas Pfeifer, Jens Baade Fraunhofer IKTS, Dresden/Germany	A0601	**Usage of Ceria for Solid Oxide Electrochemical Cells** Hirofumi Sumi (1), Eisaku Suda (2), Masashi Mori (3) (1) National Institute of Advanced Industrial Science and Technology (AIST), Moriyama-ku/Nagoya/Japan, (2) Anan Kasei Co., Ltd., Anan/Tokushima /Japan, (3) Central Research Institute of Electric Power Industry (CRIEPI), Yokosuka/Kanagawa/Japan	B0601
16:45	**Current Status of NEDO Durability Project with an Emphasis on Correlation Between Cathode Overpotential and Ohmic Loss** Harumi Yokokawa Institute of Industrial Science, The University of Tokyo, Tokyo/Japan	A0602	**Intermediate temperature proton conducting fuel cells for transportation applications** S (Elango) Elangovan (1), Dennis Larsen (1), Cortney Kreller (2), Mahlon Wilson (2), Yu Seung Kim (2), Kwan Soo Lee (2), Rangachari Mukundan (2), Nilesh Dale (3) (1) Ceramatec, Inc., Salt Lake City/USA, (2) Los Alamos National Laboratory, Los Alamos/USA, (3) Nissan Technical Center, Michigan/USA	B0602
17:00	**Stack Development at Forschungszentrum Jülich** Ludger Blum (1), Qingping Fang (1), Nikolaos Margaritis (2), Roland Peters (1) (1) Institute of Energy and Climate Research, (2) Central Institute of Engineering, Electronics and Analytics - Forschungszentrum Jülich GmbH, Jülich/Germany	A0603	**Thin film perovskite coatings and their application for SOFC ferritic steel interconnects** Stefano Frangini (1), Andrea Masi (1,2), Manuel Bianco (3), Jong-Eun Hong (4), Maurizio Carlini (2), Jan Van Herle (3), Robert Steinberger-Wilckens (4) (1) ENEA CR Casaccia, Rome/Italy, (2) DAFNE, University of Tuscia, Viterbo/Italy, (3) FUELMAT Group, Inst. Mech. Eng., Ecole Polytechnique Fédérale de Lausanne Valais (EPFL Valais), Sion/Switzerland, (4) Centre for Fuel Cell and Hydrogen Research, School of Chemical Engineering, University of Birmingham, Birmingham/England	B0603

17:15	**NEXT-FC: An SOFC-Center for tight industry-academia collaboration and demonstration** K. Sasaki (1-5), S. Taniguchi (1,2,5), Y. Shiratori (1-5), A. Hayashi (1-5), T. Oshima (3), Y. Tachikawa (5), M. Nishihara (4), J. Matsuda (4), T. Kawabata (2), M. Fujita (2), A. Zaitsu (2) (1) Next-Generation Fuel Cell Research Center (NEXT-FC), (2) International Research Center for Hydrogen Energy, (3) Faculty of Engineering (Hydrogen Energy Systems), (4) International Institute for Carbon-Neutral Energy Research (WPI-I2CNER) Kyushu University, (5) Center for Co-Evolutional Social Systems (CESS) - Kyushu University, Fukuoka/Japan	A0604	**Effect of temperature on the oxidation and Cr evaporation behavior of Co and Ce/Co coated steel** Hannes Falk-Windisch, Julien Claquesin, Jan-Erik Svensson, Jan Froitzheim Chalmers University of Technology, Energy and Materials, Göteborg/Sweden	B0604
17:30	**Status of CEA research and development on SOEC/SOFC cells, stacks and systems** J. Mougin (1), G. Roux (1), M. Reytier (1), J. Vulliet (2), F. Lefebvre-Joud (1) (1) CEA-Grenoble, LITEN, Grenoble/FRANCE, (2) CEA/-Le Ripault DMAT, Monts/France	A0605	**Benchmarking protective coatings for SOFC ferritic steel interconnects – The SCORED 2:0 project** Robert Steinberger-Wilckens (1), Shicai Yang (2), Kevin Cooke (2), Johan Tallgren (3), Olli Himanen (3), Stefano Frangini (4), Andrea Masi (4,5), Manuel Bianco (6), Jan Van herle (6), Jong-Eun Hong (1), Melissa Oum (1), Francesco Bozza (7), Alessandro Delai (8) (1) Centre for Hydrogen and Fuel Cell Research, School of Chemical Engineering, University of Birmingham, Birmingham/UK, (2) Teer Coatings Ltd, Miba Coating, Droitwich/UK, (3) VTT Technical Research Centre, Fuel Cells, Espoo/Finland, (4) ENEA CR Casaccia, Rome/Italy, (5) DAFNE, University of Tuscia, Viterbo/Italy, (6) FUELMAT Group, EPFL Valais, Sion/Switzerland, (7) Turbocoating S.p.a., Rubbiano di Solignano/Italy, (8) SOLIDpower S.p.a.	B0605
17:45	**Research and Development of SOFC and SOEC at DLR: from Next Generation Cells to Efficient and Effective Systems** Remi Costa, Günter Schiller, Marc Heddrich, Asif Ansar, K. Andreas Friedrich German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Stuttgart/Germany	A0606	**Glass ceramic sealants for CFY based SOFC** Jochen Schilm, Axel Rost, Mihails Kusnezoff, Alexander Michaelis Fraunhofer IKTS, Dresden/Germany	B0606
18:00	**End of Sessions**			
18:30	**20th EFCF Jubilee Swiss Surprise Night** Registered participants meet infront of KKL (water front)			

Thursday, July 7, 2016

Luzerner Saal

Morning

09:00	**P3: Keynote - Energy Revolution: Smart innovations & early adopters** **Nigel Brandon**	**A07**
09:00	**Changing data centers to change the world. How smart innovation and early adopters will usher in the next energy revolution.** Sean James, Microsoft Infrastructure & Operations , USA	A0701

Auditorium

Morning

09:30	**Lifetime: Cells & Stacks** **Rob Braun , Ludger Blum**	**A08**	**Modelling, validation & optimisation: Cell & stack** **Ellen Ivers-Tiffée, Jan Van herle**	**B08**
09:30	**20 000 Hours Steam Electrolysis with a Solid Oxide Cell** Annabelle Brisse, Josef Schefold European Institute for Energy Research (EIFER), Karlsruhe/Germany	A0801	**Simulation of the electrochemical impedance response of SOFC anodes: from the microstructural reconstruction to the physically-based modelling** Antonio Bertei, Enrique Ruiz-Trejo, Farid Tariq, Vladimir Yufit, Kristina Kareh, Nigel Brandon Department of Earth Science and Engineering, Imperial College London, London/UK	B0801
09:45	**Post-test analysis on a Solid Oxide Cell stack operated for 10700 hours in steam electrolysis mode** Giorgio Rinaldi (1), Stefan Diethelm (1), Pierre Burdet (1), Emad Oveisi (1), Jan Van herle (1), Dario Montinaro (2), Qingxi Fu (3), Annabelle Brisse (3) (1) École polytechnique fédérale de Lausanne Valais/Wallis, Sion/Switzerland, (2) SOLIDpower, Mezzolombardo/Italy, (3) European Institute for Energy Research , Karlsruhe/Germany	A0802	**Relaxation of stresses during reduction of anode supported SOFCs** Henrik Lund Frandsen, Christodoulos Chatzichristodoulou, Peter Stanley Jørgensen, Kawai Kwok, Peter Vang Hendriksen Technical University of Denmark, Roskilde/Denmark	B0802
10:00	**Degradation analysis of an SOEC stack operated for more than 10,000 h** Qingping Fang, Ludger Blum, Norbert H. Menzler Forschungszentrum Jülich GmbH , Institute of Energy and Climate Research, Jülich/Germany	A0803	**Designing Porous Cathode Structures for SOFCs** Jochen Joos, Helge Geisler, André Weber, Ellen Ivers-Tiffée Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany	B0803

10:15	**Long-term operation of a solid oxide cell stack for co-electrolysis of steam and CO2** Karsten Agersted (1), Ming Chen (1), Peter Blennow (2), Rainer Küngas (2), Peter Vang Hendriksen (1) (1) Department of Energy Conversion and Storage, Technical University of Denmark, Roskilde/Denmark, (2) Haldor Topsoe A/S, Kgs. Lyngby/Denmark	A0804	**Dealing with fuel contaminants degradation in Ni-anode SOFCs** Andrea Lanzini, Davide Papurello, Domenico Ferrero, Massimo Santarelli Energy Department, Politecnico di Torino, Torino/Italy	B0804
10:30	**Break - Ground Floor in the Exhibition**			

11:00	**Cell design and characterisation** **Qiong Cai, Kazunari Sasaki**	**A09**	**Metal supported SOFCs** **Dario Montinaro, Günter Schiller**	**B09**
11:00	**Mechanics of SOFC Contacting** Zhangwei Chen (1), Xin Wang (2), Nigel Brandon (3), Alan Atkinson (2) (1) Earth Science and Engineering, (2) Department of Materials, (3) Sustainable Gas Institute, Imperial College, London/UK	A0901	**Recent Results of the Christian Doppler Laboratory for Interfaces in Metal-Supported Electrochemical Energy Converters** Martin Bram (1,2), Marco Brandner (3), Jürgen Rechberger (4), Alexander Opitz (1,5) (1) Christian Doppler Laboratory for Interfaces in Metal-Supported Electrochemical Energy Converters, Jülich/Germany, (2) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK-1), Jülich/Germany, (3) Plansee SE, Innovation Services, Reutte/Austria, (4) AVL List GmbH, Graz/Austria, (5) Institute of Chemical Technologies and Analytics, Technical University Vienna, Vienna/Austria	B0901
11:15	**Relation between shape of Ni-particles and Ni migration in Ni-YSZ electrodes – a hypothesis** Mogens B. Mogensen, Anne Hauch, Xiufu Sun, Ming Chen, Youkun Tao, Sune D. Ebbesen, Peter V. Hendriksen Department of Energy Conversion and Storage, Technical University of Denmark (DTU), Roskilde/Denmark	A0902	**Validation methodology and results from a Ceres Power Steel Cell technology platform** Adam Bone, Oliver Postlethwaite, Robert Leah, Subhasish Mukerjee, Mark Selby Ceres Power Ltd., Horsham/UK	B0902

Thursday, July 7, 2016

Morning | Luzerner Saal | Auditorium | Morning

11:30	**Cation diffusion at the CGO barrier layer region of solid oxide fuel cells** M. Morales (1)*, V. Miguel-Pérez (1), A. Tarancón (1), M. Torrell (1), B. Ballesteros (2), J. M. Bassat (3), J. P. Ouweltjes (4), D. Montinaro (5), A. Morata (1) (1) IREC, Catalonia Institute for Energy Research, Dept of Advanced Materials for Energy Applications, Barcelona/Spain, (2) HTceramix SA, Yverdon-les-Bains/Switzerland, (3) CNRS, ICMCB, Pessac/France, (4) SOLIDPower SpA, Mezzolombardo/Italy	A0903	**Development of robust metal supported SOFCs and stack components in EU-METSAPP consortium** B.R. Sudireddy (1), J. Nielsen (1), Å. H. Persson (1), K. Thydén (1), K. Brodersen (1), S. Ramousse (1), D. Neagu (2), E. Stefan (2), J.T.S. Irvine (2), H. Geisler(3), A. Weber (3), G. Reiss (4), R. Schauperl (5), J. Rechberger (5), J. Froitzheim (6), R. Sachitanand (6), H. F. Windisch (6), J. E. Svensson (6), M. W. Lundberg (7), R. Berger (7), J. Westlinder (7), S. Hornauer (8), T. Kiefer (8) (1) Department of Energy Conversion and Storage, Technical University of Denmark, Roskilde/Denmark, (2) School of Chemistry, University of St Andrews, St Andrews/Scotland/UK, (3) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany, (4) ICE Strömungsforschung GmbH, Leoben/Austria, (5) AVL List GmbH, Graz/Austria, (6) Department of Chemistry and Chemical Engineering, Chalmers University of Technology, Gothenburg/Sweden, (7) AB Sandvik Materials Technology, Sandviken/Sweden, (8)ElringKlinger AG	B0903
11:45	**Direct-methane solid oxide fuel cells with ceria-coated Ni layer at reduced temperatures** Jin Goo Lee (1), Ok Sung Jeon (1), Ho Jung Hwang (2), Jeong Seok Jang (1), Yeyeon Lee (2), Sang-Hoon Hyun (3), Yong Gun Shul (1,2) (1) Department of Chemical and Bio-molecular Engineering, Yonsei University, Seoul/Republic of Korea, (2) Department of Graduate Program in New Energy and Battery Engineering, Yonsei University, Seoul/Republic of Korea, (3) Department of Materials Science and Engineering, Yonsei University, Seoul/Republic of Korea	A0904	**Development of advanced high temperature metal supported cell with perovskite based anode: a step toward the next generation of SOFC** Feng Han (1), Robert Semerad (4), Patric Szabo (1), Vitaliy Yurkiv (1), Laurent Dessemond (2,3), Rémi Costa (1) (1) German Aerospace Center (DLR), Stuttgart/Germany, (2) Université Grenoble Alpes, Laboratoire d'Electrochimie et de Physico-Chimie des Matériaux et des Interfaces, (3) CNRS, Laboratoire d'Electrochimie et de Physico-Chimie des Matériaux et des Interfaces, Grenoble/France, (4) Ceraco Ceramic Coating GmbH, Ismaning/Germany	B0904

12:00	**Investigation of high performance low temperature ceria-carbonate composite fuel cells** Muhammad Imran Asghar (1), Ieeba Khan (2), Suddhasatwa Basu (2), Peter D. Lund (1) (1) Department of Applied Physics, Aalto University, Aalto/Finland, (2) Department of Chemical Engineering, Indian Institute of Technology, New Delhi/India	A0905	**Development of metal supported proton ceramic electrolyser cells (PCEC) for renewable hydrogen production** M. Stange (1), E. Stefan (2), C. Denonville (1), Y. Larring (1), M.L. Fontaine (1), R. Haugsrud (2) (1) SINTEF Materials and Chemistry, Oslo/Norway, (2) University of Oslo, Oslo/Norway	B0905
12:15	**1D numerical modeling of direct ammonia solid oxide fuel cells** Masashi Kishimoto, Yuki Matsui, Hiroshi Iwai, Motohiro Saito, Hideo Yoshida Department of Aeronautics and Astronautics, Kyoto University, Nishikyo-ku/Kyoto/Japan	A0906	**Adapted Sintering of LSCF-Electrodes for Metal-Supported Solid Oxide Fuel Cells** D. Udomsilp (1,2), D. Roehrens (1,2), N.H. Menzler (2), W. Schafbauer (3), O. Guillon (2,4), M. Bram (1,2) (1) Christian Doppler Laboratory for Interfaces in Metal-Supported Electrochemical Energy Converters, Jülich/Germany, (2) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research – Materials Synthesis and Processing (IEK-1), Jülich/Germany, (3) PLANSEE SE, Innovation Services, Reutte/Austria, (4) Jülich Aachen Research Alliance: JARA-Energy, Aachen/Germany	B0906
12:30	**Lunch - 2nd Floor on the Terrace** **Coffee - Ground Floor in the Exhibition & 1st Floor in the Poster Session**			

Afternoon	Tract A (ground- and first floor)	Afternoon
13:15	**Poster Session II** **covering All Oral Session Topics** **Nigel Brandon, Jürgen Rechberger**	**A10**

Thursday, July 7, 2016

Thursday, July 7, 2016

Afternoon | Luzerner Saal | Auditorium | Afternoor

15:00	Lifetime: Stacks & systems Tony Wood, Jari Kiviaho	A11	Modelling, validation & optimisation: System John Bøgild Hansen, Mardit Matian	B11
15:00	**Post-Test Analysis of a Solid Oxide Fuel Cell Stack Operated for 35,000h** Norbert H. Menzler (1), Peter Batfalsky (2), Alexander Beez (1), Ludger Blum (1), Sonja-Michaela Groß-Barsnick (2), Leszek Niewolak (1), Willem J. Quadakkers (1), Robert Vaßen (1) (1) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK), Jülich/Germany, (2) Forschungszentrum Jülich GmbH, Central Institute for Engineering, Electronics and Analytics (ZEA), Jülich/Germany	A1101	**Efficient integration of SOFC and gasification system** Stephan Herrmann, Manuel Jimenez Arreola, Michael Geis, Sebastian Fendt, Hartmut Spliethoff Lehrstuhl für Energiesysteme, Technische Universität München, Garching/Germany	B1101
15:15	**Understanding lifetime limitations in the Topsoe Stack Platform using modeling and post mortem analysis** Peter Blennow, Jeppe Rass-Hansen, Thomas Heiredal-Clausen, Rainer Küngas, Tobias Holt Nørby, Søren Primdahl Haldor Topsoe A/S, Kgs. Lyngby/Denmark	A1102	**Development of the FlexPCFC: a Low-Cost Intermediate-Temperature Fuel-Flexible Protonic Ceramic Fuel Cell** Alexis Dubois (1), Kevin J. Albrecht (1), Chuancheng Duan (2), Jianhua Tong (2), Ryan O'Hayre (2), Robert J. Braun (1) (1) Department of Mechanical Engineering, (2) Department of Materials & Metallurgical Engineering, Colorado School of Mines, Golden/USA	B1102
15:30	**Understanding of SOEC Degradation Processes by means of a Systematic Parameter Study** Michael P. Hoerlein, Vitaliy Yurkiv, Günter Schiller, K. Andreas Friedrich German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Stuttgart/Germany	A1103	**A Thermodynamic Analysis of Integrated SOFC Cycles for Ships** L. van Biert, K. Visser, P.V. Aravind 3mE, Delft University of Technology, Delft/The Netherlands	B1103

15:45	**Durability assessment of SOFC stacks with several types of structures for thermal cycles during their lifetimes on residential use** Koki Sato (1), Takaaki Somekawa (1), Toru Hatae (1), Shinji Amaha (1), Yoshio Matsuzaki (1), Masahiro Yoshikawa (2), Yoshihiro Mugikura (2), Shunsuke Taniguchi (3), Toshihiro Oshima (3), Kengo Miyara (3), Kazunari Sasaki (3), Hiroshi Sumi (4), Makoto Ohmori (5), Harumi Yokokawa (6); (1) Tokyo Gas Co., Ltd., (2) Central Research Institute of Electric Power Industry, (3) Kyushu University, Fukuoka/Japan, (4) NGK Spark Plug CO. Ltd, Nagoya/Japan, (5) NGK Insulators Ltd., Tokyo/Japan, (6) The University of Tokyo, Tokyo/Japan	A1104	**Power to Power efficiencies based on a SOFC/SOEC reversible system** A. Chatroux, S. Di Iorio, G. Roux, C. Bernard, J. Mougin, M. Petitjean, M. Reytier CEA-Grenoble, LITEN, Grenoble/France	B1104
16:00	**Break - Ground Floor in the Exhibition & 1st Floor in the Poster Session**			

Thursday, July 7, 2016

Afternoon	Luzerner Saal		Auditorium	Afternoor
16:30	**Stack design and characterisation** **Annabelle Brisse, Andreas Mai**	**A12**	**Advanced characterisation tools and techniques** **Mogens Bjerg Mogensen, Ulirich Vogt**	**B12**
16:30	**Stability of SOFC cassette stacks during redox-thermal-cycling** Ute Packbier (1), Tim Bause (2), Qingping Fang (1), Ludger Blum (1), Detlef Stolten (1); (1) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK), Jülich/Germany, (2) ElringKlinger AG, Dettingen/Germany	A1201	**High spatial resolution monitoring of the temperature distribution from an operating SOFC** Manoj Ranaweera, Vijay Venkatesan, Erdogan Guk, Jung-Sik Kim Department of Aeronautical and Automotive Engineering, Loughborough University, Loughborough/UK	B1201
16:45	**Evaluation of a SOEC stack for hydrogen and syngas production: a performance and durability analysis** Mikko Kotisaari (1), Olivier Thomann (1), Dario Montinaro (2), Jari Kiviaho (1) (1) VTT Technical Research Centre of Finland Ltd., Fuel Cells, Helsinki/Finland, (2) SOLIDPower SpA, Trento/Italy	A1202	**Oxide ion blocking effect at SrZrO3/YSZ and Y-doped SrZrO3/YSZ interfaces** Katherine Develos-Bagarinao (1), Harumi Yokokawa (1, 2), Haruo Kishimoto (1) Teruhisa Horita (1), Katsuhiko Yamaji (1); (1) Research Institute for Energy Conservation, National Institute of Advanced Industrial Science and Technology, Tsukuba/Ibaraki/Japan, (2) Institute of Industrial Science, The University of Tokyo, Tokyo/Japan	B1202

17:00	**Investigation of a 500W SOFC stack fed with dodecane reformate** Massimiliano Lo Faro, Stefano Trocino, Sabrina C. Zignani, Giuseppe Monforte, Antonino S. Aricò CNR-ITAE, Messina/Italy	A1203	**Understanding performance limiting impacts in SOFCs - visualizing the nature of cathode/electrolyte interfaces using advanced focused ion beam/ scanning electron microscope (FIB-SEM) tomography techniques** F. Wankmueller (1), J. Szasz (1), J. Joos (1), V. Wilde (2), H. Stoermer (2), D. Gerthsen (2), E. Ivers-Tiffée (1) (1) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany, (2) Laboratory for Electron Microscopy (LEM), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany	B1203
17:15	**Performance Characteristics of Elcogen Solid Oxide Fuel Cell Stacks** Matti Noponen, Jukka Göös, Pauli Torri, Daniel Chade, Heikki Vähä-Piikkiö, Paul Hallanoro Elcogen Oy, Vantaa/Finland	A1204	**Experimental method to determine the changes of Ni content in operated SOFC anodes** Paolo Piccardo (1,2), Alex Morata (3), Valeria Bongiorno (1,2), Jan Pieter Ouweltijes (4) (1) Laboratory of Metallurgy and Materials, DCCI, University of Genoa, Genoa/Italy, (2) Institute for Energetics and Interphases, National Council of Research, Genoa/Italy, (3) IREC, Barcelona/Spain, (4) HTceramix SA, Yverdon/Switzerland	B1204
17:30	**Performance and degradation of an SOEC stack with different air electrodes** Y. Yan, Q. Fang, L. Blum, W. Lehnert Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research, Jülich/Germany	A1205	**In-Situ Measurement of cPOx Catalyst in Microtubular SOFC** Lois Milner, Artur Majewski, Robert Steinberger-Wilckens Centre for Hydrogen and Fuel Cell Research, School of Chemical Engineering, The University of Birmingham, Birmingham/UK	B1205
17:45	**Fuel Distributions in Anode-Supported Honeycomb Solid Oxide Fuel Cells** Hironori Nakajima(1), Tatsumi Kitahara (1), Sou Ikeda (2) (1) Department of Mechanical Engineering, Faculty of Engineering, (2) Department of Hydrogen Energy Systems, Graduate School of Engineering, Kyushu University, Fukuoka/Japan	A1206	**Tomography beyond the pretty pictures to numbers for 3D SOFC Electrodes** Farid Tariq (1,2), Vladimir Yufit (1,2), Xin An (1), Ed Cohen (1), Kristina Kareh (1), Antonio Bertei (1), Enrique Ruiz-Trejo (1), Nigel Brandon (1,2) (1) Imperial College London, London/UK, (2) IQM Elements Ltd, Quantitative Imaging Division, London/UK	B1206
18:00	**End of Sessions**			
19:30	**Dinner on the Lake** Boarding 19.20 - Lake side of KKL pier 5/6 - back 23.00 (short stop in Brunnen 22.30 for early return by train)			

Thursday, July 7, 2016

Friday, July 8, 2016

Morning	Luzerner Saal		Auditorium	Morning
09:00	**Development of systems and balance of plant components** **Mark Selby, Marc Heddrich**	**A13**	**Anodes: State-of-the-art & novel materials I** **Werner Sitte, Alan Atkinson**	**B13**
09:00	**Development of highly efficient SOFC power generating system using fuel concentration recovery process** Kazuo Nakamura, Takahiro Ide, Shumpei Taku, Tatsuya Nakajima, Marie Shirai, Tatsuki Dohkoh, Takao Kume, Yoichi Ikeda, Takaaki Somekawa, Takuto Kushi, Kei Ogasawara, Kenjiro Fujita Tokyo Gas Co., Ltd., Fundamental Technology Dept., Yokohama/Japan	A1301	**Evolution of the electrochemical interface in Solid Oxide Cells** John TS Irvine (1), Dragos Neagu (1), Maarten C Verbraeken (1), Christodoulos Chatzichristodoulou (2), Christopher Graves (2), Mogens B Mogensen (2) (1) School of Chemistry, University of St Andrews, St Andrews/UK, (2) Department of Energy Conversion and Storage, Technical University of Denmark, Roskilde/Denmark	B1301
09:15	**Prognostics-oriented simulation of an MSR fuel processor for SOFCs** Federico Pugliese (1), Andrea Trucco (2), Paola Costamagna (1) University of Genoa: (1) Department of Civil, Chemical and Environmental Engineering (DICCA), (2) Department of Electrical, Electronics and Telecommunications Engineering (DITEN), Genoa/Italy	A1302	**Elucidating structure-property-function relationships in cermet anodes through independent variation of metal and ceramic composition and microstructure** Paul Boldrin (1), Farid Tariq (1), Mengzheng Ouyang (1), Tanapa Konuntakiet (2), Nigel P. Brandon (1) (1) Department of Earth Science & Engineering, Imperial College London, London/UK, (2) Department of Chemical Engineering, Imperial College London, London/UK	B1302
09:30	**A Planar Steam Reformer Designed for 60,000 h Operation** Yves De Vos, Jean-Paul Janssens Bosal ECS NV, Lummen/Belgium	A1303	**Accessible Triple-Phase Boundary Length in Solid Oxide Fuel Cell Anodes** A. Nakajo (1,2), A.P. Cocco (1), M.B. Degostin (1), P. Burdet (3), A.A. Peracchio (1), B. N. Cassenti (1), M. Cantoni (3), J. Van herle (2), W.K.S. Chiu (1) (1) Department of Mechanical Engineering, University of Connecticut, Storrs/USA, (2) Fuelmat Group, Faculty of Engineering Sciences and Technology STI, Ecole Polytechnique Fédérale de Lausanne, Lausanne/Switzerland, (3) Interdisciplinary Centre for Electron Microscopy, Ecole Polytechnique Fédérale de Lausanne, Lausanne/Switzerland	B1303

09:45	**Proof of concept for solid oxide electrolysis systems** DI Richard Schauperl, Bsc Beppino Defner, Bsc Dominik Dunst, DI Jürgen Rechberger AVL List GmbH, Graz/Austria	A1304	**Development of Solid Oxide Fuel Cells Anode Ni-based Alloys** Rizki Putri Andarini, Aman Dhir, Robert Steinberger-Wilckens; Centre for Fuel Cell & Hydrogen Research, School of Chemical Engineering, Birmingham/UK	B1304
10:00	**SchIBZ – application of large diesel fueled SOFC systems for seagoing vessels and decentralized onshore applications** Keno Leites thyssenkrupp Marine Systems GmbH, Hamburg/Germany	A1305	**Sulfur tolerant LSCM-based composite cathode for high temperature electrolysis/co-electrolysis of H2O and CO2** Chee Kuan Lim (1,2,3), Qinglin Liu (1,2), Juan Zhou (1,2), Qiang Sun (1,4), Siew Hwa Chan (1,2,3) (1) Singapore-Peking University Research Centre, Campus for Research Excellence & Technological Enterprise (CREATE), Singapore/Singapore, (2) Energy Research Institute at NTU (ERIAN), Nanyang Technological University, Singapore/Singapore, (3) School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore/Singapore, (4) College of Engineering, Peking University, Beijing/China	B1305
10:15	**Development of a SOFC/Battery-Hybrid System for Distributed Power Generation in India** Thomas Pfeifer, Mathias Hartmann, Markus Barthel, Jens Baade, Ralf Näke, Christian Dosch Fraunhofer IKTS, Dresden/Germany	A1306	**Characterization of SOEC nanocomposite electrodes based on mesoporous ceramic scaffolds infiltration.** M. Torrell, E. Hernández, A. Slodczyk, A. Morata, A. Tarancón Catalonia Institute for Energy Research (IREC), Barcelona/Spain	B1306
10:30	**Break - Ground Floor in the Exhibition**			

Friday, July 8, 2016

Morning — **Luzerner Saal** — Morning

11:00	**Reactors, separators and storage based on solid oxide technology** **Paola Costamagna, AndreWeber**	**A14**	**Anodes: State-of-the-art & novel materials II** **John Irvine, Jun-Young Park**	**B14**
11:00	**Surface analysis and ionic transport of ScSZ/LSCrF dual-phase membrane for oxygen transport** Chi Ho Wong, Stephen Skinner Imperial College London, Department of Materials, Royal School of Mines , London/UK	A1401	**Fabrication of Ni-yttria stabilized zirconia composites for highly active and stable SOFC anodes** Viola I. Birss, Aligul Buyukaksoy (1) Department of Chemistry, University of Calgary, Calgary, Alberta/Canada, (2) Department of Materials Science and Engineering, Gebze Technical University, Gebze, Kocaeli/Turkey	B1401

11:15	**Cermet membranes for oxygen separation with low silver content** E. Ruiz-Trejo, A. Maserati, A. Bertei, P. Boldrin, N. P. Brandon Department of Earth Science and Engineering, Imperial College London, London/UK	A1402	**Redox-stable SOFC anode materials based on La-doped SrTO3 oxide with impregnated catalysts** Xuesong Shen (1), Kazunari Sasaki (1,2,3,4) (1) Department of Hydrogen Energy Systems, (2) International Research Center for Hydrogen Energy, (3) Next-Generation Fuel Cell Research Center (NEXT-FC), Fukuoka/Japan, (4) International Institute for Carbon-Neutral Energy Research (WPI-I2CNER) Kyushu University, Fukuoka/Japan	B1402
11:30	**Development of solid oxide electrolysis for oxygen production from mars atmosphere carbon dioxide.** Joseph Hartvigsen, S. Elango Elangovan, Jessica Elwell, Dennis Larsen, Laurie Clark Ceramatec, Inc., Salt Lake City/USA	A1403	**SMART catalyst based on doped Sr-titanite for advanced SOFC anodes** Dariusz Burnat (1), Roman Kontic (1), Lorenz Holzer (2), J. Andreas Schuler (3), Andreas Mai (3), Andre Heel (1) (1) IMPE - Institute for Materials and Process Engineering, (2) ICP – Institute for Computational Physics, ZHAW – Zurich University of Applied Sciences, Winterthur/Switzerland, (3) Hexis AG, Winterthur/Switzerland	B1403
11:45	**Post-test analysis of a rechargeable oxide battery (ROB) based on Solid Oxide Cells** Cornelius M. Berger (1,2), Oleg Tokariev (1,2), Norbert H. Menzler (1,2), O. Guillon (1,2), M. Bram (1,2) (1) Institute of Energy and Climate Research (IEK-1), Forschungszentrum Jülich GmbH, Jülich/Germany, (2) Jülich Aachen Research Alliance (JARA)	A1404	**Influence of multifunctional layers on the perfomance of solid oxide fuel cell anodes based on ZrxCe1-xO2-δ** Selma A. Venâncio, George G. Gomes Jr., Paulo Emílio V. de Miranda The Hydrogen Laboratory-Coppe – Department of Metallurgy and Materials Engineering, Federal University of Rio de Janeiro, Rio de Janeiro/Brazil	B1404
12:00	**Characterization of Solid Oxide Cells based Rechargeable Oxide Battery** Qingping Fang, Cornelius M. Berger, Ludger Blum, Norbert H. Menzler, Martin Bram Forschungszentrum Jülich GmbH , Institute of Energy and Climate Research, Jülich/Germany	A1405	**Development and Testing of an Impregnated La0.20Sr0.25Ca0.45TiO3 Anode for Improved Performance and Sulphur Tolerance** Robert Price (1), Mark Cassidy (1), J. Andreas Schuler (2), Ueli Weissen (2), Andreas Mai (2), John T. S. Irvine (1) (1) School of Chemistry, University of St Andrews, St Andrews/UK, (2) Hexis AG, Winterthur/Switzerland	B1405

12:15	**Convion SOFC System 5000h Validation** Kim Åström, Henri Stenberg, Matti Liukkonen, Erkko Fontell Convion Ltd, Espoo/Finland	A1406	**Changing the TPB Length through Alternation of Calcination Temperature, and its Influence to the Microstructure, Electrochemical Performance and Carbon Resistance of Ni Infiltrated CGO as the Anode of SOFC** Mengzheng Ouyang, Paul Boldrin, Nigel P. Brandon Department of Earth Science and Engineering, Imperial College London, London/UK	B1406
12:30	**Lunch - 2nd Floor on the Terrace** **Coffee - Ground Floor in the Exhibition & 2nd Floor on the Terrace**			

Friday, July 8, 2016

Afternoon	Luzerner Saal		Auditorium	Afternoon
13:30	**Current and future market issues** Andreas Richter, Bhima Sastri (tbc)	**A15**	**Cathodes: State-of-the-art & novel materials** Stephen Skinner, Andreas Friedrich	**B15**
13:30	**Operational Experience with a Solid Oxide Fuel Cell System with Low Temperature Anode off-gas Recirculation** Maximilian Engelbracht, Roland Peters, Wilfried Tiedemann, Ludger Blum, Detlef Stolten, Ingo Hoven Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK), Jülich/Germany	A1501	**Oxygen Exchange on Real Electrode Surfaces; experimentally-guided computational insight** John Kilner (1,2), Aleksandar Staykov (1), John Druce (1), Helena Téllez (1), Taner Akbay (3), Tatsumi Ishihara (1,3) (1) International Institute for Carbon-neutral Energy Research (WPI-I2CNER), Kyushu University, Fukuoka/Japan, (2) Department of Materials, Imperial College London, London/UK, (3) Advanced Research Centre for Electric Energy StorageKyushu University, Fukuoka/Japan	B1501
13:45	**A Total Cost of Ownership Analysis of SOFC Fuel Cell Systems** Shuk Han Chan (1), Max Wei (2), Ahmad Mayyas (2), Timothy Lipman (3) (1) University of California Berkeley, Etcheverry Hall/USA, (2) Lawrence Berkeley National Laboratory, Berkeley/USA, (3) Transportation Sustainability Research Center, California/USA	A1502	**High-Performance Cathode/Electrolyte Interfaces for SOFC** Julian Szasz (1), Florian Wankmüller (1), Virginia Wilde (2), Heike Störmer (2), Dagmar Gerthsen (2), Ellen Ivers-Tiffée (1) (1) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany, (2) Laboratory for Electron Microscopy (LEM), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany	B1502

14:00	**Road Truck LNG Boil-Off Converted to Battery Power by Small Planar SOFC System** Ulf Bossel ALMUS AG, Oberrohrdorf/Switzerland	A1503	**Synthesis through electrospinning of La1-xSrxCo1-yFeyO3-δ ceramic fibers for IT-SOFC electrodes** Anna Enrico (1), Bahar Aliakbarian (1), Alberto Lagazzo (1), Alessandro Donazzi (2), Rodolfo Botter (1), Patrizia Perego (1), Paola Costamagna (1) (1) Department of Civil, Chemical and Environmental Engineering, University of Genoa, Genoa/Italy, (2) Energy Department, Politecnico di Milano, Milan/Italy	B1503
14:15	**Electrochemical and Hydrogen Energy Technologies for Next-Generation Transportation Energy Systems** Whitney G. Colella (1,2) (1) Gaia Energy Research Institute, Arlington/VA/USA, (2) The Johns Hopkins University, Whiting School of Engineering, Baltimore/USA	A1504	**Effect of microstructural parameters on a performant SOFC cathode: Modelling vs Experiments** Özden Çelikbilek (1,2,4), David Jauffres (2,4), Laurent Dessemond (1,4), Monica Burriel (3,4), Christophe L. Martin (2,4), Elisabeth Djurado (1,4) (1) Univ. Grenoble Alpes, LEPMI, Grenoble/France, (2) Univ. Grenoble Alpes, Grenoble/France, (3) Univ. Grenoble Alpes, LMGP, Grenoble/France, (4) CNRS, Grenoble/France	B1504
14:30	**Solid Oxide Electrolysis Development at Versa Power Systems** Tony Wood (1), Hongpeng He (1), Tahir Joia (1), Mark Krivy (1), Dale Steedman (1), Eric Tang (1), Casey Brown (1), Khun Luc (1) Versa Power Systems, Calgary/Canada	A1505	**Quantifying the surface exchange coefficient of cathode materials in ambient atmospheres** Sam J. Cooper (1), Mathew Niania (1), Franca Hoffmann (2,3), John A. Kilner (1) (1) Department of Materials, Royal School of Mines, Imperial College , London/UK, (2) Cambridge Centre for Analysis, University of Cambridge, Cambridge/UK, (3) Department of Mathematics, South Kensington Campus, Imperial College London , London/UK	B1505
14:45	**SOEC Enabled Biogas Upgrading** John Bøgild Hansen, Majken Holstebroe, Michael Ulrik Borg Jensen, Jeppe Rass-Hansen, Thomas Heiredal-Clausen Haldor Topsøe A/S, Kongens Lyngby/Denmark	A1506	**SOFC Cathode degradation studies using Impedance Spectroscopy Genetic Program (ISGP)** Boxun Hu (1), Yoed Tsur (2), Prabhakar Singh (1) (1) University of Connecticut, Storrs/USA, (2) Technion, Israel Institute of Technology, Haifa/Israel	B1506
15:00	**5 Min to change from B15 Session to Luzerner Saal for A16 Plenary Session**			

Friday, July 8, 2016

Afternoon

Friday, July 8, 2016

Luzerner Saal

Afternoon

15:05	**P4: Closing Ceremony with Keynote by the Gold Medal of Honour Winner 2016** **Nigel Brandon, M. Spirig, O. Bucheli**	**A16**
15:05	**Summary by the Chair** Nigel Brandon Imperial College London, London/UK	A1601
15:20	**Information on Next EFCF: 6th PEFC and H2 Forum 2017 & 13th European SOFC and SOE Forum 2018** Michael Spirig, Olivier Bucheli European Fuel Cell Forum, Luzern/Switzerland	A1602
15:30	**Friedrich Schönbein Award 2016 for the Best Poster (Bronze), the Best Science Contribution (Silver) and a recognized Lifetime Work (Gold)** Nigel Brandon (1) , Olivier Bucheli (2), Michael Spirig (2) (1) Imperial College London, London/UK, (2) European Fuel Cell Forum	A1603
15:40	**Gold Medal Winner Keynote 2016** **"New materials, structures and concepts for Solid Oxide Cells"** John TS Irvine School of Chemistry, University of St Andrews, St Andrews/UK	A1604
16:05	**Thank you and Closing by the Organizers** Olivier Bucheli, Michael Spirig European Fuel Cell Forum, Luzern/Switzerland	A1605
16:15	**End of Sessions - End of Conference** Goodbye coffee and travel refreshment in front of the Luzerner Saal	

Scientific Advisory Committee

- Dr. Ainara Aguadero, ICL, UK
- Prof. Joongmyeon Bae, KAIST, Korea
- Dr. Rajendra Basu, CSIR, India
- Prof. Viola Birss, Univ Calgary, Canada
- Dr. Brian Borglum, Fuel cell energy, Canada
- **Prof. Nigel P. Brandon, Imperial College, UK (Chair)**
- Dr. Rob Braun, Colorado School of Mines, USA
- Dr. Dan Brett, UCL, UK
- Dr. Annabelle Brisse, Eu. Inst. for Energy Res. (EIFER), Germany
- Dr. Qiong Cai, Univ Surrey, UK
- Dr. Mark Cassidy, Univ St. Andrews, UK
- Prof. Jong Shik Chung, POSTEC, Korea
- Prof. Paola Costamagna, Univ Genoa, Italy
- Dr. Rich Goettler, LGFCS, USA
- Prof. Anke Hagen, Risoe Nat. Lab. / DTU, Denmark
- Prof. Min-Fang Han, Tsinghua University, China
- Mr. John Bøgild Hansen, Haldor Topsøe A/S, Denmark
- Prof. John Irvine, Univ St. Andrews, UK
- Prof. Ellen Ivers-Tiffée, Universität Karlsruhe, Germany
- Dr. Jari Kiviaho, VTT Technical Research Center of Finland, Finland
- Prof. Florence Lefebvre-Joud, CEA, H2 and FC Program, France
- Dr. Dario Montinaro, SOFCpower S.r.l., Italy
- Dr. Subhashish Mukerjee, Ceres Power, UK
- Prof. Kazunari Sasaki, Univ Kyushu, Japan
- Prof. Prabhaker Singh, Univ Connecticut, USA
- Prof. Stephen Skinner, ICL, UK
- Prof. Robert Steinberger-Wilckens, Univ Birmingham, UK
- Prof. Detlef Stolten, Forschungszentrum Jülich GmbH, Germany
- Dr. Pei-Chen Su, NTU, Singapore

The Scientific Advisory Committee has been formed to structure the technical program of the 12th EUROPEAN SOFC FORUM 2016. This panel has exercised full scientific independence in all technical matters.

A04 Poster Session I	(with all Session Topics)	**Wednesday,**	**6 July 2016**	**13.15 - 15:00**
A10 Poster Session II	(with all Session Topics)	**Thursday,**	**7 July 2016**	**13.15 - 15:00**

Poster Session

Companies & Major groups development status II — A05

Connected hydrogen storage for energy efficient buildings — A0507

Caroline Rozain, Nicolas Bardi
Sylfen, Grenoble/France

Convion SOFC System 5000h Validation — A0509

Kim Åström, Henri Stenberg, Matti Liukkonen, Erkko Fontell
Convion Ltd, Espoo/Finland

R&D at institutions - Overviews and status — A06

Solid Oxide Fuel Cell Technology Path: An investigation over the contribution of the Japanese and American Innovation System — A0607

Marina Domingues Fernandes (1), Victor Bistritzki (1), Rosana Domingues (1), Tulio Matencio (1), Márcia Rapini (2), Rubén Sinisterra (1)
Federal University of Minas Gerais: (1) Faculty of Chemistry, (2) Faculty of Economics, Belo Horizonte/Brazil

Implementation of hydrogen technologies in European regions on the example Czech Republic — A0608

Karin Stehlík (1), Martin Tkáč (2), Aleš Doucek (3,4)

(1) Research Center Rez
, Prague/Czech Republic, (2) University of Chemistry and Technology Prague, Prague/Czech Republic, (3) ÚJV Rez, Prague/Czech Republic, (4) Czech Hydrogen Technology Platform, Prague/Czech Republic

State of the art & novel processing routes — B03

Development and characterization of electroless- electrodeposited SOFC anodes with engineered microstructures — B0310

Zadariana Jamil (1,2), Enrique Ruiz-Trejo (1), Nigel P Brandon (1)
(1) Department of Earth Science and Engineering, Imperial College London, London/UK, (2) Faculty of Civil Engineering, Universiti Teknologi MARA Pahang, Pahang/Malaysia

Aqueous Tape Casting for Multilayer and Co-sintered Ni/8YSZ Substrates for SOFC (see B0305) <-- — B0312

Development Solid Oxide Fuel Cell Electrolyte Coating Process using YSZ solution — B0314

Kunho Lee, Juhyun Kang, Sanghun Lee, Joongmyeon Bae

Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, Daejeon/Republic of Korea

Tape Casting of Lanthanum Chromite — B0315

Diego Rubio (1,2), Crina Suciu (1), Ivar Waernhus (1), Arild Vik (1), Alex C. Hoffmann (2)
(1) Prototech AS, Bergen/Norway, (2) Faculty of Physics and Technology, Bergen/Norway

Characterization and testing of the SOECs prepared from water based slurries by the tape casting method — B0316

Filip Karas, Martin Paidar, Karel Bouzek

Poster Session

A Strategic Energy Technology Development Plan In Case of Low Oil Prices and Additional Nuclear Plant Construction Comparing with Multi-criteria Decision Making Approaches A0609

Seongkon Lee, Jongwook Kim

Energy Policy Research Team, Korea Institute of Energy Research, Daejeon/Republic of Korea

The Brazilian Experience in SOFC Development A0610

Marina Domingues Fernandes (1), Victor Bistritzki (1), Rosana Domingues (1), Tulio Matencio (1), Márcia Rapini (2), Rubén Sinisterra (1)
Universidade Federal de Minas Gerais: (1) Faculty of Chemistry, Pampulha/Belo Horizonte/Brazil, (2) Faculty of Economics, Pampulha/Belo Horizonte/Brazil

Lifetime: Cells & Stacks A08

Cr Poisoning of (La,Sr)(Co,Fe)O3-δ SOFC Cathodes at the Micrometre to Nanometre Scale A0807

Na Ni, Samuel Cooper, Stephen Skinner

Imperial College London, London/UK

SOFC Operation on Biogas- Threshold Impurity level A0808

Hossein Madi (1), Christian Ludwig (2), Jan Van herle (1)

(1) FUELMAT Group, Faculty of Engineering Sciences (STI), Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne/Switzerland, (2) Paul Scherrer Institut, General Energy Research Department, Bioenergy and Catalysis Laboratory, Villigen/Switzerland

La2NiO4+δ as SOEC anode material A0809

Andreas Egger, Nina Schrödl, Werner Sitte

Montanuniversitaet Leoben, Chair of Physical Chemistry, Leoben/Austria

Chromium and silicon poisoning of La0.6Sr0.4CoO3-δ IT-SOFC cathodes at 800°C A0810

E. Bucher (1), N. Schrödl (1), C. Gspan (2), T. Höschen (3), F. Hofer (2), W. Sitte (1)
University of Chemistry and Technology Prague, Department of Inorganic Technology, Praha/Czech Republic

Cellulose as a Pore Former in Electroless Co-Deposited Anodes for Solid Oxide Fuel Cells B0317

Rob Turnbull, Alan Davidson, Neil Shearer, Callum Wilson

Edinburgh Napier University , Edinburgh/Scotland/UK

Optimization of ultrasonic-assisted electroless plating process for Ni-YSZ anode fabrication for SOFCs B0318

Juhyun Kang, Hoyong Shin, Kunho Lee, Joongmyeon Bae

Korea Advanced Institute of Science and Technology (KAIST), Daehak-ro/Yuseong-gu/Daejeon

Micro-structured, Multi-channel Hollow Fibers for Micro-tubular Solid Oxide Fuel Cells (MT-SOFCs) B0319

Tao Li (1), Xuekun Lu (2), Paul Shearing (2), Kang Li (1)

(1) Department of Chemical Engineering, Imperial College London, London/UK, (2) Electrochemical Innovation Lab, Department of Chemical Engineering, University College London, London/UK

Prospect of Electrochemical Deposition Technique for Fuel Cell and Electrolysis Cell Applications B0320

Mark K. King Jr.(1), Nik Jindal (1), Manoj K. Mahapatra, (1), Prabhakar Singh (2)
(1) Department of Materials Science and Engineering, University of Alabama at Birmingham, Birmingham/Alabama/USA, (2) Center for Clean Energy Engineering, Materials Science and Engineering, University of Connecticut, Storrs/USA

Scalable synthetic method for IT-SOFCs compounds B0321

A. Wain, A. Morán-Ruiz, K. Vidal, A. Larrañaga, M. I. Arriortua
Universidad del País Vasco/ Euskal Herriko Unibertsitatea (UPV/EHU). Facultad de Ciencia y Tecnología, Bilbao/Spain

Lifetime: Materials and cells B05

Sulfur-Tolerance of Ceria-based Anodes B0507

Poster Session

(1) Chair of Physical Chemistry, Montanuniversitaet Leoben, Leoben/Austria, (2) Institute for Electron Microscopy and Nanoanalysis (FELMI), Graz University of Technology & Graz Center for Electron Microscopy (ZFE), Austrian Cooperative Research (ACR), Graz/Austria, (3) Max Planck Institute for Plasma Physics, Boltzmannstraße 2, Garching/Germany		André Weber, Thorsten Dickel, Ellen Ivers-Tiffée	
Study of variables for accelerating lifetime testing of SOFCs Alexandra Ploner, Anke Hagen, Anne Hauch Technical University of Denmark, Department of Energy Conversion and Storage, Roskilde/Denmark	A0812	Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany	
SOFC Anode Protection Using Electrolysis Mode during Thermal Cycling Young Jin Kim, Seon Young Bae, Hyung-Tae Lim School of Materials Science and Engineering, Changwon National University, Gyeongnam/South Korea	A0813	**Carbon removal from the fuel electrode of ASC-SOFC and regeneration of the cell performance** Vanja Subotić (1), Christoph Schluckner (1), Bernhard Stoeckl (1), Hartmuth Schroettner (2), Christoph Hochenauer (1) (1) Institute of Thermal Engineering, Graz University of Technology, Graz/Austria, (2) Institute for Electron Microscopy and Nanoanalysis of the TU Graz (FELMI), Graz University of Technology, Graz/Austria	B0508
Degradation analysis of SOFC performance Tohru Yamamoto, Kenji Yasumoto, Hiroshi Morita, Masahiro Yoshikawa, Yoshihiro Mugikura Central Research Institute of Electric Power Industry (CRIEPI), Yokosuka/Kanagawa/Japan	A0814	**Quantitative correlation of Cr-deposition from the gas phase with chemical origin of cathodes and electrolytes in SOFCs** Elena Konysheva, Wei Liu, Yushan Hou, Xiaomei Zhang Department of Chemistry, Xi'an Jiaotong-Liverpool University, Suzhou/China	B0509
Development of protective coatings on SOFC metallic interconnects fabricated by powder metallurgy V. Miguel-Pérez (1), M. Torrell (1)*, M. Morales (1), B. Colldeforns (1), A. Morata (1), M.C. Monterde (2), J.A. Calero (2), A. Tarancón (1) (1) IREC, Catalonia Institute for Energy Research, Dept of Advanced Materials for Energy Applications, Barcelona/Spain, (2) AMES Carrer de Laureà Miró, Sant Feliu de Llobregat/Barcelona	A0815	**New challenges for steel interconnects: lower temperature, higher steam content and dual atmosphere effect** Patrik Alnegren, Swathi Kiranmayee Manchili, Jan-Erik Svensson, Jan Froitzheim Energy and Materials, Chalmers University of Technology, Gothenburg/Sweden	B0510
SOFC methane direct feeding: carbon deposition prevention via oxygen-bearers addition to fuel Arianna Baldinelli, Linda Barelli, Gianni Bidini Università di Perugia - Dipartimento di Ingegneria, Perugia/Italia	A0816	**Assessment of limiting steps and degradation processes of an advanced metals supported cell with LST based anode** Vitaliy Yurkiv (1), Laurent Dessemond (2,3), Feng Han (1), Patric Szabo (1), Robert Semerad (4), Rémi Costa (1) (1) German Aerospace Center (DLR), Stuttgart/Germany, (2) Université Grenoble Alpes, Laboratoire d'Electrochimie et de Physico-Chimie des Matériaux et des Interfaces, (3) CNRS, Laboratoire d'Electrochimie et de Physico-Chimie des Matériaux et des Interfaces, Grenoble/France, (4) Ceraco Ceramic Coating GmbH, Ismaning/Germany	B0511
		The effect of polarization on SOFC seal ageing Stéphane Poitel (1,3), Yannik Antonnetti (2), Zacharie Wuillemin (2), Jan Van Herle (1), Cécile Hébert (3)	B0512

Poster Session

Degradation of the SOFC anode by contaminants in biogenic gaseous fuels A0817

Michael Geis, Stephan Herrmann, Sebastian Fendt, Hartmut Spliethoff

Institute for Energy Systems, Technische Universität München, Garching/Germany

Mechanical properties of La0.58Sr0.4M0.1Fe0.9O3-δ (M: Co and Ni) perovskites as electrod material for SOFCs A0818

Ali Akbari-Fakhrabadi, Marcelo Orellana, Viviana Meruane

Advanced Materials Laboratory, Department of Mechanical Engineering, University of Chile, Santiago/Chile

Cell design and characterisation A09

Electrochemical and microstructural characterization of Micro-Tubular SOFC: The effect of the operation mode A0907

M. Torrell (1), A. Hornés (1), A. Morata (1), K. Kendall (2), A. Slodczyk (1), A. Tarancón (1)

(1) Catalonia Institute for Energy Research (IREC), Barcelona/Spain, (2) Adelan, Birmingham/UK

CFY-Stacks: Progress in Development A0908

S. Megel (1), M. Kusnezoff (1), W. Beckert (1), N. Trofimenko (1), C. Dosch1, A. Weder (1), M. Jahn (1), A. Michaelis (1), C. Bienert (2), M. Brandner (2), S. Skrabs (2), W. V. Schulmeyer (2), L. S. Sigl (2)

(1) Fraunhofer Institute for Ceramic Technologies and Systems, Dresden/Germany, (2) Plansee SE, Reutte/Austria

New all-European high-performance stack (NELLHI): Experimental evaluation of an 1 kW SOFC stack A0909

Christoph Immisch (1), Andreas Lindermeir (1), Matti Noponen (2), Jukka Göös (2)

(1) Clausthaler Umwelttechnik-Institut GmbH, Clausthal-Zellerfeld/Germany, (2) Elcogen Oy, Vantaa/Finland

Triode Solid Oxide Fuel Cell operation under carbon deposition and Sulphur poisoning conditions A0910

(1) SCI-STI-JVH FUELMAT Group, Faculty of Engineering Sciences (STI), Ecole Polytechnique Fédérale de Lausanne (EPFL), Sion/Switzerland, (2) SOLIDpower, Yverdon-Les-Bains/Switzerland, (3) Interdisciplinary Centre for Electron Microscopy (CIME), Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne/Switzerland

Long-term test of commercial alloys for SOFC interconnect in dry and wet air B0513

Manuel Bianco, Maxime Auchlin, Stefan Diethelm, Jan Van herle

FUELMAT group, École Polytechnique Fédérale de Lausanne, Sion/Switzerland

Experiments on metal-Glass-metal samples simulating the fuel inlet/outlet manifolds in SOFC stacks B0514

Paolo Piccardo (1,2), Maria Paola Carpanese (3), Andrea Pecunia (1), Roberto Spotorno (1,2), Simone Anelli (1)

(1) Laboratory of Metallurgy and Materials, DCCI, University of Genoa, Genoa/Italy, (2) Institute for Energetics and Interphases, National Council of Research, Genoa/Italy, (3) Dept. of Civil, Chemical and Environmental Engineering, University of Genoa, Genoa/Italy

Silver as current collector for SOFC B0515

Artur J. Majewski, Aman Dhir

School of Chemical Engineering, The University of Birmingham, Birmingham/UK

Improvement of interface between electrolyte and electrodes in solid oxide electrolysis cell B0516

Nikolai Trofimenko, Mihails Kusnezoff, Alexander Michaelis

Fraunhofer IKTS, Dresden/Germany

Local Evolution of Three-dimensional Microstructure of Ni-YSZ Anode in Solid Oxide Fuel Cell Stack after Long-term Operation B0517

Grzegorz Brus (1), Hiroshi Iwai (2), Yuki Otani (2), Motohiro Saito (2), Hideo Yoshida (2), Janusz S. Szmyd (1)

(1) AGH University of Science and Technology, Krakow/Poland, (2) Kyoto University, Kyoto/Japan

Fuel heterogeneity in solid oxide carbon fuel cells: according to the internal gasification of carbon B0518

Hansaem Jang (1), Youngeun Park (1), Jaeyoung Lee (1,2)

Poster Session

Priscilla Caliandro, Stefan Diethelm, Jan Van herle FUELMAT, École Polytechnique fédérale de Lausanne, Sion/Switzerland	
Pressurized Operation of a 10 Layer Solid Oxide Electrolysis Stack Marc Riedel, Marc P. Heddrich, Moritz Henke, K. Andreas Friedrich German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Stuttgart/Germany	A0911
Evaluation of Zr doped BaCe0.85Y0.15O3-δ as PCFC electrolyte Ha-Ni Im, Dae-Kwang Lim, Jae-Woon Hong, In-Ho Kim, Sun-Ju Song Chonnam National University, Ionics Laboratory, School of Materials Science and Engineering, Gwang-Ju/Republic of Korea	A0912
Homogenization of the thermo-elastic properties of SOFC stacks operating for 1900 and 4700h. Volume and grid independence study of SOFC stacks Toni Vešović (1,2), Arata Nakajo (2), Fabio Greco (2), Jan Van Herle (2), Frano Barbir (1), Pierre Burdet (2,3) (1) Institute of Thermodynamics, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture FESB, Split/Croatia, (2) Fuelmat Group, Faculty of Engineering Sciences and Technology STI, Ecole Polytechnique Fédérale de Lausanne, Lausanne/Switzerland, (3) Interdisciplinary Centre for Electron Microscopy, Ecole Polytechnique Fédérale de Lausanne, Lausanne/Switzerland	A0913
Evaluation of H2O/CO2 co-electrolysis of LSCF6428-GDC Electrode SOFC on microstructural parameters Sang-Yun Jeon(1), Young-Sung Yoo(1), Mihwa Choi(1), Ha-Ni Im(2), Jae-Woon Hong(2), Sun-Ju Song (2) (1) Fusion Energy Group, Future Technology Research Lab., Korea Electric Power Research Institute (KEPRI), Korea Electric Power Corporation (KEPCO), Munji-Ro/Yuseong-Gu/Daejeon/Republic of Korea, (2) Ionics Lab, School of Materials Science and Engineering, Chonnam National University, Buk-gu/Gwang-Ju/Republic of Korea	A0914
Temperature effect on elastic properties of SOFC layers Alessia Masini, Zdeněk Chlup, Ivo Dlouhý Institute of Physics of Materials (IPM), Brno/Czech Republic	A0915

(1) Electrochemical Reaction and Technology Laboratory, School of Environmental Science and Engineering, Gwangju Institute of Science and Technology (GIST), Gwangju/South Korea, (2) Ertl Center for Electrochemistry and Catalysis, Research Institute for Solar and Sustainable Energies, Gwangju/South Korea	
Anomalous Shrinkage of Ni-YSZ Cermet during Low Temperature Oxidation Keiji Yashiro, Fei Zhao, Shinichi Hashimoto, Tatsuya Kawada Graduate School of Environmental Studies, Tohoku University, Sendai/Japan	B0519
Time-dependent Degradation of Nickel-infiltrated ScSZ Anodes J. Chen, X. Wang, A. Atkinson, N. P Brandon Imperial College London, London/UK	B0520
Impact of redox cycling on microstructure related mechanical property change in Ni-YSZ Solid Oxide Fuel Cell anodes Bowen Song, Enrique Ruiz Trejo, Farid Tariq, Kristina Maria Kareh, Nigel P Brandon Earth Science and Engineering Department, Imperial College London, London/UK	B0521

Electrolytes, interconnects, seals — B06

Improved Durability of ScSZ Electrolyteby Addition of RE2O3 (RE=Gd, Yb, Sm) Hee Lak Lee (1), Hyeong Cheol Shin (1), Ji Haeng Yu (2), Su Jeong Lee (1), Kyoung Tae Lim (1) (1) KCeraCell Co., Ltd., Geumsan-gun/Chungcheongnam-do/Republic of Korea, (2) Korea Institute of Energy Research (KIER), Daejeon/Republic of Korea	B0607
Thin film perovskite coatings and their application for SOFC ferritic steel interconnects (see B0603) <--	B0608

Poster Session

Characterization of the performance and long term degradation of anode supported multilayered tape cast Solid Oxide Cells A0917

M. Torrell (1), D. Rodríguez (2), B. Colldeforns (2), M. Blanes (2), A. Morata (1), F. Ramos (2), A. Tarancón (1)

(1) IREC, Catalonia Institute for Energy Research, Dept of Advanced Materials for Energy Applications, Barcelona/Spain, (2) FAE, L'Hospitalet de Llobregat/Spain

Hydrogen membrane fuel cell using Ni-Zr alloy membrane A0918

SungBum Park, Sung Gwan Hong, Yong-il Park

Kumoh National Institute of Technology, Gumi/Gyeongbuk/Korea

Lifetime: Stacks & systems A11

Performance Modelling of anode supported cells on a SOFC stack layer level A1107

Helge Geisler, Jochen Joos, André Weber, Ellen Ivers-Tiffée

Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany

An environmental and energetic performance assessment of an integrated power-to-gas concept system A1108

Dimitrios Giannopoulos (1), Marianna Stamatiadou (1), Manuel Gruber (2), Maria Founti (1), Dimosthenis Trimis (2)

(1) Laboratory of Heterogeneous Mixtures and Combustion Systems, Thermal Engineering Section, School of Mechanical Engineering, National Technical University of Athens, Athens/Greece, (2) Karlsruhe Institute of Technology, Engler-Bunte-Institute, Karlsruhe/Germany

Stack design and characterisation A12

Potential for critically-high electrical efficiency of multi-stage SOFCs with proton-conducting solid electrolyte A1208

Yoshio Matsuzaki (1,2), Yuya Tachikawa (3), Takaaki Somekawa (1,4), Kouki Sato (2), Hiroshige Matsumoto (5), Shunsuke Taniguchi (2,3,6), Kazunari Sasaki (2,3,4,5,6)

Mechanical stability aspects of SOFC sealants B0609

J. Wei, G. Pećanac, S. M. Gross-Barsnick, D. Federmann, J. Malzbender

Forschungszentrum Jülich GmbH, IEK-2 , Jülich/Germany

A combined microstructural and ionic conductivity study of multiple aliovalent doping in ceria electrolytes B0610

Alice V. Coles-Aldridge, Richard T. Baker

School of Chemistry, University of St. Andrews, St Andrews/UK

Multi-layered metallic coating on steel interconnects: oxidation and evaporation of chromic species B0611

Rakshith Sachitanand, Maria Nikumaa, Sead Canovic, Jan-Erik Svensson, Jan Froitzheim

Energy and Materials, Chalmers University of Technology, Gothenburg/Sweden

Densification of Cerium Pyrophosphate-Polystyrene Composite as Electrolytes of PCFCs B0612

Jae-Woon Hong, Ha-Ni Im, In-Ho Kim, Sun-Ju Song

Chonnam National University, Ionics Laboratory, School of Materials Science and Engineering, Gwang-Ju/Republic of Korea

Nitriding influence on SOFC ferritic steel interconnects B0613

Manuel Bianco (1), Shicai Yang (2), Johan Tallgren (3), Jong-Eun Hong (4), Olli Himanen (3), Kevin Cooke (2), Robert Steinberger-Wilckens (4), Jan Van herle (1)

(1) FUELMAT group, École Polytechnique Fédérale de Lausanne, Sion/Switzerland, (2) Teer Coatings Ltd, Miba Coating Group, Droitwich/UK, (3) VTT Technical Research Centre of Finland Ltd, Fuel Cells, Helsinki/Finland, (4) School of Chemical Engineering, College of Engineering and Physical Sciences University of Birmingham, Birmingham/England

Precoated EN 1.4622 and EN 1.4509 For SOFC Interconnect Steel B0614

Mats W Lundberg, Robert Berger, Jörgen Westlinder

Poster Session

(1) Fundamental Technology Department, Tokyo Gas Co. Ltd., Yokohama City/Kanagawa/Japan, (2) Next-generation Fuel Cell Research Center, Kyushu University, Fukuoka/Japan, (3) Center for Co-Evolutional Social Systems (CESS), Kyushu University, Fukuoka/Japan, (4) Faculty of Engineering, Kyushu University, Fukuoka/Japan, (5) International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Fukuoka/Japan, (6) International Research Center for Hydrogen Energy, Kyushu University, Fukuoka/Japan

Performance testing for a SOFC stack with bio-syngas — A1209

Ruey-Yi Lee (1), How-Ming Lee (1), Ching-Tsung Yu (1), Yung-Neng Cheng (1), Szu-Han Wu (1), Chien-Kuo Liu (1), Chun-Hsiu Wang (2), and Chun-Da Chen (2)

(1) Institute of Nuclear Energy Research, Taoyuan City/Taiwan, (2) China Steel Corporation, Kaohsiung/Taiwan

Development of systems and balance of plant components — A13

Sulfur Tolerant WGS-Catalysts — A1307

Thorsten Dickel (1), André Weber (1) Michael Scharrer (2), Claus Peter Kluge (2)

(1) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany, (2) CeramTec GmbH, Marktredwitz/Germany

Control strategy for a SOFC gas turbine hybrid power plant — A1309

Moritz Henke (1), Mike Steilen (1), Ralf Näke (2), Marc Heddrich (1), K. Andreas Friedrich (1)

(1) German Aerospace Center (DLR), Stuttgart/Germany, (2) Fraunhofer IKTS,, Dresden/Germany

rSOC plant concept for renewable energy storage — A1312

Matthias Frank (1), Roland Peters (1), Van Nhu Nguyen (1), Robert Deja (1), Ludger Blum (1), Detlef Stolten (1,2)

(1) Juelich Research Center IEK-3: Electrochemical Process Engineering , Jülich/Germany, (2) RWTH Aachen University Lehrstuhl für Brennstoffzellen, Fakultät für Maschinenwesen , Aachen/Germany

AB Sandvik Materials Technology, Sandviken/Sweden

Charge and Mass Transport Properties of BaCe0.9Y0.1O3-δ — B0615

Ha-Ni Im, Dae-Kwang Lim, Jae-Woon Hong, In-Ho Kim, Sun-Ju Song

Chonnam National University, Ionics Laboratory, School of Materials Science and Engineering, Gwang-Ju/Republic of Korea

Characterization of Porous Stainless Steel 430L for Low Temperatures Solid Oxide Fuel Cell Application — B0616

Kyung Sil Chung, Lingyi Gu, Sannan Toor, Eric Croiset

Chemical Engineering, University of Waterloo, Ontario/Canada

Electrical interconnect based on AISI 430 stainless steel coated with recycled cobalt from spent Li-ion batteries — B0618

Eric Marsalha Garcia (1), Hosane Aparecida Taroco (1), Rubens Moreira de Almeida (2), Antonio de Padua Lima Fernandes (2), Rosana Zacarias Domingues (2), Tulio Matencio (2)

(1) Federal University of São João del Rei, Sete Lagoas/Minas Gerais/Brazil, (2) Federal University of Minas Gerais-Departamento de Química, Minas Gerais/Brazil

Comparison of different manganese-cobalt-iron spinel protective coatings for SOFC interconnects — B0619

Johan Tallgren (1), Manuel Bianco (2), Jyrki Mikkola (1), Olli Himanen (1), Markus Rautanen (1), Jari Kiviaho (1), Jan Van herle (2)

(1) VTT Technical Research Centre of Finland Ltd, Fuel Cells, Helsinki/Finland, (2) FUELMAT group, École Polytechnique Fédérale de Lausanne (EPFL), Sion/Switzerland

La-Fe Perovskite Thin Film Coatings of Ferritic Stainless Steels by Surface Chemical Conversion: Dual Atmosphere Oxidation Testing — B0620

Andrea Masi (1,2), Davide Pumiglia (1,2), Maurizio Carlini (2), Amedeo Masci (1), Stephen McPhail (1), Stefano Frangini (1)

Poster Session

Investigation of a novel catalytic partial oxidation and pre-reforming radial reactor of a micro-CHP SOFC-system with anode off-gas recycle Timo Bosch (1), Maxime Carré (1), Angelika Heinzel (2), Michael Steffen (2), François Lapicque (3) (1) Robert Bosch GmbH, Renningen/Germany, (2) Zentrum für BrennstoffzellenTechnik GmbH, Duisburg/Germany, (3) Laboratoire Réactions et Génie des Procédés, CNRS-Univ. Lorraine, Nancy/France	A1313	(1) ENEA CR Casaccia, Rome/Italy, (2) DAFNE, University of Tuscia, Viterbo/Italy
Performance evaluation of solid oxide carbon fuel cells operating on steam gasified carbon fuels Tak-Hyoung Lim, Jong-Won Lee, Seung-Bok Lee, Seok-Joo Park, Rak-Hyun Song Fuel Cell Research Laboratory, Korea Institute of Energy Research (KIER), Yuseong-gu/Daejeon/Korea	A1315	**Insight of Reactive Sintering in Manganese Cobalt Spinel Oxide of Protective Layer for Solid Oxide Fuel Cell Metallic Interconnects** B0621 Jong-Eun Hong (1), Andrea Masi (1, 2), Manuel Bianco (3), Jan Van herle (3), Robert Steinberger-Wilckens (1) (1) Centre for Hydrogen and Fuel Cell Research, School of Chemical Engineering, University of Birmingham, Birmingham/UK, (2) DAFNE, University of Tuscia, Viterbo/Italy, (3) FUELMAT Group, Inst. Mech. Eng., Ecole Polytechnique Fédérale de Lausanne Valais (EPFL Valais), Sion/Switzerland
Methane Steam Reforming Reaction over Ni/CeO2-ZrO2 Catalysts Loaded on Metallic Monolith Jong Dae Lee Department of Chemical Engineering, Chungbuk National University, Seowon-gu Cheong-ju/Chungbuk/Korea	A1316	**High performance ceria-carbonate composite electrolytes for low temperature hybrid fuel cells** B0623 Ieeba Khan (1), Muhammad Imran Asghar (2), Peter D. Lund (2), Suddhasatwa Basu (1) (1) Department of Chemical Engineering, Indian Institute of Technology, New Delhi/India, (2) Department of Applied Physics, Aalto University, Aalto/Finland
System validation tests for a SOFC power system at INER Shih-Kun Lo, Wen-Tang Hong, Hsueh-I Tan, Huan-Chan Ting, Ting-Wei Liu, Ruey-Yi Lee Institute of Nuclear Energy Research, Taoyuan City/Taiwan	A1317	**Fabrication of MS-SOFC by Electrophoretic Deposition Technique and its Characterization** B0624 Shambhu Nath Maity, Debasish Das, Biswajoy Bagchi, Rajendra N. Basu CSIR-Central Glass and Ceramic Research Institute, Fuel Cell & Battery Division, Kolkata/India
A Global Reaction Model of Carbon Gasification with K2CO3 in the External Anode Media of a DCFC Shinae Song, Jun Ho Yu, Kyungtae Kang, Jun Young Hwang Korea Institute of Industrial Technology, Ansan/South Korea	A1319	**Synthesis and studies of BaCe0.7Zr0.1Y0.1Pr0.1O3-d perovskite material for IT-SOFCs** B0625 Shahzad Hossain, Juliana Hj Zaini, Abul Kalam Azad Faculty of Integrated Technologies, Universiti Brunei Darussalam, Gadong/Brunei Darussalam
Experimental study on the fuel ejector for solid oxide fuel cell system Kanghun Lee (1), Sanggyu Kang (1, 2), Youngduk Lee (1), Kook-Young Ahn (1,2) (1) Korea Institute of Machinery and Materials (KIMM), (2) University of Science and Technology (UST), Yuseong-Gu/Daejeon/Republic of Korea	A1320	**Composite BaZr0.85Y0.15O3-d / Nd0.1Ce0.9O2-δ electrolytes for intermediate temperature-solid oxide fuel cells** B0626 Ka-Young Park, Jun-Young Park Department of Nanotechnology and Advanced Materials Engineering, Sejong University, Seoul/Korea
		Joint strength of an SOFC glass-ceramic sealant with LSM-coated metallic interconnect B0627 Chih-Kuang Lin (1), Fan-Lin Hou (1), Atsushi Sugeta (2), Hiroyuki Akebono (2), Szu-Han Wu (3), Peng Yang (3)

Poster Session

Reactors, separators and storage based on solid oxide technology

A14

Novel membrane materials and membranes based on La6-xWO12-δ via spray pyrolysis and tape casting Andreas B. Richter (1), Guttorm Syvertsen-Wiig (1), Wendelin Deibert (2), Mariya E. Ivanova (2) (1) CerPoTech AS, Tiller/Norway, (2) Forschungszentrum Jülich GmbH, Jülich/Germany	A1407	**Nanoindentation of La-Fe Oxide Perovskite Thin Films for Solid Oxide Fuel Cells Steel Interconnects: First Findings** Andrea Masi (1,2), Ivan Davoli (3), Massimiliano Lucci (3), Maurizio Carlini (2), Amedeo Masci (1), Stephen McPhail (1), Stefano Frangini (1) (1) ENEA CR Casaccia, Rome/Italy, (2) DAFNE, University of Tuscia, Viterbo/Italy, (3) Department of Physics, University of Rome Tor Vergata, Roma/Italy	B0628
Transport properties of LSCrF-ScSZ based mixed conducting ceramic composites Zonghao Shen, Stephen Skinner, John Kilner Department of Materials, Imperial College London, London/UK	A1408	**Investigation of Advanced Cathode Contacting Solutions in SOFC** Patric Szabo (1), Remi Costa (1), Manho Park (2), Bumsoo Kim (2), Insung Lee (3) (1) DLR e.V., Stuttgart/Germany, (2) Alantum, Sangdaewon/Seongnam/Korea, (3) RIST, Gyeongbuk/Korea	B0629
Solid oxide electrolysis of CO2 on ceria based materials Neetu Kumari (1), M. Ali Haider (1), Nishant Sinha (2), S. Basu (1) Indian Institute of Technology, Delhi, New Delhi/India, (2) Dassault Systemes, Bangalore/India	A1410	**Co-deposition of rare earths along with (Mn,Co)3O4 spinel as a protective coating for SOFC metallic interconnects** Vinothini Venkatachalam, Sebastian Molin, Wolf-Ragnar Kiebach, Ming Chen, Peter Vang Hendriksen Department of Energy Conversion and Storage, Technical University of Denmark, Roskilde/Denmark	B0630
Electrochemical deoxygenation of bio-oil S. Elango Elangovan (1), Dennis Larsen (1), Evan Mitchell (1), Joseph Hartvigsen (1), James Mosby (1), Byron Miller (1), Jessica Elwell (1), Pieter Billen (2), Sabrina Spatari (2) (1) Ceramatec, Inc., Salt Lake City/USA, (2) Drexel University, Philadelphia/USA	A1411	**Cu-Fe substituted Mn-Co spinels by High Energy Ball Milling for interconnect coatings: insight on sintering properties** Andrea Masi (1,2), Jong-Eun Hong (3), Robert Steinberger-Wilckens (3), Maurizio Carlini (2), Mariangela Bellusci (1), Franco Padella (1), Priscilla Reale (1) (1) ENEA CR Casaccia, Rome/Italy, (2) DAFNE, University of Tuscia, Viterbo/Italy, (3) Centre for Fuel Cell and Hydrogen Research, School of Chemical Engineering, University of Birmingham Edgbaston, Birmingham/UK	B0631
Advanced electrochemical characterization of solid oxide electrolysis stacks (SOEC) M. Lang, S. Kurz, M. Braig, C. Auer German Aerospace Center (DLR), Institute for Engineering Thermodynamics, Stuttgart/Germany	A1412	**Electrolyte supported cells with thin electrolytes** Hendrik Pöpke, Franz-Martin Fuchs Kerafol GmbH, Eschenbach i. d. Opf./Germany	B0632

Poster Session

Effect of conductivity and mechanical strength of bi-layer matrix on the performances of carbonate-ceramic dual-phase membranes A1413

Mélanie Rolland (1), Dario Montinaro (2), Andrea Azzolini (2), Alessandro Dellai (2), Vincenzo Maria Sglavo (1)

(1) University of Trento, Department of Industrial Engineering, Trento/Italy, (2) SOLIDpower, Mezzolombardo/Italy

Economic viability of high temperature electrolysis integrating with renewable sources for a power to gas solution A1414

Sarika Tyagi (1), Delia Muñoz (1), Truls Norby (2)

(1) Abengoa Hidrogeno, Energía Solar nº1, Seville/Spain, (2) University of Oslo, Oslo/Norway

Electrochemical performance of H2O-CO2 co-electrolysis with a tubular solid-oxide co-electrolysis (SOC) cell A1415

Tak-Hyoung Lim, Jong-Won Lee, Seung-Bok Lee, Seok-Joo Park, Rak-Hyun Song

Fuel Cell Research Laboratory, Korea Institute of Energy Research (KIER), Yuseong-gu/Daejeon/Korea

Electrochemical characterization of a high temperature Metal / Metal Oxide battery A1416

Saffet Yildiz, Isabell Loll, Venkatesh Sarda, Izaak Vinke, Bert de Haart, Rüdiger Eichel

Institute of Energy and Climate Research IEK-9, Forschungszentrum Jülich GmbH, Jülich/Germany

Current and future market issues A15

Hydrogen Production Using Solid Oxide Electrolyser Cells at Shanghai Institute of Applied Physics A1507

Guoping Xiao, Chengzhi Guan, Xinbing Chen, Jian-Qiang Wang

Center for Thorium Molten Salt Reactor System, Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shangha/China

Topsoe Stack Platform (TSP) – a robust stack technology for solid oxide cells A1508

Jeppe Rass-Hansen, Peter Blennow, Thomas Heiredal-Clausen, Rainer Küngas, Tobias Holt Nørby, Søren Primdahl

Haldor Topsoe A/S, Kgs. Lyngby/Denmark

High Temperature Electrolysis for Hydrogen Production A1509

Modelling, validation & optimisation: Cell & stack B08

A steady state and dynamic 1-D model study of reversible solid oxide cells for energy storage B0807

Srikanth Santhanam, Marc P. Heddrich, K.A. Friedrich

German Aerospace Centre (DLR), Institute of Engineering Thermodynamics, Stuttgart/Germany

Analysis of temperature profiles in SOECs during startup and shutdown periods B0808

Filip Karas, Roman Kodým, Martin Paidar, Karel Bouzek

University of Chemistry and Technology Prague, Department of Inorganic Technology, Praha/Czech Republic

A Physical Model to Interpret Electrochemical Impedance Spectra for LSM/YSZ Composite Cathodes B0809

Aayan Banerjee, Olaf Deutschmann

Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany

Modelling of gas diffusion limitations in Ni/YSZ electrode material in CO2 and co-electrolysis B0810

Jakob Dragsbæk Duhn (1), Anker Degn Jensen (1), Stig Wedel (1), Christian Wix (2)

(1) DTU Chemical Engineering, Kgs. Lyngby/Denmark, (2) Haldor Topsoe A/S, Kgs. Lyngby/Denmark

Evaluation of Solid Oxide Cell (SOC) performance and degradation: Combined experimental and modeling study B0811

Vitaliy Yurkiv, Michael P. Hoerlein, Günter Schiller, K. Andreas Friedrich

German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Stuttgart/Germany

Nonlinear Model Predictive Control (NMPC) for SOFC B0813

Yousif Al-sagheer, Vikrant Venkataraman, Robert Steinberger-Wilckens

Centre for Fuel Cell and Hydrogen Research, School of Chemical Engineering, The University of Birmingham, Birmingham/UK

FEA analysis and modelling of thermal stress in SOFCs B0815

Dr Harald Schlegl, Dr Richard Dawson

Poster Session

Whitney G. Colella (1,2) (1) Gaia Energy Research Institute, Arlington/VA/USA, (2) The Johns Hopkins University, Whiting School of Engineering, Baltimore/USA		Lancaster University Engineering Dept., Lancaster/UK	
Quality Evaluation and Analysis Method Development of Byproduct Hydrogen Using Gas-Chromatography Daeic Chang(1), Jong Kuk Kim (1), Jongseong Lee (2), Hangsoo Woo (2) (1) Fine Chemical and Material Technical Institute, Ulsan/Republic of Korea, (2) New Energy Technology Institute, Ulsan/Republic of Korea	A1510	**Numerical investigation of fuel starvation effect at high current in novel planar SOFC design** Tomasz Zinko, Paulina Pianko-Oprych, Zdzisław Jaworski Faculty of Chemical Technology and Engineering, Institute of Chemical Engineering and Environmental Protection Processes, West Pomeranian University of Technology, Szczecin/Poland	B0816
Solid Oxide Fuel Cell application analysis Ling-yuan Tseng Electric Energy Express, ChuBei, Hsinchu 302/Taiwan	A1511	**Numerical surface coverage condition analysis of a porous Ni/YSZ anode during internal reforming** Christoph Schluckner, Vanja Subotić, Christoph Hochenauer Institute of Thermal Engineering, Graz University of Technology, Graz/Austria	B0818
		Geometric modeling of infiltrated solid oxide fuel cell electrodes with directional backbones Mehdi Tafazoli (1), Majid Baniassadi (2), Alireza Babaei (3), Mohsen Shakeri (1) (1) Department of Mechanical Engineering, Babol University of Technology, Babol/Iran, (2) School of Mechanical Engineering, College of Engineering, University of Tehran, Tehran/Iran, (3) School of Metallurgy and Materials Eng. College of Engineering, University of Tehran, Tehran/Iran	B0819
B			
		Accuracy of the Numerically Computed Spatial Current and Temperature Variations in SOFCs Özgür Aydın (1), Hironori Nakajima (2), Tatsumi Kitahara (2) (1) Department of Hydrogen Energy Systems, Graduate School of Engineering, Kyushu University, Fukuoka/Japan, (2) Department of Mechanical Engineering, Kyushu University, Fukuoka/Japan	B0820
Metal supported SOFCs	**B09**		
		Evaluation of SOFC anode polarization characteristics with pillar-based YSZ structure Takaaki Shimura (1), Keisuke Nagato (2,3), Naoki Shikazono (1,4) (1) Institute of Industrial Science, The University of Tokyo, Tokyo/Japan, (2) Department of Mechanical Engineering, Graduate School of Engineering, Tokyo/Japan, (3) JST PRESTO, Tokyo/Japan, (4) JST CREST, Tokyo/Japan	B0821
Anodes: State-of-the-art & novel materials I	**B13**		
Recent advancements in the utilization of dry biofuel for SOFCs Massimiliano Lo Faro (1), Sabrina C. Zignani (1), Stefano Trocino (1), R. M. Reis (2), G.G.A. Saglietti (2), E.A. Ticianelli (2), Antonino S. Aricò (1)	B1307	**Local reacting environment within SOFC stacks examined by three-dimensional numerical simulations**	B0822

Poster Session

(1) CNR-ITAE, Messina/Italy, (2) USP-IQSC, São Carlos/Brasil

Changing the TPB Length through Alternation of Calcination Temperature, and its Influence to the Microstructure, Electrochemical Performance and Carbon Resistance of Ni Infiltrated CGO as the Anode of SOFC (see B1406) <-- B1308

Fracture toughness and creep of SOFC anode substrates B1309

Jianping Wei, Goran Pećanac, Jürgen Malzbender

Forschungszentrum Jülich GmbH, IEK-2 , Jülich/Germany

High Performance Solid Oxide Electrolyzer Cell with Ba0.9Co0.7Fe0.2Nb0.1O3-δ Anode Based on YSZ/GDC Bilayer Electrolyte B1310

Zehua Pan (1,2), Qinglin Liu (2), Siew Hwa Chan (1,2)

(1) School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore/Singapore, (2) Energy Research Institute at NTU (ERIAN), Nanyang Technological University, Singapore/Singapore

Engineering Ceramic Scaffold Electrodes for SOFCs and SOECs B1311

Graham R Stevenson, Nigel P Brandon, Enrique Ruiz-Trejo ()

Imperial College London, London/UK

Exploring oxygen-deficient Ruddlesden-Popper La1-xSr1+xNiO4-d nickelates as oxygen electrode materials for SOFC/SOEC B1312

Aleksey Yaremchenko (1), Ekaterina Kravchenko (1,2), Kiryl Zakharchuk (1), Jekabs Grins (3), Gunnar Svensson (3), Vladimir Pankov (2)

Sanghyeok Lee (1,2), Hyoungchul Kim (1), Kyung Joong Yoon (1), Ji-Won Son (1), Jong-Ho Lee (1), Byung-Kook Kim (1), Wonjoon Choi (2), Jongsup Hong (1)

(1) High-temperature Energy Materials Research Center, Korea Institute of Science and Technology (KIST) , Seoul/South Korea, (2) Department of Mechanical Engineering, Korea University, Seoul/South Korea

Geometric characterisation and performance improvement of IT-SOFCs in highly efficient CHP systems B0823

Luca Mastropasqua (1), Stefano Campanari (1), Paolo Iora (2)

(1) Department of Energy, Politecnico di Milano, Milano/Italy, (2) Department of Mechanical and Industrial Engineering, Università di Brescia, Brescia/Italy

3D simulation of a patterned LSM cathode considering reaction on LSM/pore double-phase boundary B0824

Takuma Miyamae, Hiroshi Iwai, Motohiro Saito, Masashi Kishimoto, Hideo Yoshida

Department of Aeronautics and Astronautics, Kyoto University, Nishikyo-ku/Kyoto/Japan

Numerical Evaluation of Direct Internal Reforming SOFC Operated with Biogas B0826

Tran Dang Long (1), Tran Quang Tuyen (2), Yusuke Shiratori (1,2)

(1) Department of Hydrogen Energy Systems, Faculty of Engineering, (2) International Research Center for Hydrogen Energy - Kyushu University, Fukuoka/Japan

Harvesting Big Data in SOFC Short Stacks – A Step Beyond Contemporary Characterization Techniques B0827

Carlos Boigues Muñoz (1,2), Davide Pumiglia (1,3), Francesca Santoni (1,4), Stephen J. McPhail (1), Gabriele Comodi (2)

(1) DTE-PCU-SPCT, ENEA C.R. Casaccia, Rome/Italy, (2) Dipartimento di Ingegneria Industriale e Scienze Matematiche, Università Politecnica delle Marche, Ancona/Italy, (3) DAFNE, Università degli Studi della Tuscia, Viterbo/Italy, (4) Department of Science and Technology, Parthenope University, Naples/Italy

Numerical study on the SOFC characteristics variation with various internal reforming ratio B0828

Poster Session

(1) CICECO, Department of Materials and Ceramic Engineering, University of Aveiro, Aveiro/Portugal, (2) Department of Chemistry, Belarusian State University, Minsk/Belarus, (3) Department of Materials and Environmental Chemistry, Stockholm University, Stockholm/Sweden

Properties of perovskite with high value of A-site cation size mismatch obtained under different synthetic conditions — B1313

K. Vidal (1), A. Morán-Ruiz (1), A. Larrañaga (1), M. A. Laguna-Bercero (2), R. Baker (3), M. I. Arriortua (1)

(1) Universidad del País Vasco/ Euskal Herriko Unibertsitatea (UPV/EHU), Facultad de Ciencia y Tecnología, Bilbao/Spain, (2) Instituto de Ciencia de Materiales de Aragón (ICMA), CSIC-Universidad de Zaragoza, Zaragoza/Spain, (3) School of Chemistry, University of St Andrews, Fife/UK

Cerium-Cobalt-Copper oxide based SOFC anodes for the direct utilisation of methane as fuel — B1314

Bernardo J. M. Sarruf (1,2), Jong-Eun Hong (1), Robert Steinberger-Wilckens (1), Paulo Emílio V. de Miranda (2)

(1) Centre for Fuel Cell and Hydrogen research - School of Chemical Engineering, University of Birmingham, Birmingham/UK, (2) Hydrogen Laboratory COPPE, Metallurgical and Materials Engineering, Federal University of Rio de Janeiro , Rio de Janeiro/Brazil

Synthesis and electrical properties of Ti-doped Sr2FeMoO6 as an anode material for solid oxide fuel cells — B1316

Afizul hakem bin karim (1), Abdalla Mohamed Abdalla (1), Shahzad Hossain (1), Hidayatul Qayyimah Hj Hairul Absah (1), Mohamad Iskandar Petra (2), Abul Kalam Azad(1)

(1) Department of chemical and process engineering, Faculty of Integrated Technology, University Brunei Darussalam, Gadong/Brunei Darussalam, (2) Department of systems engineering, Faculty of Integrated Technology, University Brunei Darussalam, Gadong/Brunei Darussalam

Ni-YSZ anode impregnated with molybdenum for direct use of bio-ethanol in SOFC — B1318

Rosana Zacarias Domingues, Rubens Moreira, Antônio de Pâdua, Edyth da Silva, Tulio Matencio

Sanggyu Kang (1, 2), Youngduk Lee (1), Kook-Young Ahn (1,2), Jacob Brouwer (3)

(1) Korea Institute of Machinery and Materials (KIMM), (2) University of Science and Technology (UST), (3) National Fuel Cell Research Center (NFCRC), Yuseong-Gu/Daejeon/KoreaYuseong-Gu Daejeon/Republic of Korea

Modelling, validation & optimisation: System — B11

Sensitivity analysis and optimization of solid oxide fuel cells: a review — B1107

Seyedehmina Tonekabonimoghadam (1), Yashar S. Hajimolana (1,2), Mohammed Harun Chakrabarti (2), Jelle Nicolas Stam (3), Mohd Azlan Hussain (1), Nigel Brandon (3), Mohd Ali Hashim (1), P.V. Aravind (2)

(1) Chemical Engineering Department, Faculty of Engineering, University of Malaya, Kuala Lumpur/Malaysia, (2) Process and Energy Department, Delft University of Technology, CA Delft/The Netherlands, (3) Department of Earth Science and Engineering, Imperial College London, London/UK

Dynamic behavior of the solid oxide fuel cell-engine hybrid system — B1108

Sanggyu Kang (1, 2), Kanghun Lee (1), Keunwon Choi (1), Youngduk Lee (1), Kook-Young Ahn (1,2)

(1) Korea Institute of Machinery and Materials (KIMM), (2) University of Science and Technology (UST), Yuseong-Gu/Daejeon/Republic of Korea

Potential of Waste Biomass Gasification Hybrid Solid Oxide Fuel Cell, Turbine Integrated System — B1109

Poster Session

Universidade Federal de Minas Gerais - Departamento de Química, Belo Horizonte/Brazil	
Single triple-phase-boundary and platinum–yttria stabilized zirconia composite as cathodes for IT-SOFCs	B1319
Yan Yan (1), Paul Muralt (2) (1) Faculty of Materials and Energy, Southwest University, Chong Qing/China, (2) Ceramics Laboratory, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne/Switzerland	
Highly efficient and durable hydrogen production of SOECs using layered perovskite electrodes	B1320
Guntae Kim School of Energy and Chemical Engineering, UNIST, Ulsan/Republic of Korea	
Role of dopants on ceria-based anodes for IT-SOFCs powered by hydrocarbon fuels	B1321
Araceli Fuerte, Rita Ximena Valenzuela, María José Escudero Energy Department, CIEMAT, Madrid/Spain	
Operation of ceria-electrolyte solid oxide fuel cell on simulated biogas mixtures	B1322
M.J. Escudero, A. Fuerte CIEMAT, Madrid/Spain	
Paper-structured catalyst for the stable operation of direct-internal reforming SOFC running on biofuels	B1323
Taku Kaida (1), Mio Sakamoto (2), Hao Le (1), Tran Tuyen Quang (2), Yusuke Shiratori (1,2) (1) Department of Hydrogen Energy Systems, Faculty of Engineering, (2) International Research Center for Hydrogen Energy - Kyushu University, Fukuoka/Japan	
Enhancement of Long-term Stability of Ni-YSZ based SOFC Anode by Infiltration of Transition Metals	B1324
Seung-Bok Lee (1,2), Muhammad Shirjeel Khan (1), Rak-Hyun Song (1,2), Jong-Won Lee(1,2), Tak-Hyoung Lim(1,2), Seok-Joo Park(1,2)	
Mayra Recalde, Theo Wousdtra, P.V. Aravind Process and Energy, Delft University of Technology, Delft/The Netherlands	
Thermochemical and Kinetic Modelling of Chromium- Rich Alloys	B1111
Mélissa Oum, Jong-Eun Hong, Robert Steinberger-Wilckens Centre for Fuel Cell & Hydrogen Research, School of Chemical Engineering, Birmingham/UK	
Multi-stage highly-efficient SOFC system using proton and oxide-ion conducting electrolyte	B1112
Yuya Tachikawa (1), Yoshio Matsuzaki (2,3), Takaaki Somekawa (2,4), Shunsuke Taniguchi (1,3,6), Kazunari Sasaki (1,3,4,5,6) (1) Center for Co-Evolutional Social Systems (CESS), Kyushu University, Fukuoka/Japan, (2) Fundamental Technology Department, Tokyo Gas Co., Ltd., Yokohama City/Kanagawa/Japan, (3) Next-Generation Fuel Cell Research Center (NEXT-FC), Kyushu University, Fukuoka/Japan, (4) Faculty of Engineering, Kyushu University, Fukuoka/Japan, (5) International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Fukuoka/Japan, (6) International Research Center for Hydrogen Energy, Kyushu University, Fukuoka/Japan	
Solid Oxide Fuel Cells Operating on Methane with Anode Off-Gas Recirculation	B1114
Tsang-I Tsai, Robert Steinberger-Wilckens School of Chemical Engineering, University of Birmingham, Edgbaston/UK	
Model development of integrated CPOx reformer and SOFC stack system	B1115
Paulina Pianko-Oprych, Mehdi Hosseini, Zdzislaw Jaworski Faculty of Chemical Technology and Engineering, Institute of Chemical Engineering and Environmental Protection Processes, West Pomeranian University of Technology, Szczecin/Poland	
Stationary, Polygenerative Electrochemical Systems	B1116
Whitney G. Colella (1,2) (1) Gaia Energy Research Institute, Arlington/VA/USA, (2) The Johns Hopkins University, Whiting School of Engineering, Baltimore/USA	
Development of BoP model of the SOFC sub-system with CPOx reforming	B1117

Poster Session

(1) Fuel Cell Research Center, Korea Institute of Energy Research, Daejeon/Republic of Korea, (2) Department of Advanced Energy Technology, University of Science and Technology, Daejeon/Republic of Korea

Cathodes: State-of-the-art & novel materials — B15

Synthesis through electrospinning of La1-xSrxCo1-yFeyO3-δ ceramic fibers for IT-SOFC electrodes (see B1503) <-- — B1507

High-throughput screening of SOFC cathode materials — B1508

Aitor Hornés, Aruppukottai Bhupathi Saranya, Alex Morata, Albert Tarancón

Catalonia Institute for Energy Research (IREC), Department of Advanced Materials for Energy, Barcelona/Spain

Chrome Poisoning of Non-Manganiferous Cathode Materials for Solid Oxide Fuel Cells — B1509

Kevin Schiemann, Izaak C. Vinke, L.G.J de Haart, Rüdiger-A. Eichel

Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research, Fundamental Electrochemistry (IEK-9), Jülich/Germany

Development of LCFCN system perovskites as interconnect and cathode materials for SOFCs — B1510

Abhigna Kolisetty, Zhezhen Fu, Rasit Koc

Department of Mechanical Engineering and Energy Processes, Southern Illinois University Carbondale, Carbondale/USA

Evaluation of Cathode performance in co-sintered inert-supported SOFC — B1511

Eric Matte (1), Piero Lupetin (1), Detlef Stolten (2)

Barbara Zakrzewska, Paulina Pianko-Oprych

West Pomeranian University of Technology, Szczecin, Institute of Chemical Engineering and Environmental Protection Processes, Szczecin/Poland

Electrochemical Impedance Spectroscopy model for a symmetric cell as an SOFC application — B1118

Oktay Demircan, Gulsun Demirezen

Alternative Energy Lab., Boğaziçi University, Department of Chemistry, Istanbul/Turkey

SOFC simplified performance prediction model — B1119

Irad Brandys (1,2), Yedidia Haim (3), Yaniv Gelbstein (4)

(1) NRCN, Beer Sheva/Israel, Ben Gurion University of the Negev: (2) Faculty of Engineering
, Beer Sheva/Israel, (3) Dept. of Mechnical Engineering, Beer Sheva/Israel, (4) Dept. of Energy, Beer Sheva/Israel

Advanced characterisation tools and techniques — B12

Determining the Oxygen Transport Kinetics of Ba0.5Sr0.5Co0.8Fe0.2O3-δ by a Detailed Electrochemical Study — B1207

Laura Almar, Julian Szász, André Weber, Ellen Ivers-Tiffée

Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany

High spatial resolution monitoring of the temperature distribution from an operating SOFC (see B1201) <-- — B1209

Spatially Resolved Characterization of Anode Supported Solid Oxide Fuel Cells — B1210

Patric Szabo (1), Günter Schiller (1), Dario Montinaro (2), Jan Pieter Ouweltjes (3)

Poster Session

(1) Robert Bosch GmbH, Robert-Bosch-Campus 1, Renningen/Germany, (2) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK), Jülich/Germany		(1) German Aerospace Center (DLR), Stuttgart/Germany, (2) SOLIDPower SpA, Trento/Italy, (3) SOLIDpower SA, Yverdon-les-Bains/Switzerland	
Thermodynamic aspects of Cr poisoning for LSCF cathodes Xiaoyan Yin, Lorenz Singheiser, Robert Spatschek Forschungszentrum Jülich GmbH, IEK-2, Jülich/Germany	B1512	**Increase of the quality assurance of SOFC stacks by electrochemical methods** C. Auer(1), M. Braig(1), M. Lang(1), S. Kurz(1), K. Couturier(2), E.R. Nielsen(3), Q. Fu(4), Q. Liu(5) (1) German Aerospace Center (DLR), Institute for Technical Thermodynamics, Stuttgart/Germany, (2) CEA, Grenoble/France, (3) DTU, Roskilde/Denmark, (4) EIFER, Karlsruhe/Germany, (5) NTU, Singapore/Singapore	B1211
Optimization of GDC interlayer against SrZrO3 formation in LSCF/GDC/YSZ triplets Jeffrey C. De Vero (1), Katherine Develos-Bagarinao (1), Haruo Kishimoto (1), Do-Hyung Cho (1), Katsuhiko Yamaji (1), Teruhisa Horita (1), Harumi Yokokawa (1,2) (1) National Institute of Advanced Industrial Science and Technology Tsukuba, Ibaraki/Japan, (2) Institute of Industrial Science, The University of Tokyo, Tokyo/Japan	B1513	**Model-based design and 3D characterization of a SOFC electrode microstructure** Kristina Maria Kareh (1), Enrique Ruiz Trejo (1), Antonio Bertei (1), Farid Tariq (1,2), Vladimir Yufit (1,2), Nigel Brandon (1,2) (1) Imperial College London, London/UK, (2) IQM Elements Ltd, Quantitative Imaging Division, London/UK	B1212
		Four-point bending testing: estimation of the accuracy and identification of the mechanical properties Fabio Greco, Arata Nakajo, Jan Van herle FUELMAT Group, Institute of Mechanical Engineering, Faculty of Engineering Sciences and Technology, EPFL, Sion/Switzerland	B1213
		Analysis and improvement on DRT reconstruction from Electrochemical Impedance Spectroscopy data Tommaso Ferrari (1), Roberto Spotorno (2,3), Paolo Piccardo (2,3), Cristiano Nicolella (1) (1) Department of Civil and Industrial Engineering, University of Pisa, Pisa/Italy, (2) Laboratory of Metallurgy and Materials, DCCI, University of Genoa, Genoa/Italy, (3) Institute for Energetics and Interphases, National Council of Research, Genoa/Italy	B1214
		Thin Film THERMONO for Cathode Temperature Gradient of SOFC Erdogan Guk, Manoj Ranaweera, Vijay Venkatesan, Jung-Sik Kim Department of Aeronautical & Automotive Engineering Department, Loughborough University, Loughborough/UK	B1215
		Influence of Working Parameters and Degradation on Anode-Supported Cells studied by Electrochemical Impedance Spectroscopy Roberto Spotorno (1,2), Tommaso Ferrari (3), Cristiano Nicolella (3), Paolo Piccardo (1,2)	B1216

Scientific Organizing Committee

- Dr. Antonio Bertei, ICL, UK
- Dr. Paul Boldrin, ICL, UK
- **Prof. Nigel P. Brandon, ICL, UK (Chair)**
- Dr. Richard Dawson, Univ Lancaster, UK
- Dr. Kristina Kareh, ICL, UK
- Dr. Jung-Sik Kim, Univ Loughborough, UK
- Dr. Zeynep Kurban, ICL, UK
- Dr. Mardit Matian, SOLIDpower/HTceramix, CH
- Dr. Enrique Ruiz Trejo, ICL, UK
- Dr. Paul Shearing, UCL, UK
- Dr. Farid Tariq, ICL, UK
- Dr. Vladimir Yufit, ICL, UK

Poster Session

(1) Laboratory of Metallurgy and Materials, DCCI, University of Genoa, Genoa/Italy, (2) Institute for Energetics and Interphases, National Council of Research, Genoa/Italy, (3) Department of Civil and Industrial Engineering, University of Pisa, Pisa/Italy	
Nucleation and crystallization processes of glass-ceramic sealants for SOFCs	B1217
Jeerawan Brendt, Sonja M. Gross-Barsnick, Carole Babelot, Ghaleb Natour Forschungszentrum Jülich, Central Institute of Engineering, Electronics and Analytics (ZEA) - Engineering and Technology (ZEA-1), Jülich/Germany	
New full ceramic kit for gas analysis and integrated steamer for SOEC	B1218
Pierre Coquoz, André Pappas, Raphael Ihringer Fiaxell Sàrl, Lausanne/Switzerland	
Impedance insight into Ceres Power's Steel Cell technology: latest results	B1219
Gavin Reade (2), André Weber (1), Adam Bone (2), Subhasish Mukerjee (2), Mark Selby (2) (1) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany, (2) Ceres Power Ltd. , Horsham/UK	

International conference on SOLID OXIDE FUEL CELL and ELECTROLYSER

12th EUROPEAN SOFC & SOE FORUM 2016

5 - 8 July 2016

Kultur- und Kongresszentrum Luzern (KKL) Lucerne / Switzerland

Chairman: Prof. Nigel Brandon

Imperial College London

Abstracts of all Oral & Poster Contributions

Legend:

- The program includes three **major thematic blocks,** covering **SOFC, SOE, Reactors** and **Separators**:
  1. Fuel Cell Market, Korean Industry, EU Overview, Energy Revolution (A01, A02, A07), Company & Major groups development status (EU - A03, A05, A06) and market issues (A15)
  2. Advanced Characterisation, Diagnosis and Modelling and Tools (B08, A06, B11, B12);
  3. Technical Sessions on cells, stacks, systems – lifetime, design, operation, balance of plant (B05, A08, A11, A13, A09, B09) as well as interconnects, seals (B06) and novel materials for Anodes + Cathodes (B13, B14, B15)

- **Abstracts** are identified and preliminarily sorted by presentation number (= EFCF-ID) e.g. A0504, B1205, etc. first all A and then all B. However some very similar session topics like - A03-A05-A06-A14-A15 (overview, industry, market), B05-A08-A11 (Lifetime) were grouped to chapters, which correspond to the chapters of the proceedings (see also www.EFCF.com/Lib)
  - Oral abstracts consist of numbers where last two digits are lower than 07
  - Poster abstracts are linked to related sessions by letter and first two digits: e.g. A05.., B10, …etc
  - Due to late changes some numbers (second two digits) are missing or changed

Chapter-Session-Overview

Chapter 01 A01 P1: Opening Session
A02 P2: Fuel Cell Market - Korean Industry - EU Overview
A07 P3: Keynote - Energy Revolution: Smart innovations & early adopters
A16 P4: Keynote by the Gold Medal of Honour Winner 2016

Chapter 02 A03+A05 Companies & Major groups development status I+II
A06 R&D at institutions - Overviews and status
A14 Reactors, separators and storage based on solid oxide technology
A15 Current and future market issues

Chapter 03 A09 Cell design and characterisation
A12 Stack design and characterisation

Chapter 04 A13: Development of systems and balance of plant components

Chapter 05 B03: State of the art & novel processing routes

Chapter 06 B05: Lifetime: Materials and cells
A08: Lifetime: Cells & Stacks
A11: Lifetime: Stacks & systems

Chapter 07 B06: Electrolytes, interconnects, seals

Chapter 08 B08 Modelling, validation & optimisation: Cell & stack
B11 Modelling, validation & optimisation: System

Chapter 09 B09: Metal supported SOFCs

Chapter 10 B12: Advanced characterisation tools and techniques

Chapter 11 B13+B14: Anodes: State-of-the-art & novel materials I + II

Chapter 12 B15: Cathodes: State-of-the-art & novel materials

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

Chapter 01 - Sessions A01, A02, A07, A16

A01: Plenary 1: Opening Session
A02: Plenary 2: Fuel Cell Market - Korean Industry - European Overview
A07: Plenary 3: Keynote - Energy Revolution: Smart innovations & early adopters
A16: Plenary 4: Keynote by the Gold Medal of Honour Winner 2016

Content **Page A01, A02, A07, A16 - ..**

A0101 (Plenary without Abstract) ... 3
Welcome by the Organizers **3**
Olivier Bucheli, Michael Spirig 3
A0102 (Plenary without Abstract) ... 3
Welcome by the Chair **3**
Nigel Brandon 3
A0103 (Plenary without Abstract) ... 3
Welcome to Switzerland - FCH Research and Realisation **3**
Stefan Oberholzer, Rolf Schmitz, Walter Steinmann 3
A0201 (Keynote) ... 4
The Fuel Cell Industry 2015: the most shipments yet **4**
David Hart (1), Franz Lehner (1) 4
A0202 (Keynote) ... 5
Current Status of Fuel Cell Industry in Korea **5**
Hae-Weon Lee, Jong-Ho Lee, Byung Kook Kim 5
A0203 (Plenary without Abstract) ... 6
Europe: Overview on FCH-JU projects & activities in stationary applications **6**
Mirela Atanasiu 6
A0701 (Keynote without Abstract) ... 7
Changing data centers to change the world. How smart innovation and early adopters will usher in the next energy revolution. **7**
Sean James 7
A1604 (Keynote without Abstract) ... 8
Gold Medal Winner Keynote 2016: New materials, structures and concepts for Solid Oxide Cells **8**
John TS Irvine 8

A0101 (Plenary without Abstract)

Welcome by the Organizers

Olivier Bucheli, Michael Spirig
European Fuel Cell Forum
Obgardihalde 2, 6043 Adligenswil/Luzern
forum@efcf.com

A0102 (Plenary without Abstract)

Welcome by the Chair

Nigel Brandon
Imperial College London
London/UK
n.brandon@imperial.ac.uk

A0103 (Plenary without Abstract)

Welcome to Switzerland - FCH Research and Realisation

Stefan Oberholzer, Rolf Schmitz, Walter Steinmann
Swiss Federal Office of Energy; Bern/Switzerland
stefan.oberholzer@bfe.admin.ch

Remark: Please see the presentations on www.EFCF.com/LIB or contact the authors directly for further information.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0201 (Keynote)

The Fuel Cell Industry 2015: the most shipments yet

David Hart (1), Franz Lehner (1)
(1) 1E4tech Sarl, Av. Juste Olivier 2, 1006 Lausanne, Switzerland
Tel.: +41-21-331-1570
Fax: +41-21-331-1561
hart@e4tech.com

Abstract

E4tech conducts an annual Fuel Cell Industry Review [1], interviewing industry participants to gauge the state of the industry. The 2015 report shows a slight increase in unit shipments and an all-time record in megawatts of fuel cells shipped globally. But behind this positive overall picture lies a struggle for commercial competitiveness, recognition and even survival: much of the shipments are currently underpinned by direct or indirect governmental support. However, fuel cells are seen as a future competitive solution to meet ever stricter CO2 and air-pollutant limits. This is evidenced – for example – in the substantial investment in fuel cell vehicle roll-outs by automotive OEMs such as Toyota and Hyundai.

A0202 (Keynote)

Current Status of Fuel Cell Industry in Korea

Hae-Weon Lee, Jong-Ho Lee, Byung Kook Kim
Korea Institute of Science and Technology
High Temperature Energy Materials Research Center
5 Hwarangro 14-gil, Seongbuk-gu, Seoul, Korea
Tel.: +82-02-958-5523
Fax: +82-02-958-5529
hwlee@kist.re.kr

Abstract

Global fuel cell market has been driven by domestic public policies in each countries. Fuel cell markets in Korea also showed a strong dependence on the public policies implemented by both central and local governments. Among them RPS (renewable portfolio standard) in Korea made serious impact on the fuel cell market growth, while Green Home Scheme, for residential FC m-CHP program similar to ENE-FARM in Japan, gave a marginal influence on both industrial investment and market growth.
Since fuel cell receives one of the highest REC (renewable energy certificate) credit in RPS, some of utilities responsible for RPS are in favor of fuel cells despite the high initial cost owing to several advantages like short installation time, easy siting and high capacity factor. With the appearance of PAFC (Doosan) in 2015, RPS market appears to go through reshaping in coming years from early dominance of MCFC (Posco Energy). Since the heat recovered generates extra revenue in the range 7-10% of total, the siting and heat quality will play significant roles in market reshaping. In general, MCFC is in favor in industrial complexes with high temperature heat, while PAFC makes its presence in municipal district heating.
Unlike RPS market, the residential market driven by Green Home Scheme has been continuously shrinking in recent years and instead PEMFC manufacturers find more dynamic market opportunity due to one of the highest correction factor given in Green Building Certification System by City of Seoul. Since the allocation of national budget will be dependent on the past record in accordance with the 4th National Plan for NRE, many local governments with highly-populated metropolitan area are eager to attract fuel cell projects for district heating in collaboration with the utilities obligated to RPS.
Recently, KEA (Korea Energy Agency) started to look for implementing greenhouse gas abatement performance into the public policies. Capital intensity for greenhouse gas abatement, which is defined as the additional initial investment divided by total greenhouse gas avoided over the lifetime, may be used for the target cost and lifetime of SOFCs by comparing with others already in policy market. For example in RPS market, SOFCs can be competitive with PAFCs when the system cost is 6000$/kW and its lifetime is 7 years. In contrast, SOFCs can penetrate into residential and building market even with 3 year lifetime and 8000 $/kW system cost. Two SOFC system developers in Korea are preparing for entering Green Home Scheme within a couple of years by establishing domestic supply chain of key components for early market.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0203 (Plenary without Abstract)

Europe: Overview on FCH-JU projects & activities in stationary applications

Mirela Atanasiu
FCH JU, Busssles/Belgium
Mirela.Atanasiu@fch.europa.eu

Remark: Plenary presentations often do not have an abstract. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0701 (Keynote without Abstract)

Changing data centers to change the world. How smart innovation and early adopters will usher in the next energy revolution.

Sean James
Microsoft Infrastructure & Operations USA
Sean.James@microsoft.com

Remark: Keynote presentations often do not have an abstract. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1604 (Keynote without Abstract)

Gold Medal Winner Keynote 2016: New materials, structures and concepts for Solid Oxide Cells

John TS Irvine
School of Chemistry, University of St Andrews
St Andrews/UK
Tel.: +44 1334 463817
jtsi@st-and.ac.uk

Remark: Keynote presentations often do not have an abstract. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

Chapter 02 - Sessions A03, A05, A06, A14, A15

A03: Companies & major groups development status I
A05: Companies & major groups development status II
A06: R&D at Institutions – Overviews and status
A14: Reactors, separators and storage based on solid oxide technology
A15: Current and future market issues

Content **Page A03, A05, A06, A14, A15 - ..**

A0301 ... 5
Advances in HEXIS' SOFC development **5**
Andreas Mai, Felix Fleischhauer, J. Andreas Schuler, Roland Denzler, Volker Nerlich, Alexander Schuler 5
A0302 ... 6
Solid Oxide Fuel Cell Development at Versa Power Systems & FuelCell Energy **6**
Brian Borglum (1) and Hossein Ghezel-Ayagh (2) 6
A0303 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 7
Development status of Ceres Power Steel Cell technology: further improvements in manufacturability, durability and performance **7**
Robert Leah, Adam Bone, Mike Lankin, Mahfujur Rahman, Eva Hammer, Ahmet Selcuk, Andy Clare, Subhasish Mukerjee, Mark Selby 7
A0304 ... 8
High-efficiency cogenerators from SOLIDpower SpA **8**
Massimo Bertoldi (1), Olivier Bucheli (2), Alberto V. Ravagnia (2) 8
A0305 ... 9
25kW Stack Module Development - Status at sunfire **9**
Christian Walter (1), Thomas Strohbach (1), Peter Meisel (1), Kai Herbrig (1), Danilo Schimanke (1), Oliver Posdziech (1) 9
A0306 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 10
Development and Demonstration of a Novel Reversible SOFC System for Utility and Micro Grid Energy Storage **10**
Joshua Mermelstein (1), Oliver Posdziech (2) 10
A0501 (Will be published elsewhere) ... 11
Recent Advances in MSC Stack Technology for Mobile Applications at Plansee **11**
Wolfgang Schafbauer, Christian Bienert, Matthias Rüttinger, Marco Brandner, Lorenz S. Sigl 11
A0502 ... 12
Solid Oxide Fuel Cell APUs for Transport Applications **12**
Juergen Rechberger, Michael Reissig, Jörg Mathe, Bernd Reiter 12
A0503 ... 13
Status of Elcogen unit cell and stack development **13**
Matti Noponen (1), Paul Hallanoro (1), Jukka Göös (1), Enn Õunpuu (2) 13
A0504 ... 14
Sylfen: a new energy storage company using solid oxide fuel cell & electrolysis technology **14**
Nicolas Bardi (1), Caroline Rozain (1) 14
A0507 ... 15
Connected hydrogen storage for energy efficient buildings **15**
Caroline Rozain (1), Nicolas Bardi (1) 15

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0509 (Abstract only) ... 16
Convion SOFC System 5000h Validation **16**
Kim Åström, Henri Stenberg, Matti Liukkonen, Erkko Fontell 16
A0601 ... 17
Status of SOFC/SOEC Stack and System Development and Commercialization Activities at Fraunhofer IKTS **17**
Mihails Kusnezoff, Stefan Megel, Matthias Jahn, Thomas Pfeifer, Jens Baade 17
A0602 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 18
Current Status of NEDO Durability Project with an Emphasis on Correlation Between Cathode Overpotential and Ohmic Loss **18**
Harumi Yokokawa 18
A0603 (Will be published elsewhere) ... 19
Stack Development at Forschungszentrum Jülich **19**
Ludger Blum (1), Qingping Fang (1), Nikolaos Margaritis (2), Roland Peters (1) 19
A0604 (Will be published elsewhere) ... 20
NEXT-FC: An SOFC-Center for tight industry-academia collaboration and demonstration **20**
K. Sasaki (1-5), S. Taniguchi (1,2,5), Y. Shiratori (1-5), A. Hayashi (1-5), T. Oshima (3), Y. Tachikawa (5), M. Nishihara (5), J. Matsuda (4), T. Kawabata (2), M. Fujita (2), A. Zaitsu (2) 20
A0605 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 21
Status of CEA research and development on SOEC/SOFC cells, stacks and systems **21**
J. Mougin (1), J. Laurencin (1), J. Vulliet (2), S. Di Iorio (1), G. Roux (1), M. Reytier (1), F. Lefebvre-Joud (1) 21
A0606 (Abstract only) ... 22
Research and Development of SOFC and SOEC at DLR: from Next Generation Cells to Efficient and Effective Systems **22**
Remi Costa, Günter Schiller, Marc Heddrich, Asif Ansar and K. Andreas Friedrich 22
A0607 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 23
Solid Oxide Fuel Cell Technology Path: An investigation over the contribution of the Japanese and American Innovation System **23**
Marina Domingues Fernandes (1), Victor Bistritzki (1), Rosana Domingues (1), Tulio Matencio (1), Márcia Rapini (2), Rubén Sinisterra (1) 23
A0608 ... 24
Development of Hydrogen Technologies in the Czech Republic **24**
Karin Stehlík (1), Martin Tkáč (1,2), Karel Bouzek (2) 24
A0609 (Will be published elsewhere) ... 25
A Strategic Energy Technology Development Plan In Case of Low Oil Prices and Additional Nuclear Plant Construction Comparing with Multi-criteria Decision Making Approaches **25**
Seongkon Lee, Jongwook Kim* 25
A0610 (Abstract only) ... 26
The Brazilian Experience in SOFC Development **26**
A1401 (Will be published elsewhere) ... 27
Surface analysis and ionic transport of ScSZ/LSCrF dual-phase membrane for oxygen transport **27**
Chi Ho Wong, John Kilner, Stephen Skinner 27
A1402 (Will be published elsewhere) ... 28
Cermet membrane reactors for oxygen separation with low silver content **28**
E. Ruiz-Trejo (1), A. Bertei (1), A. Maserati (1), P. Boldrin (1), N. P. Brandon (1) 28

A1403 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....29
Development of solid oxide electrolysis for oxygen production from mars atmosphere carbon dioxide. 29
Joseph Hartvigsen, S. Elango Elangovan, Jessica Elwell, Dennis Larsen, Laurie Clark 29
A1404....30
Post-test analysis of a rechargeable oxide battery (ROB) based on Solid Oxide Cells 30
Cornelius M. Berger (1,2), Oleg Tokariev (1,2), Norbert H. Menzler (1,2), O. Guillon (1,2), M. Bram (1,2) 30
A1405 (Will be published elsewhere)....31
Characterization of Solid Oxide Cells based Rechargeable Oxide Battery 31
Qingping Fang, Cornelius M. Berger, Ludger Blum, Norbert H. Menzler, Martin Bram 31
A1406 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....32
Convion SOFC System 5000h Validation 32
Kim Åström, Henri Stenberg, Matti Liukkonen, Erkko Fontell 32
A1407 (Abstract only)....33
Novel membrane materials and membranes based on $La_{6-x}WO_{12-\delta}$ via spray pyrolysis and tape casting 33
Andreas B. Richter (1), Guttorm Syvertsen-Wiig (1), Wendelin Deibert (2), Mariya E. Ivanova (2) 33
A1408 (Will be published elsewhere)....34
Transport properties of LSCrF-ScSZ based mixed conducting ceramic composites 34
Zonghao Shen, Stephen Skinner, John Kilner 34
A1410 (Abstract only)....35
Solid oxide electrolysis of CO_2 on ceria based materials 35
Neetu Kumari (1), M. Ali Haider (1), Nishant Sinha (2), S. Basu 35
A1411....36
Electrochemical deoxygenation of bio-oil 36
S. Elango Elangovan (1), Dennis Larsen (1), Evan Mitchell (1), Joseph Hartvigsen (1), James Mosby (1), Byron Millet (1), Jessica Elwell (1), Pieter Billen (2), Sabrina Spatari (2) 36
A1412 (Will be published elsewhere)....37
Advanced electrochemical characterization of solid oxide electrolysis stacks (SOEC) 37
M. Lang, G. Braniek, S. Kurz, N. Muck, T. Schneider, Y. Zhang 37
A1413 (Will be published elsewhere)....38
Effect of conductivity and mechanical strength of bi-layer matrix on the performances of carbonate-ceramic dual-phase membranes 38
Mélanie Rolland (1), Dario Montinaro (2), Andrea Azzolini (2), Alessandro Dellai (2), Vincenzo Maria Sglavo (1) 38
A1414 (Will be published elsewhere)....39
Economic viability of high temperature electrolysis integration with renewable sources for a power to gas solution 39
Sarika Tyagi (1), Delia Muñoz (1), Truls Norby (2) 39
A1415 (Abstract only)....40
Electrochemical performance of H_2O-CO_2 co-electrolysis with a tubular solid-oxide co-electrolysis (SOC) cell 40

Tak-Hyoung Lim(*), Jong-Won Lee, Seung-Bok Lee, Seok-Joo Park, Rak-Hyun Song 40
A1416 (Will be published elsewhere)....41
Electrochemical characterization of a high temperature metal / metal oxide battery 41
S. Yildiz, I.C. Vinke, R.-A. Eichel, L.G.J. de Haart 41
A1501 (Will be published elsewhere)....42
Operational Experience with a Solid Oxide Fuel Cell System with Low Temperature Anode off-gas Recirculation 42
Maximilian Engelbracht, Roland Peters, Wilfried Tiedemann, Ingo Hoven, Ludger Blum, Detlef Stolten 42
A1502 (Abstract only)....43
A Total Cost of Ownership Analysis of SOFC Fuel Cell Systems 43
Shuk Han Chan (1), Max Wei (2), Ahmad Mayyas (2), Timothy Lipman (3) 43
A1503 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....44
Road Truck LNG Boil-Off Converted to Battery Power by Small Planar SOFC System 44
Ulf Bossel 44
A1504 (Abstract only, published elsewhere)....45
Electrochemical and Hydrogen Energy Technologies for Next-Generation Transportation Energy Systems 45
Whitney G. Colella (1, 2) 45
A1505 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....46
Solid Oxide Electrolysis Development at Versa Power Systems 46
Tony Wood (1), Hongpeng He (1), Tahir Joia (1), Mark Krivy (1), Dale Steedman (1), Eric Tang (1), Casey Brown (1), Khun Luc (1) 46
A1506....47
SOEC Enabled Biogas Upgrading 47
John Bøgild Hansen, Majken Holstebroe, Michael Ulrik Borg Jensen, Jeppe Rass-Hansen, Thomas Heiredal-Clausen 47
A1507 (Abstract only)....48
Hydrogen Production Using Solid Oxide Electrolyser Cells at Shanghai Institute of Applied Physics 48
Guoping Xiao, Chengzhi Guan, Xinbing Chen, Jian-Qiang Wang* 48
A1507 (see A1502)....49
A1508....50
Topsoe Stack Platform (TSP) – a robust stack technology for solid oxide cells 50
Jeppe Rass-Hansen, Peter Blennow, Thomas Heiredal-Clausen, Rainer Küngas, Tobias Holt Nørby, Søren Primdahl 50
A1509 (Abstract only, published elsewhere)....51
High Temperature Electrolysis for Hydrogen Production 51
Whitney G. Colella (1, 2) 51
A1510 (Abstract only)....52
Quality Evaluation and Analysis Method Development of Byproduct Hydrogen Using Gas-Chromatography 52
Daeic Chang*†, Jong Kuk Kim†, Jongseong Lee‡ and Hangsoo Woo‡ 52
A1511 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....53
Solid Oxide Fuel Cell application analysis 53
Ling-yuan Tseng 53

A0301

Advances in HEXIS' SOFC development

Andreas Mai, Felix Fleischhauer, J. Andreas Schuler, Roland Denzler, Volker Nerlich, Alexander Schuler
HEXIS Ltd.
Zum Park 5
CH-8404 Winterthur
Tel.: +41-52-26-26312
Fax: +41-52-26-26333
andreas.mai@hexis.com

Abstract

HEXIS is developing and manufacturing SOFC-based micro-CHP systems for single-family or small multi-family houses. The current system Galileo 1000 N has an output of 1 kW electrical power. It furthermore covers the full heat demand of a standard single family house.

This contribution reports on the achievements in testing Galileo 1000 N, namely:

- Lifetime and degradation measurements on short-stack and complete systems. Highlights are tests for 18'000 h (short stacks), 18'000 h (lab tests) and 15'000 h (field tests), where power degradations of 0.2 % per kh have been demonstrated. This leads to lifetime prognoses of 40'000 h and more.
- High reproducibility of cell and stack performance could be demonstrated and the performance of short-stacks, lab systems and field systems are similar to each other and that the operation parameters only have small influence within the given operation window on the degradation.
- High robustness against planned but also unforeseeable shut-downs and external or internal failures could be shown, resulting in similar results in field and lab tests.

Galileo 1000 N has achieved the technical market readiness and introduction into pilot-markets in Europe was started in late 2013.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0302

Solid Oxide Fuel Cell Development at Versa Power Systems & FuelCell Energy

Brian Borglum (1) and Hossein Ghezel-Ayagh (2)
(1) Versa Power Systems, Ltd.
4852 – 52nd Street SE
Calgary, Alberta, T2B 3R2 / Canada
(2) FuelCell Energy, Inc.
3 Great Pasture Road
Danbury, Connecticut, 06813 / United States
Tel.: +1-403-204-6110
Fax: +1-403-204 6101
bborglum@fce.com

Abstract

Versa Power Systems (VPS) and FuelCell Energy (FCE) are developing solid oxide fuel cells (SOFCs) for clean power generation. FCE is the global leader in the design, manufacture and distribution of Molten Carbonate Fuel Cell (MCFC) power plants. From an economic perspective, MCFCs scale-up very well and as a result FCE's MCFC products are in the multi-megawatt size range. SOFCs are complementary because they scale-down well and hence are suited to sub-megawatt applications. VPS and FCE are taking advantage of the scalability and modularity of SOFC technology in order to advance towards commercial deployment of highly efficient distributed generation SOFC systems. This paper highlights the status of VPS and FCE's SOFC technology in the areas of cell, stack and system development.

A0303 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Development status of Ceres Power Steel Cell technology: further improvements in manufacturability, durability and performance

Robert Leah, Adam Bone, Mike Lankin, Mahfujur Rahman, Eva Hammer, Ahmet Selcuk, Andy Clare, Subhasish Mukerjee, Mark Selby
Ceres Power Ltd.
Viking House
Foundry Lane
Horsham RH13 5PX/ UK
Tel.: +44-1403-273463
Fax: +44-1403-327860
robert.leah@cerespower.com

Abstract

Ceres Power is continuing to make excellent progress in the development of its low-temperature metal supported SOFC design (the 'Steel Cell') based predominantly around the use of ceria. This unique design architecture allows for a robust, low cost, subsidy free fuel cell product, whilst retaining the advantages of fuel flexibility, high efficiency and low degradation.
A particular focus over the last year has been on improving maturity of the technology as well as simplification of the cell manufacturing process without compromising performance, as a result of which a number of manufacturing steps have been combined or eliminated enabling a further significant reduction in cost. Extensive verification of the technology has been undertaken both by Ceres and commercial partners, demonstrating low degradation and excellent robustness to thermal and REDOX cycling across multiple stacks at short stack, tall stack, fuel cell module and product levels.
Further performance development of the core cell and stack technology has also been undertaken, with significant improvements demonstrated in power density and efficiency operating on steam reformed hydrocarbons.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0304

High-efficiency cogenerators from SOLIDpower SpA

Massimo Bertoldi (1), Olivier Bucheli (2), Alberto V. Ravagnia (2)
(1) SOLIDpower SpA,
I-38017 Mezzolombardo, Italy
(2) HTceramix SA,
CH-1400 Yverdon-les-Bains, Switzerland
massimo.bertoldi@solidpower.com

Abstract

SOLIDpower provides efficient energy solutions based on its unique proprietary planar SOFC technology. Thanks to the acquisition in July 2015 of the German assets and employees of Ceramic Fuel Cells GmbH (CFC), the company has consolidated its SOFC experience especially about system operation in the field. More than 650 units and 10 GWh of electric power has been proven so far by the existing BlueGEN fleet. Therefore, SOLIDpower can offer now as a unique selling proposition the most efficient, high-availability, and competitive mCHP units in the world.

The product portfolio includes a 60% electric efficiency 1.5 kWe mCHP unit, the BlueGEN, and a 50% electric, 90% cogeneration efficiency 2.5 KWe unit called EnGen™-2500. Both systems are CE certified and are currently installed in Europe, partially within the frame of Ene.field demonstration program and, starting from 2016, will be further deployed in the European market with a focus on Germany, Italy, UK and Benelux. The two products are manufactured in different production plants in Northern Italy and Germany, respectively, each one with a production capacity of about 2 MW/yr on single shift. Based on an ordering volume of 50 MW, the stack and balance of stack components match target market requirements, allowing selling and operating systems at grid parity prices.

Besides the micro-CHP program, SOLIDpower pursues also strategic development activities to demonstrate larger SOFC systems, including generators for data-center, SOE, polygeneration, biogas and waste-to-energy (WTE) applications. A specific product development line to address a high efficiency 10 kW electric generator for data-centers has been started in 2015.

The paper provides an update of the stack and system development results, including stack durability, robustness and operational results of SOFC-based micro-CHP in the field.

A0305

25 kW Stack Module Development - Status at sunfire

Christian Walter (1), Thomas Strohbach (1), Peter Meisel (1), Kai Herbrig (1), Danilo Schimanke (1), Oliver Posdziech (1)
(1) Sunfire GmbH
Gasanstaltstr. 2, D-01237 Dresden
Tel.: +49-351-896797-963
Fax: +49-351-896797-886
Christian.Walter@sunfire.de

Abstract

This paper describes the development status of larger solid oxide cell (SOC) modules within sunfire. To this end, improvements of the stack technology based on the key value costs / KWh are presented. Furthermore, details regarding degradation and the enhancement of stack production yields are shown. Besides that, the development of the larger modules (P_{SOFC}>25 kW, P_{SOEC}>100 kW) is illustrated. Some of the improvements like the optimization of the modules for a fuel flexible and reversible SOFC (rSOC) operation and a homogenized temperature distribution over all stacks are described in detail. The processes that are used to ensure a constant quality of the delivered modules are given. Finally, several core applications that can be addressed using larger SOC modules like commercial CHP, industrial hydrogen and energy storage are presented, which show the wide range of market opportunities and cooperation opportunities for sunfire's customers.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0306 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Development and Demonstration of a Novel Reversible SOFC System for Utility and Micro Grid Energy Storage

Joshua Mermelstein (1), Oliver Posdziech (2)
(1) Boeing
14441 Astronautics Lane, Huntington Beach, CA 92647
Tel: +1-714-896-6110
joshua.m.mermelstein@boeing.com
(2) sunfire GmbH
Gasanstaltstrasse 2, D-01237 Dresden
Tel.: +49 351 89 67 97 - 965
oliver.posdziech@sunfire.de

Abstract

Energy storage is a critical component to supply local energy generation for both grid and off-grid connected facilities and communities, enabling localized grid independent energy secure power in cases of emergencies or unreliable traditional grid use. The high cost and energy security of importing fuel to islanded grids has led to a growing need to generate power onsite with alternative and renewable energy technologies while reducing facility costs of importing electrical power. However, utility grid operators are being faced with the challenges of intermittent and variability in energy production from renewables. Therefore energy storage is crucial to balance micro and utility grids, improve efficiency, reduce fuel consumption, and provide critical power in the event of power outages. There has been particular interest in reversible solid oxide fuel cells (RSOFCs) in the energy sector for electricity, energy storage, grid stabilization and improvement to power plant system efficiency due to favorable thermodynamic efficiencies of high temperature steam electrolysis. Boeing has been active in the development of a fully integrated, grid tied RSOFC system for micro grid and commercial utility energy storage using Sunfire fuel cell technology. In this system, excess grid energy or curtailed power generated by renewables is sent to the system operating in electrolysis mode to produce H_2. The H_2 is stored and then used in the system's fuel cell mode to provide supplemental power to the grid during peak hours or as needed. As part of this program, Boeing has developed a H_2 storage and compression system, power distribution system, and master controller to interface with RSOFC subsystems. Sunfire developed a reversible solid oxide cell module with a power output of 50 kW in SOFC mode and 120 kW input in electrolysis mode producing 3.5 kg H_2/hr. The system was demonstrated while connected to the local utility grid and operated in a microgrid test environment. This paper will discuss the development, integration, and demonstration of the RSOFC system.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A0501 (Will be published elsewhere)

Recent Advances in MSC Stack Technology for Mobile Applications at Plansee

Wolfgang Schafbauer, Christian Bienert, Matthias Rüttinger, Marco Brandner, Lorenz S. Sigl
Plansee SE
6600 Reutte, Austria
Tel.: +43-5672-600-2439
Fax: +43-5672-600-563
wolfgang.schafbauer@plansee.com

Abstract

Thin-film metal-supported SOFCs (MSC) are of high interest for mobile applications where highly efficient energy converters are required. Compared to other SOFC types, the Plansee MSC technology shows a high potential for mobile applications where cells are facing severe conditions, e.g. mechanical stress or thermal cycling. Furthermore, metallic cell supports and dense metal parts, like interconnects and/or frame sheets, can be more easily integrated into light-weight stack designs by means of a laser welding process.
This key feature of MSCs is in the focus of current research activities. While overall feasibility of the Plansee MSC technology has already been demonstrated on the level of single cells, now performance results in real stack environment are of interest.
Therefore, a proprietary stack design, well-suited for MSCs, has been developed. The stack is aiming for mobile applications, e.g. APU systems or range extender systems.
In this contribution, first results of the stack development will be presented. This includes the manufacturing of the MSC in the corresponding dimensions but also the progress of the joining development up to the presentation of initial electrochemical tests of the novel stack design cells.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0502

Solid Oxide Fuel Cell APUs for Transport Applications

Juergen Rechberger, Michael Reissig, Jörg Mathe, Bernd Reiter
AVL List GmbH
Hans-List-Platz 1
A-8020 Graz, Austria
Tel.: +43-316-787-3426
Juergen.rechberger@avl.com

Abstract

AVL is developing since 2002 Solid Oxide Fuel Cell Auxiliary Power Units (SOFC APU) for transport applications. With the latest APU generation III a new platform has been developed to integrate different stack platforms. The GenIII has also been upgraded to provide up to 5kW of electrical power, ~35% electrical efficiency and a packaging size to comply with all major intended applications. A major step forward has been implemented towards an integrated power electronics module for easy vehicle integration. The latest technical achievements and test results will be presented.

Together with the partners Eberspächer, TOFC, Volvo and Forschungszentrum Jülich, AVL has performed within the FCH JU DESTA project a very successful APU truck integration. In total around 10 APU systems have been built up and tested in various environments like laboratory, vibration, salt spray and vehicle. Almost all project objectives have been reached and will be presented.

Since 2015 AVL is heavily involved in a new development program with a global passenger car OEM and key technology providers to develop SOFC based range extender systems for passenger cars. SOFC technology provides major benefits for this application like compatibility with logistic fuels, high efficiency and low noise. However, there are also major challenges to be solved like power density and rapid start up. In the presentation, the motivation and first conceptual considerations will be presented.

A0503

Status of Elcogen unit cell and stack development

Matti Noponen (1), Paul Hallanoro (1), Jukka Göös (1), Enn Õunpuu (2)
(1) Elcogen Oy
Niittyvillankuja 4, 01510 Vantaa, Finland
(2) Elcogen AS
Valukoja 23, Tallinn 11415, Estonia
Tel.: +358 10 323 3060
finland@elcogen.com

Abstract

Elcogen is a private company focusing on commercialization of solid oxide fuel cell technology. Elcogen manufactures both unit cells and stacks. Elcogen solid oxide fuel cell unit cells and stacks provide excellent performance characteristics at reduced operation temperatures between 600 – 700 °C reaching 74 % gross efficiency. Elcogen stacks combine unique features of Elcogen's well-proven unit cell technology together with innovative sealing, contact and flow distribution solutions combined with cost optimized design for mass manufacturing. Through modular stack design, Elcogen provides stack solutions from micro-CHP to commercial stationary applications. Elcogen E1000 with closed air manifold structure is optimized for 0.7 – 1.5 kW_e electricity output, and E3000 with open air manifold structure from 1.5 – 3 kW_e as a single stack setup up-to hundreds of kW_e as multiple stack assemblies.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0504

Sylfen: a new energy storage company using solid oxide fuel cell & electrolysis technology

Nicolas Bardi (1), Caroline Rozain (1)
(1) Sylfen,
Minatec Bât. 52, 7 parvis Louis Néel, F-38040 Grenoble Cedex 9, France
Tel.: +33-6 74 95 10 65
nicolas.bardi@sylfen.com

Abstract

Sylfen is a new company established in Grenoble in June 2015, based on reversible solid oxide fuel cell and electrolysis technology developed at CEA-Liten. Sylfen's ambition is to contribute to a world where energy is renewable and produced locally, thanks to its high capacity energy storage and conversion technology. Sylfen's smart energy hub makes it possible to create responsible buildings, producing, storing and using locally produced energy, thus reducing carbon emissions, making them partners of local smart grids and with a protected patrimonial value.
With the smart energy hub, surplus power produced by the building is stored as hydrogen. Hydrogen is then used to provide combined heat and power to the building when needed. Energy can still be sold or bought from the grid, at chosen times, and additional energy can be produced from methane or bio-methane. The smart energy hub integrates batteries, the energy processor built from 35 kWe electrolysis modules, hydrogen tanks, and software to optimize the energy storage strategies.
Based on the "Sydney" reversible system demonstrated by CEA-Liten in 2015, Sylfen is now developing its product to be qualified in field tests, and targets delivery of first commercial units in 2018. Sylfen also engages a R&D road-map, opened to cooperation with the SOFC/SOEC scientific community, in order to achieve 80% round-trip efficiency systems.

A0507

Connected hydrogen storage for energy efficient buildings

Caroline Rozain (1), Nicolas Bardi (1)
(1) Sylfen, Minatec Bât52, 7 parvis Louis Néel, F-38040 Grenoble Cedex 9
Tel.: +33-68-467-8126
caroline.rozain@sylfen.com

Abstract

We investigate in this study the potential of a reversible high temperature fuel cell for the establishment of a decentralized energy storage network. Thanks to its unique ability to operate both in electrolysis (conversion of electricity into hydrogen and heat) and fuel cell (conversion of hydrogen into electricity and heat) mode, the reversible fuel cell coupled with batteries allows local storage of excess energy at buildings scale. A simulation model has been built, based on hourly time step for renewable energy production and building's consumption which includes both building's needs (light, heat and cooling, sanitary water and ventilation) and specific electrical consumption (like computers). For each case study, the components sizing is optimized (battery capacity, hub power, size of hydrogen storage) and an operation strategy is designed according to local conditions. The economic viability of the scenario is then assessed.
Thanks to the simulation model, several business cases of Sylfen's solution coupled to buildings have been identified as promising for renewable production integration and reduction of the demand energy during on-peak hours at building scale.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0509 (Abstract only)

Convion SOFC System 5000h Validation

Kim Åström, Henri Stenberg, Matti Liukkonen, Erkko Fontell
Convion Ltd
Tekniikantie 12
FIN-02150 Espoo / Finland
Tel.: +358-40-845-3072
kim.astrom@convion.fi

Abstract

Convion Ltd. is a leading fuel cell system developer committed to commercializing solid oxide fuel cell (SOFC) systems in power range of 50–300kW for distributed power generation. In 2015 Convion started validation of its upcoming C50 product in a 20kW scale. The test unit, based on Plansee/IKTS stack technology, has successfully accumulated 5000 hours of operation with power delivery to the utility grid. Convion has also successfully demonstrated ability to automatically switch between grid parallel and grid independent operation to provide backup power for critical customer loads in grid outage situations.

During the validation period the test unit has undergone both long term steady state nominal as well as well as part-load and transient operation testing. Performance and emissions of the system have been characterized. The presentation will highlight Convion's unique approach for combining simplicity, robustness, performance and flexibility in a SOFC system to address cost competitiveness challenges. Key findings on the experiences from the 20kW operation regarding performance, emissions, islanding, thermal cycling and effects of a multi-stack configuration will be presented.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0601

Status of SOFC/SOEC Stack and System Development and Commercialization Activities at Fraunhofer IKTS

Mihails Kusnezoff, Stefan Megel, Matthias Jahn, Thomas Pfeifer, Jens Baade
Fraunhofer IKTS
Winterbergstraße 28
D-01277 Dresden / Germany
Tel.: +49-351-2553-7707
Fax: +49-351-2554-134
mihails.kusnezoff@ikts.fraunhofer.de

Abstract

Since the mid-1990's, Fraunhofer IKTS is developing SOFC on cell, stack and system level, conducting various R&D and engineering projects funded by public bodies, industrial customers and Fraunhofer-internal programs. According to intrinsic objectives of the Fraunhofer business model, matured technical solutions are transferred to practical applications and commercial products, following different commercialization strategies, e.g. contract research, technology licensing and corporate spin-offs. Some of today's well-established SOFC products – a subset of Kerafol's MEAs and glass tapes, sunfire's SOFC stacks and Vaillant's SOFC micro-CHP systems to name here – date back to R&D collaborations with IKTS in the 2000s. Meanwhile, IKTS has evolved into one of the major hubs for SOFC technology, worldwide.
Out of a long-term relationship with Plansee SE, the CFY stack technology emerged as a robust and reliable standard solution for SOFC systems in arbitrary applications. In 2015, the company MPower GmbH was formed for the commercial distribution and series manufacturing of CFY stacks. Backed by private investment, IKTS and MPower are going to develop a commercial stack production and deployment facility in the next three years.
On system level, one of the major activities since 2008 was the development of the eneramic® system, a portable, LPG-fueled 100 W SOFC power generator for off-grid applications. The program was funded by the Fraunhofer Future Foundation, and led to the foundation of the company Ceragen GmbH in 2015. The spin-off company will further promote the product development and commercial deployment of eneramic® systems, with continued R&D and engineering support by IKTS. Apart from the eneramic® development, several other projects for application-specific SOFC system solutions have been initiated, e.g. a 1 kW SOFC/battery-hybrid system for the Indian market, contracted by h2e Power Systems.
In the status presentation, the major technical outcomes of recent SOFC and SOEC development activities at IKTS will be outlined together with a brief description of ongoing commercialization activities and business opportunities, supported by IKTS.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0602 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Current Status of NEDO Durability Project with an Emphasis on Correlation Between Cathode Overpotential and Ohmic Loss

Harumi Yokokawa
Institute of Industrial Science, The University of Tokyo, Tokyo 153-8505 Japan
Tel. & Fax: +81-3-5405-6780
yokokawa@iis.u-tokyo.ac.jp

Abstract

Long-term behavior of six stacks with different materials, processing and design has been investigated by stack performance measurement by CRIEPI (Central Research Institute for Electric Power Industry). Comparison with results in the previous project clarifies the interesting differences that cathode overpotential degradation in some stacks exhibits significant magnitude, although the rest of stacks show excellent durability. Such large degradation in cathode is in many cases accompanied with corresponding increase in ohmic loss to be contributed from many parts. It has been also found that cathode degradation does not seem to be governed by materials properties alone. It must depend on 1) existence of ceria-based interlayer, 2) morphology (porous or dense) of such inserted interlayer, 3) impurity level and their interaction with others, 4) operation conditions including impurities in air or in environmental materials. Detailed analyses on cathode performance degradation due to sulfur impurities have revealed that there exist several different degradation mechanisms which are accompanied with different behavior of the ohmic part; this may provide a basis of distinguishing nature of cathode degradations in terms of differences in correlation between cathode overpotential and ohmic loss. Complicated features in cathode performance suggest that 1) IT cathodes such as LSCF may exhibit two different performance stages which may be affected by some impurities without severe degradation, 2) cathode performance seems to be strongly correlated with materials state of combined ceria-based interlayer and adjacent YSZ electrolyte layer, 3) preexist sulfur component in cathodes may affect features of performance degradation due to strong interactions and their changes among low concentration-level impurities based on acid-base properties. New features appearing in the present durability project makes it necessary to make further detailed analyses on changes in chemical state in the vicinity of electrochemical reaction sites as well as to apply strongly cooperated analyses based on both simulation techniques and experimentally obtained knowledge accumulated from previous projects.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A0603 (Will be published elsewhere)

Stack Development at Forschungszentrum Jülich

Ludger Blum (1), Qingping Fang (1), Nikolaos Margaritis (2), Roland Peters (1)
Forschungszentrum Jülich GmbH
(1) Institute of Energy and Climate Research
(2) Central Institute of Engineering, Electronics and Analytics
Wilhelm-Johnen-Straße, D-52428 Jülich, Germany
Tel.: +49-2461-616709
Fax: +49-2461-616695
l.blum@fz-juelich.de

Abstract

Since 2000, JÜLICH has been developing kW-class SOFC stacks for use in stationary applications. To accommodate the internal manifolds and also allow an operation time of at least 40,000 h, the interconnects are relatively thick (2.5 mm). For the kW-class stacks, a cell size of 20 x 20 cm² was initially chosen. On the basis of this concept, several 5 kW stacks and one 10 kW stack were developed and tested successfully. One of the next development goals is an increase of the stack power towards 15 kW. However, to reduce cell costs, the design should allow the use of standard sized cells offered by various cell manufacturers, which means smaller cell sizes. Therefore, JÜLICH changed the stack design to a window-frame concept incorporating in a first step four cells of 10 x 10 cm². In addition, the design of the manifolds and frames was changed to allow the stacking of 120 layers and to reduce the manufacturing effort. First stack test results will be presented.
Using the existing stack design incorporating cells of 20 x 20 cm² together with the Integrated Module, demonstrated with a 20 kW system, an optimized plant concept with anode off-gas recirculation was developed and realized. Operating at a DC power of 4 kW a system fuel utilization of 90% could be achieved resulting to a system efficiency of 56%.
In addition to the aforementioned stationary stack design, the development of a cassette stack design was initiated a few years ago, aimed at APU applications where, on the one hand, shorter start-up time is required but on the other, shorter operation time is foreseen. The fifth generation of this design consists of thin stamped metal sheets of 0.3 mm thickness with cells 10 x 18 cm² in size. Design concept and stack test results will be presented.
As a special highlight, the long-term tests with short stacks under continuous operation at 700 °C and 0.5 Acm⁻², of which one has now reached an operation time of more than 74,500 h (degradation 0.6%/kh), which marks a world record for SOFC long-term operation, will be reported.
Nowadays high temperature electrolysis is a field of growing interest. Based on our standard short stack design we are testing SOFC stacks also in the SOE mode. Such a short stack is now in operation for 11,500 h with a voltage degradation of 0.7%/kh.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0604 (Will be published elsewhere)

NEXT-FC: An SOFC-Center for tight industry-academia collaboration and demonstration

K. Sasaki (1-5), S. Taniguchi (1,2,5), Y. Shiratori (1-5), A. Hayashi (1-5), T. Oshima (3), Y. Tachikawa (5), M. Nishihara (5), J. Matsuda (4), T. Kawabata (2), M. Fujita (2), A. Zaitsu (2)
Kyushu University
(1) Next-Generation Fuel Cell Research Center (NEXT-FC)
(2) International Research Center for Hydrogen Energy
(3) Faculty of Engineering (Dept. of Hydrogen Energy Systems)
(4) International Institute for Carbon-Neutral Energy Research (WPI-I2CNER)
(5) Center for Co-Evolutional Social Systems (CESS)
Motooka 744, Nishi-ku, Fukuoka 819-0395 / Japan
Tel: +81-92-802-3143
Fax: +81-92-802-3223
sasaki@mech.kyushu-u.ac.jp

Abstract

Next-Generation Fuel Cell Research Center (NEXT-FC) has been established in 2012 in Kyushu University, Japan. This paper explains the concept, aim, and current activities of this Center, offering various opportunities for tight industry-academia collaboration and demonstration. Many private companies and leading university teams have already opened their own laboratories in the center building for collaborative research projects for science, technology, and commercialization of advanced fuel cells, especially solid oxide fuel cells. We are challenging to realize a fuel-cell-powered campus at Kyushu University where SOFC technology plays a major role. The Smart Fuel Cell Demonstration Project, supported by Cabinet Secretariat/Office of Japan, enables us to install one 250kW-class SOFC-MGT (Micro Gas Turbine) power generation system, various fuel cell units, and the world-first university-owned fuel cell vehicle to which renewable hydrogen gas is supplied from the hydrogen refueling station in this campus using electrolyzers. Various demonstrative projects are on-going along with related efforts to accelerate industry-academia collaboration and fundamental scientific studies using advanced analytical facilities.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0605 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Status of CEA research and development on SOEC/SOFC cells, stacks and systems

J. Mougin (1), J. Laurencin (1), J. Vulliet (2), S. Di Iorio (1), G. Roux (1), M. Reytier (1), F. Lefebvre-Joud (1)
(1) Univ Grenoble Alpes CEA/LITEN, 17 rue des Martyrs, 38054 Grenoble , FRANCE
(2) CEA/-Le Ripault, DMAT, F-37260 Monts, France
Tel.: +33-(0)4-38-78-10-07
Fax: +33-(0)4-38-78-54-79
Julie.mougin@cea.fr.

Abstract

The technology based on solid oxide cells (SOC) has been considered for many years for combined heat and power applications (CHP) when operated in the fuel cell mode (SOFC). The same cells can be operated in electrolysis mode (SOEC) to produce hydrogen. As a consequence it enables reversible operation that is of most interest for storing intermittent renewable energies. This technology can also be operated in co-electrolysis mode by adding CO_2 to H_2O for producing syngas (H_2/CO) that can subsequently be transformed into synthetic fuels (methane, DME, methanol). This flexibility, complemented by attractive efficiencies without any noble-metal catalysts offers a technological and economic potential to this SOC technology that is not achievable with other fuel cell/electrolysis technologies.

CEA research and development activities cover these different application areas, from cell development to stack and system design and operation, supported by multi-physics and multi-scales modeling activities and advanced characterization.

Particular emphasis is given to the understanding of performance and degradation controlling parameters at every scale in order to optimize ceramic cells and to design robust and reliable SOC stacks.

System integration has been given specific attention allowing the design of complete system producing 1.2 Nm^3 H_2/h with an electric yield of 3.5 kWh/Nm^3 assuming an available steam source at 150°C.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0606 (Abstract only)

Research and Development of SOFC and SOEC at DLR: from Next Generation Cells to Efficient and Effective Systems

Remi Costa, Günter Schiller, Marc Heddrich, Asif Ansar and K. Andreas Friedrich
German Aerospace Center (DLR)
Institute of Engineering Thermodynamics,
Pfaffenwaldring 38-40, D-70569 Stuttgart, Germany
Tel.: +49-711-6862-278
Fax: +49-711-6862-1278
andreas.friedrich@dlr.de

Abstract

Reducing emission of greenhouses gases represents a huge societal challenge, Among the portfolio of technologies, High Temperature Solid Oxide Cells (SOC) present key advantages in term of efficiency to be used either for power generation or energy storage. From cells to system, research activities at German Aerospace Center activities are covering the whole technological chain.

Over the last decades continuous improvement in materials, architecture and manufacturing processes have been achieved to improve performance durability and lifetime. The advanced concept of a metal-supported SOC where the functional ceramic layers are deposited onto a mechanically stable porous metal support is the most advanced approach for mobile application as auxiliary power units (APU). This application requires low volume, limited weight and improved ability for rapid start-up and thermal cycling. At DLR, functional layers are consecutively deposited by plasma spray technology onto a metal substrate. Recently, further research efforts have started to develop a metal-supported cell with thin-film electrolyte applied through PVD technology preparing the next generation of SOCs.

The German Aerospace Center (DLR) aims to build and operate a hybrid power plant with an electrical power output of 30 kW which can be operated at higher efficiency than conventional plants. This hybrid power plants consists of a gas turbine coupled with solid oxide fuel cells. Theoretical studies suggest electrical efficiencies of up to 70%. The system concept and design of the power plant have been finalized and the specification of all major system components has been carried out. Currently, different system components are being purchased and tested.

The presentation provides first an overview of the metal-supported cell development including materials aspects, stack technology and electrochemical performance. In a second part, an overview of the current status of the project of hybrid power plant will be given, illustrating the general concept of the power plant. Important specifications characteristics and test results of the components will be presented.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

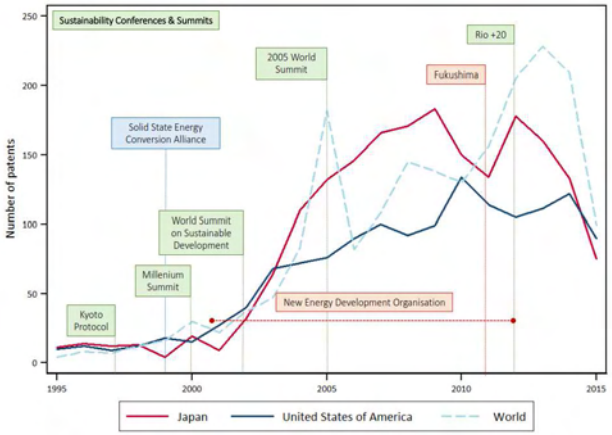
A0607 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Solid Oxide Fuel Cell Technology Path: An investigation over the contribution of the Japanese and American Innovation System

Marina Domingues Fernandes (1), Victor Bistritzki (1), Rosana Domingues (1), Tulio Matencio (1), Márcia Rapini (2), Rubén Sinisterra (1)
Federal University of Minas Gerais
(1) Faculty of Chemistry, (2) Faculty of Economics
Av. Pres. Antônio Carlos, 6627 - Pampulha, Belo Horizonte, Brazil
marinadomingues2609@gmail.com

Abstract

This paper analyzes the technology path of Solid Oxide Fuel Cells in the United States and Japan. Some previous studies discuss this path regarding technical advances of SOFCs (compounds, manufacturing methods, applications), others the evolution of company structures. We propose to discuss on the grounds of the Japanese and American Innovation Systems, complementing our analyses with sustainable development matters and historical facts intrinsic to the technology development itself.
We support our argumentation using a patent landscape including 942 published patents from 1995 to 2015 and a panel company database comprising 66 SOFC related companies. The high amount of American and Japanese patents (70% of all inventions analyzed) raised the question of what historical elements distinguished the development of SOFCs in those from other countries, including Germany and the UK considered to be the cradle of the fuel cell.



Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0608

Development of Hydrogen Technologies in the Czech Republic

Karin Stehlík (1), Martin Tkáč (1,2), Karel Bouzek (2)
Centrum výzkumu Řež,
Hlavní 130, 25068 Husinec-Řež, Czech Republic
(2) University of Chemistry and Technology (UCT), Prague,
Dep. of Inorganic Technology,
Technická 5, 166 28 Prague 6, Czech Republic
Tel.: +420-266-17-2045
karin.stehlik@cvrez.cz

Abstract

Keywords: hydrogen technologies, Visegrad countries, Czech Republic, national strategy, research and demonstration activities, Czech Hydrogen Technology Platform

From the beginning of the Czech activities in the field of hydrogen technologies it is about 20 years. Experts in the Czech Republic gathered technology know-how during national and international co-operations and projects. The most visible result is the first hydrogen bus in the new EU member states. The TriHyBus project was implemented by a consortium around ÚJV together with Škoda Electrics, Proton Motors in Germany, Linde Gas, IF Halden in Norway, and the Czech Ministery of Transport. The bus was operated close to Prague in the town Neratovice.

For further development of the hydrogen technologies and their commercialization in the Czech Republic a clear national strategy is necessary. Unfortunately this concept is still missing. On the conference Hydrogen Days 2015 in Prague it crystallized that a similar situation can be found in all countries of the former Eastern Bloc. With support of the Visegrad Fund an expert network between Poland, Hungary, Slovakia, Czech Republic, and Romania was set up in the project “Strengthening Competencies in Hydrogen Technologies in the Visegrad countries”. A focus of this year 7th int. conference Hydrogen Days 2016 was the status of hydrogen technologies in the states of this region and to provide an occasion to meet each other directly.

The project partners wish to continue their collaboration and present their results on the World Hydrogen Technology Convention 2017 in Prague organized by the Czech Hydrogen Technology Platform. An important lesson learnt from Visegrad project and the conference Hydrogen Days 2016 is that the convincing politics, bringing the topic into public is as important as the technological progress. Actual research in the Czech Republic is undergoing in catalyst research, e.g. LeanCat consortium, for PEM fuel cells and electrolysers. Applied research for alkaline electrolysers as well as in high-temperature technologies is conducted, e.g. the SUSEN project at the Centrum výzkumu Rez. Last but not least a demonstration project for energy accumulation for households is in the test phase, coordinated by the engineering company ÚJV.

A0609 (Will be published elsewhere)

A Strategic Energy Technology Development Plan In Case of Low Oil Prices and Additional Nuclear Plant Construction Comparing with Multi-criteria Decision Making Approaches

Seongkon Lee, Jongwook Kim*
Energy Policy Research Team, Korea Institute of Energy Research, Daejeon, Republic of Korea
*Tel.: +82-42-860-3176
*Fax: +82-42-860-3097
*jongwkim@kier.re.kr

Abstract

Energy environment has been rapidly changing according to the rapid growth of developing and undeveloped countries with rapid depletion of fossil fuel resource. In case of Korea, Korea is the very poor natural resource nation. Korea is easily affected directly and indirectly affected by the change of fossil fuel resource such as oil price. A strategic energy technology development is a key issue for the advanced economies including developing economies. We also have been facing the competition of environmental friendly green technology development for leading the green energy market initiative. Advanced nations such as U.S, Japan, and German have been trying to implement strategic energy technology development plans considering their sustainable development and coping with the climate change. In this research, we suggest and establish a strategic energy technology development plan with systematic procedure in case of low oil prices and additional nuclear power plant construction comparing with AHP (analytic hierarchy process) and Fuzzy AHP approaches. We assess the relative weights of criteria and 15 energy technologies including hydrogen and fuel cell technology with two time peer-review. The results of this research provide the policy makers with a scientific systematic procedure and fundamental data for establishing a strategic energy technology development to cope with the rapid environmental change and sustainable development.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0610 (Abstract only)

The Brazilian Experience in SOFC Development

Marina Domingues Fernandes (1), Victor Bistritzki (1), Rosana Domingues (1), Tulio Matencio (1), Márcia Rapini (2), Rubén Sinisterra (1)
Universidade Federal de Minas Gerais
(1) Faculty of Chemistry, (2) Faculty of Economics
Av. Pres. Antônio Carlos, 6627 - Pampulha, Belo Horizonte, Brazil
marinadomingues2609@gmail.com

Abstract

This paper describes the Brazilian experience regarding the development of Solid Oxide Fuel Cell (SOFC) technologies over the last 20 years, with a special focus on the research and development (R&D) projects located in the state of Minas Gerais.
Since 1995, the Brazilian Department of Science and Technology stimulates SOFCs R&D, funding universities and companies' research. After 2001, the investment increased as the government created new instruments to allocate resources in many economic sectors, including the energy one. Moreover, in the same year, the country faced the worst energy crisis of its history motivating a more incisive reaction to diversify the possible energy sources available. As a promising alternative, the government increased the investment in SOFC technologies. Among other states that the government invested, Minas Gerais was the one achieving best technical aspects, developing the complete cell using Brazilian technology. The description of this paper outlines the positive and negative points of the Brazilian experience. The Minas Gerais experience is described in details and the outcomes of the projects are based on the project contracts signed by that time.

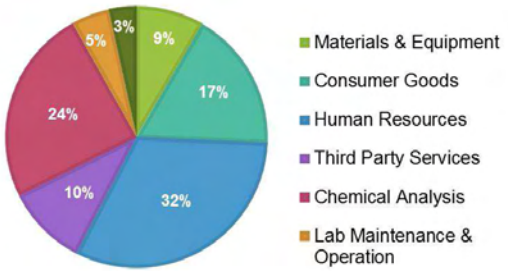


Fig. 1: SOFC resource distribution for R&D in Minas Gerais 2003 - 2015

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1401 (Will be published elsewhere)

Surface analysis and ionic transport of ScSZ/LSCrF dual-phase membrane for oxygen transport

Chi Ho Wong, John Kilner, Stephen Skinner
Imperial College London
Department of Materials, Royal School of Mines
South Kensington, London SW7 2BP, UK
c.wong13@imperial.ac.uk

Abstract

Surface chemistry and oxygen ion diffusion kinetics were examined for dual-phase composite ScSZ/LSCrF membranes aged under simulated operating conditions for use as oxygen transport membranes in synthesis gas production. The outer-surface and near-surface were characterized using Low Energy Ion Scattering (LEIS) and X-ray Photoelectron Spectroscopy (XPS) respectively, and oxygen ion self-diffusion was examined using the Isotope Exchange Depth Profiling technique coupled with Secondary Ion Mass Spectrometry (IEDP-SIMS). The outer- and near-surface of the dual-phase membrane appears to vary even at aging lengths of 300 h, with presence of impurities observed. Elevated dopant concentrations were observed on the outer-surface, supporting dopant depletion observed in the near-surface. The oxygen ion transport properties do not appear to be strongly influenced by the surface chemistry, with both the oxygen ion self-diffusion and oxygen surface exchange coefficients remaining in the same order of magnitude after 300 h of aging.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1402 (Will be published elsewhere)

Cermet membrane reactors for oxygen separation with low silver content

E. Ruiz-Trejo (1), A. Bertei (1), A. Maserati (1), P. Boldrin (1), N. P. Brandon (1)
(1) Department of Earth Science and Engineering
Imperial College London
SW7 2AZ, UK
Tel.: +44 207 594 9695
eruiztre@imperial.ac.uk

Abstract

In this contribution we first present our results for oxygen separation/membrane reactors with silver and doped ceria and our approach to manufacturing cermets with low metal content (silver < 10 vol%) and then we concentrate on our more recent results on Sc-stabilized zirconia and silver.

Dense composites of silver and Sc-stabilized ZrO_2 (Ag-ScSZ) are manufactured from ScSZ sub-micrometric particles coated with Ag via Tollens' reaction. There is a significant reduction in the level of silver, (11.9 vol %), required for percolation. This ensures a metallic conductivity of 186 S cm^{-1} and an oxygen flux of 0.014 μmol cm^{-2} s^{-1} at 600°C for a 1-mm thick membrane when used as a pressure-driven separation membrane between air and argon. We measure and model the impedance of a non-percolating sample to show that oxygen transport in the silver droplets inside the composite is dominated by diffusion of neutral species and not by the charge transfer reaction at the interface between ScSZ and silver. The model establishes that oxygen transport takes place in both silver and ScSZ but it is still dominated by transport in the ionic conductor, and that the surface of a separation membrane does not require further activation as the silver can reduce oxygen readily.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1403 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Development of solid oxide electrolysis for oxygen production from mars atmosphere carbon dioxide.

Joseph Hartvigsen, S. Elango Elangovan, Jessica Elwell, Dennis Larsen, Laurie Clark
Ceramatec, Inc.
2425 South 900 West, Salt Lake City, UT 84119-1517, USA
Tel.: +1-801-978-2163
Fax: +1-801-972-1925
jjh@ceramatec.com

Abstract

Space exploration is among the most challenging of human endeavors, requiring a logistics supply not only of food, fuel and tools, but also sophisticated environmental control with atmosphere revitalization and oxidizer for propulsion during the return to Earth. The cost of launching initial mass into low earth orbit (IM-LEO) is said to make these supplies worth their weight in gold. For a mission to Mars, the transit, entry, decent and landing (EDL) on Mars will multiply the mass specific value of supplies. For decades the idea of exploiting local resources, (in situ resource utilization or ISRU) has been accepted as a foundational concept in manned space mission planning, but no such system has been demonstrated to date. In 2014, NASA announced an experiment suite for the Mars 2020 mission, a Curiosity-class Mars rover, that would include MOXIE, the Mars Oxygen ISRU Experiment. This first non-terrestrial ISRU experiment will demonstrate initial feasibility of solid oxide electrolysis of Martian atmosphere CO_2 as a means of producing oxygen for propellant oxidant in a Mars Ascent Vehicle (MAV).

Ceramatec is developing the solid oxide electrolysis (SOXE, or SOEC) stack for MOXIE. The rover host platform for the MOXIE project imposes severe constraints on mass, volume, peak power and total cycle energy, but it offers an early opportunity to demonstrate non-terrestrial ISRU. Additional challenges arise in an unmanned operational environment, with once daily uplink and downlink schedules making man in the loop operation infeasible. From an electrochemical perspective, perhaps the most challenging constraints trace back to thermodynamics of CO_2 electrolysis in a system lacking steam or hydrogen. This paper addresses the thermodynamic boundaries for direct electrolysis of Mars atmosphere CO_2. Aspects of the design, as driven by mission specific constraints, will be discussed along with results of testing of flight prototype hardware.

Acknowledgment: This material is based on work supported by NASA through JPL's prime contract under JPL subcontract number 1515459. The authors would like to acknowledge the contributions of Michael Hecht (MIT, MOXIE Principal Investigator, PI), Jeff Hoffman (MIT, MOXIE Deputy PI), Jeff Mellstrom (JPL, MOXIE Project Manager), Carl Guernsey (JPL, SOXE Contract Technical Manager), Gerald Voecks (JPL, SOXE lead) in support of the Ceramatec role in the MOXIE.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1404

Post-test analysis of a rechargeable oxide battery (ROB) based on Solid Oxide Cells

Cornelius M. Berger (1,2), Oleg Tokariev (1,2), Norbert H. Menzler (1,2), O. Guillon (1,2), M. Bram (1,2)
(1) Institute of Energy and Climate Research (IEK-1), Forschungszentrum Jülich GmbH
Wilhelm Johnen Strasse, D-52428 Jülich
(2) Jülich Aachen Research Alliance (JARA)
Tel.: +49-2461-61-9705
c.berger@fz-juelich.de

Abstract

Solid oxide fuel cells have made large advances in their electrochemical performance owing to the development of new functional materials but also because of the microstructural optimisations of established materials and better manufacturing routes. Using their ability to be used in reverse mode as electrolysis cells, their combination with a storage material leads to so-called rechargeable oxide batteries (ROB). An ROB comprises a regenerative solid oxide cell (rSOC) and a reversible storage for oxygen ions (Figure 1).

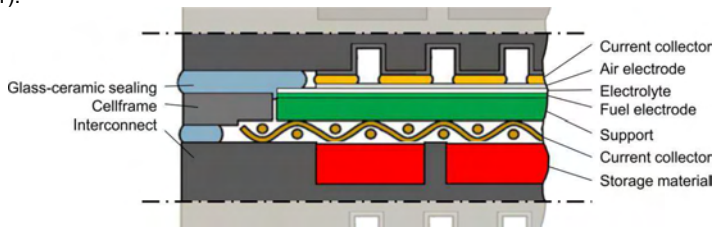


Figure 2: Schematic cross section of a repeating unit of a rechargeable oxide battery based on the Jülich F-10 rSOC design

Whereas the rSOC converts power and steam into hydrogen or vice versa, the iron oxide base storage is reduced by hydrogen or oxidised by steam to store or to release chemical energy. As the rSOC is already far-advanced as compared to the storage material, the focus of the development is on the latter. Starting from an iron oxide scaffolded by zirconia, porous storage components were manufactured by tape casting or extrusion, sintered, exposed to an atmosphere that simulates the conditions present in an ROB, and finally working batteries were assembled. These batteries were operated at 800°C for 200 cycles of uninterrupted automated charging-discharging at 150 mA/cm^2 and a voltage of around 1 V/cell. After terminating the test, the battery was dismantled and post-test analysed. The storage components were examined employing analysis techniques like scanning electron microscopy (SEM) and x-ray diffraction (XRD) for microstructure and materials interaction characterisation. Depending on the chemical composition and microstructure the formation of relatively thick layers composed of wustite phase (FeO) were detected close to the surface of the initially porous storage body. These detrimental effects were suppressed by the increase of porosity as well as the use of calcia instead of zirconia as a scaffold.

A1405 (Will be published elsewhere)

Characterization of Solid Oxide Cells based Rechargeable Oxide Battery

Qingping Fang, Cornelius M. Berger, Ludger Blum, Norbert H. Menzler, Martin Bram
Forschungszentrum Jülich GmbH
Institute of Energy and Climate Research
Wilhelm-Johnen-Straße
D-52428 Jülich / Germany
Tel.: +49-2461-611573
Fax: +49-2461-616695
q.fang@fz-juelich.de

Abstract

A rechargeable oxide battery (ROB) comprises high temperature solid oxide cells (SOC) as energy converters and a metal/metal-oxide as storage material. The SOCs work alternately in fuel cell and electrolysis mode at approximately 800 °C. Instead of externally storing the fuel, a stagnant atmosphere consisting of hydrogen and steam is used as an oxidizing and reducing agent for the storage material. As a consequence, all the expenses related to pumping losses, heat losses and further components can be avoided. Also, using iron as economic and ecologic storage material results in a theoretical storage capacity of up to 1340 Wh/kg iron [1].
One of the challenges in testing and characterizing the battery is how to keep a stagnant atmosphere at the fuel side of the SOCs. For this purpose, the available test benches for normal solid oxide fuel cell and electrolysis stacks were modified. Experimental results show that the established stagnant atmosphere is sufficient for characterizing the rechargeable oxide batteries without complicated processes, and the JÜLICH fuel cell stack design can be used for this type of battery characterization with only minor modifications. The preliminary battery concept was tested and more than 200 cycles were achieved at power densities of 130~170 $mWcm^{-2}$ with durations of more than 60 min/cycle. Optimization of storage compositions and manufacturing led to even higher power densities and longer cycle durations.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1406 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Convion SOFC System 5000h Validation

Kim Åström, Henri Stenberg, Matti Liukkonen, Erkko Fontell
Convion Ltd
Tekniikantie 12
FIN-02150 Espoo / Finland
Tel.: +358-40-845-3072
kim.astrom@convion.fi

Abstract

Convion Ltd. is a leading fuel cell system developer committed to commercializing solid oxide fuel cell (SOFC) systems in power range above 50 kW for distributed power generation. In 2015 Convion started validation of its upcoming C50 product in a 20 kW scale. The test unit, based on Plansee/IKTS stack technology, has successfully accumulated 5000 hours of operation with power delivery to the utility grid with high reliability and efficiency exceeding 50% (net Ac) in natural gas or bio gas operation. Convion has also successfully demonstrated ability to automatically switch between grid parallel and grid independent operation to provide ability to secure critical customer loads in grid outage situations.

During the validation period the test unit has undergone both long term steady state nominal as well as well as part-load and transient operation testing. Performance and emissions of the system have been characterized. The presentation will highlight Convion's unique approach for combining simplicity, robustness, performance and flexibility in a SOFC system to address cost competitiveness challenges. Key findings on the experiences from the 20 kW operation regarding performance, emissions, islanding, thermal cycling and effects of a multi-stack configuration will be presented.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1407 (Abstract only)

Novel membrane materials and membranes based on $La_{6-x}WO_{12-\delta}$ via spray pyrolysis and tape casting

Andreas B. Richter (1), Guttorm Syvertsen-Wiig (1), Wendelin Deibert (2), Mariya E. Ivanova (2)
(1) CerPoTech AS
Kvenildmyra 6, 7093 Tiller, Norway
(2) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research, IEK-1
52425 Jülich, Germany
guttorm.syvertsen@cerpotech.com

Abstract

Hydrogen is an important resource for chemical industry, power plant technology or as energy carrier in mobile systems. H_2 extraction, as for example H_2 separation from gas mixtures at elevated temperatures, is therefore a growing field of interest. In this context, H_2 permeation membranes play a key role in improving the energy conversion efficiency and decreasing the greenhouse gas emissions from electricity generation. An attractive material class for H_2 separation membrane application is the class of defective fluorites as lanthanide tungstates (LaWO) [i -iii]. The conductivity and H_2-permeation of non-substituted and selected substituted LaWOs has already been investigated on bulk membranes specimens with typical thickness between 500 and 1000 µm. Increased H_2 permeation rate can be achieved in practice by partially substituting the W-sites and developing asymmetric structures consisting of a gas tight functional membrane layer and a thick and porous supporting layer.

The present work focuses on development of 15-30 µm-thick $La_{6-x}W_{1-y}A_yO_{12-\delta}$, where A is Mo or Re [i], membranes onto 250-350 µm-thick LaWO or MgO porous substrates by means of the tape casting fabrication technique, described in detail in [micron, iv-v]. Sub-LaWO-based powders were produced from aqueous precursors by spray pyrolysis at CerPoTech. Microstructure and sintering behavior were studied as a function of the starting powder properties and thermal programs used for sintering the supported structures. A calcination temperature of 600°C was selected to optimize the powder morphology with respect to tape casting of the membranes. Finally, the optimal sintering conditions for the development of flat and reproducible supported gas tight membranes from the selected initial compounds were elucidated.

[i] J.M. Serra, S. Escolastico, W.A. Meulenberg, M.E. Ivanova, H.P. Buchkremer, D. Stöver, Inventors: UPV-CSIC and Forschungszentrum Jülich GmbH, Patent Numbers: DE102010027645-A1; WO2012/010386-A1.
[ii] J. Seeger, M.E. Ivanova, W.A. Meulenberg, D. Sebold, D. Stöver, T. Scherb, G. Schumacher, S. Escolástico, C. Solís, J. M. Serra, Inorganic Chemistry 52, 10375 (2013).
[iii] S. Escolástico, J. Seeger, S. Roitsch, M.E. Ivanova, W.A. Meulenberg, J.M. Serra, ChemSusChem, 6, 1523–1532 (2013).
[iv] W. Deibert, M.E. Ivanova, W.A. Meulenberg, R. Vaßen, O. Guillon, J. Mem. Sci., 492, 439–451 (2015).
[v] M.E. Ivanova, J. Seeger, J.M. Serra, C. Solis, W.A. Meulenberg, W. Fischer, St. Roitsch, H.P. Buchkremer, Chemistry and Materials Research, 2 (1), 56-81 (2012).

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1408 (Will be published elsewhere)

Transport properties of LSCrF-ScSZ based mixed conducting ceramic composites

Zonghao Shen, Stephen Skinner, John Kilner
Department of Materials
Imperial College London
Prince Consort Road, SW7 2BP, UK
zonghao.shen12@imperial.ac.uk

Abstract

In dual phase ceramics for Oxygen Transport Membranes (OTM), the Mixed Ionic-Electronic Conducting (MIEC) dense separation layer is a vital component. In the current work this dense layer consists of a Lanthanum Strontium Chromium Ferrite (LSCrF) based perovskite as an electronic pathway and Scandia Stabilized Zirconia (ScSZ) as an ionic conductor. Among all the essential criteria, transport properties in the dense layer of membranes profoundly affect the membrane performance. Hence, the present work is mainly focused on the electrical conductivity and ionic transport property of the dual phase dense layer and optimisation strategies have been applied in order to achieve improved performance. All the materials were characterised by XRD, SEM, 4-point DC conductivity measurements and Isotopic-Exchange Depth Profiling (IEDP) analysis[1].

In addition to the analysis of the dual phase materials, the LSCrF phase which influences the transport properties and stability of the membrane device has been independently studied. Potential fast grain boundary diffusion behavior has been observed in LSCrF73 single phase sample (Cr:Fe=70:30) (see Fig.1). Further investigation on different LSCrF compositions has been performed in order to improve performance of the electronic phase in the dual phase dense layer. For example, at 800 °C the surface exchange coefficient of LSCrF55 (Cr:Fe=50:50) is almost one order of magnitude higher than that of LSCrF73. Therefore, the importance of optimising the LSCrF composites and whether the grain boundary diffusion significantly affects the dual phase device will be presented.

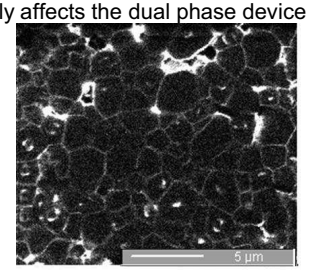


Fig.1 O elemental mapping on ^{18}O exchanged LSCrF73 sample (0.9 µm beneath sample surface) showing grain boundary enhancement of ^{18}O

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1410 (Abstract only)

Solid oxide electrolysis of CO_2 on ceria based materials

Neetu Kumari (1), M. Ali Haider (1), Nishant Sinha (2), S. Basu
(1) Indian Institute of Technology, Delhi, New Delhi -110016, India
(2) Dassault Systemes, Bangalore 560008, India

Abstract

The mechanism of CO_2 reduction to CO and CH_3OH on CeO_2 (110) was studied using density functional theory (DFT) calculations. CO_2 molecule sitting in the vicinity of oxygen vacancy site on the surface, is activated to form bent carbonate $CO_3^{\delta-}$ species which dissociates into CO via the incorporation of the oxygen atom into the vacancy. The calculated activation barrier and reaction energy for this redox reaction is 258.9 kJ/mole and 238.6 kJ/mole respectively. The effect of lateral interactions were studied by performing calculations for the same reaction step on two oxygen vacancy (di-vacancy) on 2x2 supercell unit. The activation barrier and reaction energy on a di-vacancy were significantly reduced to 134.3 and 127.3 kJ/mole respectively. DFT calculations showed that the hydrogen atom co-adsorbed on the surface could further assist the CO_2 dissociation. In the presence of a hydrogen atom the dissociation reaction occurs in two exothermic steps: CO_2+H→ COOH, COOH→CO+OH. CO_2 or CO adsorbed on the ceria surface could hydrogenate to methanol carboxyl (COOH) mediated mechanisms. The intrinsic activation barriers were calculated on stoichiometric ceria surface. COOH dissociation step has the maximum barrier (126 kJ/mole), could be the rate determining step of this route. The activation energy of this rate determining step was calculated on reduced ceria surface which is lower (by ~50kJ/mole) than that on stoichiometric ceria surface. Classical molecular dynamics simulations were utilized to calculate oxygen anion diffusivity on gadolinium doped ceria materials. Combined with high catalytic activity and fast oxygen anion transport, ceria materials could be a potential candidate for catalytic or electrocatalytic reduction of CO_2.

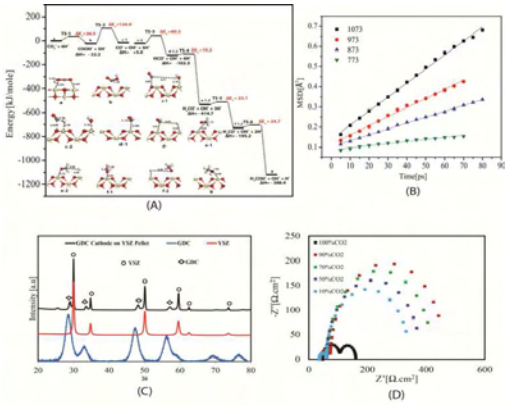


Figure 1 (A) Reaction energy diagram, (B) mean square displacement plot at different temperature, (C) XRD pattern, (D) EIS plots with different percentage of CO2/CO

Table 1
Diffusivity (D) of GDC at different temperature

T(K)	D(cm^2s^{-1})
1073	1.15E-07
973	7.50E-08
873	4.83E-08
773	1.83E-08

Reference
Kumari, N., Sinha, N., Haider, M. A. & Basu, *Electrochimica Acta* 177 (2015) 21–29

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1411

Electrochemical deoxygenation of bio-oil

S. Elango Elangovan (1), Dennis Larsen (1), Evan Mitchell (1), Joseph Hartvigsen (1), James Mosby (1), Byron Millet (1), Jessica Elwell (1), Pieter Billen (2), Sabrina Spatari (2)
(1) Ceramatec, Inc.
2425 South 900 West, Salt Lake City, UT 84119-1517, USA
(2) Drexel University
3141 Chestnut Street, Philadelphia, PA 19104, USA
Tel.: +1-801-978-2162
Fax: +1-801-972-1925
elango@ceramatec.com

Abstract

Biomass is a potential renewable source for liquid fuels and numerous commodity chemicals. Lignocellulosic biomass such as agricultural and forestry residue can be converted to liquid fuels via bio-oil production by fast pyrolysis. The high oxygen content of bio-oil poses a challenge for its practical use. The conventional approach to deoxygenate the oil is the hydro-deoxygenation process. Typical bio-oil is biphasic and only the organic phase is processed in subsequent conventional upgrading steps, leaving behind valuable carbon-containing material in the aqueous phase.

An alternative approach for deoxygenation is being investigated under DOE's CHASE (Carbon, Hydrogen and Separation Efficiencies in Bio-oil Conversion Pathways) program. An oxygen ion conducting ceramic membrane based electrochemical cell is used to deoxygenate bio-oil constituents. The cell is operated in the temperature range of 500 – 600 °C to match the pyrolysis temperature. Model compounds and aqueous phase of yellow pine pyrolysis oil from the Pacific Northwest National Laboratory were tested. The product from the electrochemical cell contained a suite of compounds with significantly lower oxygen content indicating the potential of this approach.

The electrochemical approach will allow both physical and process integration of the unit with the pyrolyzer to enable deoxygenation of bio-oil vapors prior to condensing. The electrolysis process will remove oxygen from the oxygenated organic molecule as well from steam to produce hydrogen in-situ. Thus, no external hydrogen is needed for the deoxygenation, allowing for a distributed, small scale upgrading unit integrated directly into the pyrolysis process.

Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-EE0006288.

A1412 (Will be published elsewhere)

Advanced electrochemical characterization of solid oxide electrolysis stacks (SOEC)

M. Lang, G. Braniek, S. Kurz, N. Muck, T. Schneider, Y. Zhang
German Aerospace Center (DLR), Institute for Engineering Thermodynamics
Pfaffenwaldring 38-40
D-70569 Stuttgart / Germany
Tel.: +49-711-6862-605
Fax: +49-711-6862-747
michael.lang@dlr.de

Abstract

The present paper focuses on the advanced electrochemical characterization of solid oxide electrolysis stacks (SOEC). The experiments are performed in the frame of the EU-funded project “SOCTESQA”. The main objective of this project is to develop uniform and industry wide test procedures for SOEC and SOFC stacks in order to improve the quality assurance. In this project 5-cell short-stacks with anode supported cells (ASC) are used, which are provided by an experienced stack supplier. The characterization methods of the stacks consist of current-voltage characteristics (j-V), electrochemical impedance spectroscopy (EIS) and long term operation under constant current. The paper reports on the electrochemical results of the SOEC short stacks under different operating conditions. The most important parameters influencing the quality of the current voltage curves and the electrochemical impedance spectra are presented. In this context the impact of the commonly observed voltage fluctuations due to the steam generator on the stack results are discussed. The influences of these fluctuations on the determination of the area specific resistances and on the impedances of the stack repeat units are outlined. Moreover, the results of the different characterization methods are validated in context to each other and to theoretical calculations. The knowledge gained within this paper is used in order to optimize the test procedures and test modules of the SOCTESQA project further.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1413 (Will be published elsewhere)

Effect of conductivity and mechanical strength of bi-layer matrix on the performances of carbonate-ceramic dual-phase membranes

Mélanie Rolland (1), Dario Montinaro (2), Andrea Azzolini (2), Alessandro Dellai (2), Vincenzo Maria Sglavo (1)
(1) University of Trento, Department of Industrial Engineering
9 Via Sommarive, 38127 Trento (Italy)
(2) SOLIDpower
115/117 Viale Trento, 38017Mezzolombardo (Italy)
melanie.rolland@unitn.it

Abstract

In the last few years, Molten Carbonate-Ceramic dual-phase Membranes (MCCM) have been increasingly studied for their ability to separate carbon dioxide from other gases at high temperature. For instance, placed at the output of a Solid Oxide Fuel Cell (SOFC) fed with syngas, these membranes could allow a clean energy production thanks to the removal of carbon dioxide emissions. Composed of an ionic conductor ceramic matrix infiltrated with a carbonate mixture, the MCCM have shown some drawbacks regarding their mechanical strength and their stability related to carbonate leak. In this study, 3YSZ ($Y_{0.03}Zr_{0.97}O_2$) was inserted in the 8YSZ ($Y_{0.08}Zr_{0.92}O_2$) bi-layer matrices in order to overcome the low mechanical strength and stability of the membranes. The bi-layer matrices were composed of a thick porous layer, here called active layer, deposited on a thin layer with a lower porosity, the support layer. Whereas the active layer has an optimized porosity for the carbonate infiltration, the support layer has a porosity low enough to avoid carbonate loss but high enough to allow gases to pass through it. Both the support and active layers were prepared by tape casting from a 3YSZ:8YSZ slurry (0:100, 10:90, 20:80, 50:50). The porosity of the active layer was controlled by addition of 2 wt.% of pore former. Active layer matrices only were also prepared and used as reference samples. The matrices were sintered at 1300°C for 2h and then they were infiltrated with a Li_2CO_3:Na_2CO_3:K_2CO_3 carbonate mixture. The ionic conductivity of the membranes was obtained by electrochemical impedance spectroscopy and their mechanical strength was measured by four-point bending flexural tests. Moreover, the membrane microstructure was investigated by SEM and the porosity of the matrices was determined performing image analysis. Finally, the performances of the membranes, based on their ability to separate carbon dioxide from other gases were measured with a gas analyzer. A correlation between the membrane performances and the matrix microstructure, ionic conductivity and mechanical strength were established in order to determine the best parameters, such as composition, for the preparation of molten carbonate ceramic membranes.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1414 (Will be published elsewhere)

Economic viability of high temperature electrolysis integration with renewable sources for a power to gas solution

Sarika Tyagi (1), Delia Muñoz (1), Truls Norby (2)
(1) Abengoa Hidrógeno
C/ Energía Solar nº1, 41014 Sevilla, Spain
(2) Department of Chemistry, University of Oslo, Norway
Tel.: +47-22840654
truls.norby@kjemi.uio.no

Abstract

Proton Ceramic Electrolyzer Cells (PCEC) and Solid Oxide Electrolyzer Cells (SOEC) technologies have a great potential within the scope of the Energy Transition and the Climate Change. These technologies can facilitate the transition in several important ways, as they can enable integration of Variable Renewable Energy (VRE) into the grid, improve the network flexibility and connectivity with bio-methane or syngas blending in built pipelines, conquer CO_2 sequestration, increase the energy efficiency and decrease the volatility of the needed raw materials.

The integration of solar PV and wind power into the grid will allow the network to remain clean, raising the share of renewables in the energetic mix and decreasing carbon emission so that the climate change may be mitigated. However, the intermittent nature of these two power sources creates a new problem when trying to integrate them into the grid due to control, arbitrage and stability problems.

Any critical analyses will shortlist the necessity for both flexible storage and energy transformation as important requirements for realizing above plans. Development of hydrogen, as a surplus energy carrier produced from the surplus electricity, comply with above two requirements. As more renewable energy comes online into the grid, more new flexible solutions are needed. These innovative solutions will be needed as more regions would enter in the “curtailment zone”, worsening the financial models for their generation plants. We propose that one solution is to use water electrolysis with the surplus electricity, in order to produce hydrogen and then transform it to be introduced in the advanced fuel market. This process defines the so-called Power-to-Gas solution. We envisage that it could become an indispensable feature for producing hydrogen, bio-methane, or synthetic gas (syngas).

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1415 (Abstract only)

Electrochemical performance of H_2O-CO_2 co-electrolysis with a tubular solid-oxide co-electrolysis (SOC) cell

Tak-Hyoung Lim(*), Jong-Won Lee, Seung-Bok Lee, Seok-Joo Park, Rak-Hyun Song
Fuel Cell Research Laboratory, Korea Institute of Energy Research (KIER)
152 Gajeong-ro, Yuseong-gu, Daejeon 34129, Korea
Tel.: +82-42-860-3608
Fax: +82-42-860-3297
ddak@kier.re.kr

Abstract

The H_2O-CO_2 electrochemical conversion process in solid-oxide co-electrolysis (SOC) cells may be one of the most efficient ways to reduce CO_2 emissions and to store renewable power simultaneously. In this study, a tubular solid-oxide co-electrolysis (SOC) cell based on a general electrode support solid-oxide fuel cell was fabricated and investigated. For this purpose, we fabricated tubular electrode support tubes through an extrusion process, and after which the essential SOC cell components, i.e., the electrolyte and the electrode, were coated onto the surface of the ceramic support consecutively using a vacuum slurry and dip-coating method. The cell was operated while varying the operating temperature, cathode gas flow rate, and the supplied amount of H_2O. The results demonstrate that the fabricated tubular SOC cell is a promising candidate for many practical applications, such as technology to mitigate climate change and power fluctuations associated with renewable energy.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1416 (Will be published elsewhere)

Electrochemical characterization of a high temperature metal / metal oxide battery

S. Yildiz, I.C. Vinke, R.-A. Eichel, L.G.J. de Haart
Institute of Energy and Climate Research, Fundamental Electrochemistry (IEK-9),
Forschungszentrum Jülich GmbH, 52425 Jülich, Germany
Tel.: +49-2461-61-8841
s.yildiz@fz-juelich.de

Abstract

A high temperature metal / metal oxide (MeMO) battery consists of a solid oxide cell (SOC) combined with a metal / metal oxide (Fe-based) storage material. The SOC must be reversible, i.e. operates as an electrolyser splitting water while charging, and operates as a fuel cell consuming hydrogen and oxygen while discharging. In addition, the SOC must offer high performance, minimal cell resistance and remain stable for long operation times under both modes of operation. To demonstrate these capabilities, single SOCs were tested under various temperatures and steam ratios using current voltage measurements and electrochemical impedance spectroscopy (EIS). The SOCs showed stable performance between fuel cell and electrolysis mode at short cycling times. However, high current densities and prolonged operation under the electrolysis mode resulted in delamination of the air electrode [1]. To further investigate this electrode side, symmetric button cells are characterized at different oxygen partial pressures, temperatures and humidities. Based on the results, an attempt is made towards understanding the reaction mechanism occurring at the oxygen electrode.

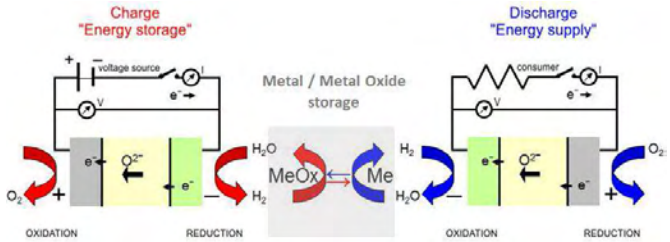


Figure 1: Schematic outlining the working principle of a MeMO battery

The Authors do not want to publish their full contribution in these proceedings and possibly have published it in a journal. Please contact the authors directly for further information.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1501 (Will be published elsewhere)

Operational Experience with a Solid Oxide Fuel Cell System with Low Temperature Anode off-gas Recirculation

Maximilian Engelbracht, Roland Peters, Wilfried Tiedemann, Ingo Hoven, Ludger Blum, Detlef Stolten
Forschungszentrum Jülich GmbH
Institute of Energy and Climate Research (IEK)
Wilhelm-Johnen-Straße
52428 Jülich, Germany
Tel.: +49-2461-614652
Fax: +49-2461-616695
m.engelbracht@fz-juelich.de

Abstract

The recirculation of anode off-gas within an SOFC system has two significant advantages. Firstly, unused fuel at the stack outlet is recirculated back to the stack inlet. Therefore, the amount of fresh fuel fed into the system can be reduced. This increases the system fuel utilization and allows electrical efficiency of more than 60%. Secondly, the recirculated electrochemically produced steam can be used for the steam reforming process. Thus, during operation an external steam generation is no longer necessary.
Challenging is the high anode off-gas temperature of at least 700 °C, which prohibits the use of commercially available blower units. Therefore, the use of ejectors is discussed in literature. There are also approaches to develop high temperature blowers or to use commercial blowers in combination with a heat exchanger.

At Forschungszentrum Jülich GmbH an SOFC system with an anode off-gas recirculation loop was built. The anode off-gas recirculation loop include heat exchanger and low temperature blower, which operates at temperatures up to 200 °C. With this system, tests were carried out to analyze the influence of recirculation rate and fuel utilization on the system operation. During the tests the system fuel utilization was changed between 90 and 93%, while the recirculation rate varied between 73 and 82%. The test results indicate that changes in recirculation rate affect for example the cell voltage, the cathode-side cooling air amount and the electrical efficiency. In principle, at constant current density high recirculation rates decrease the cell voltage, as well as the amount of cooling air. The highest electrical efficiency was achieved with a high system fuel utilization, low recirculation rate and in consequence high stack fuel utilization.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1502 (Abstract only)

A Total Cost of Ownership Analysis of SOFC Fuel Cell Systems

Shuk Han Chan (1), Max Wei (2), Ahmad Mayyas (2), Timothy Lipman (3)
(1) University of California Berkeley
1115 Etcheverry Hall, CA 94720-1740
(2) Lawrence Berkeley National Laboratory
1 Cyclotron Rd, Mail Stop: 90R2002, Berkeley, CA 94720
(3) Transportation Sustainability Research Center
2150 Allston Way #280, Berkeley, CA 94704
Tel.: +1-626-673-2519
shukhan@berkeley.edu

Abstract

A total cost of ownership model is described for emerging applications in stationary fuel cell systems, specifically solid oxide fuel cell (SOFC) systems for use in combined heat and power and prime power applications from 1 to 250kW. This work expands the cost modelling framework of other studies to include life-cycle impact assessment of possible ancillary financial benefits during operation and at end-of-life, including credits for reduced emissions of global warming gases such as CO_2 and CH_4, reductions in environmental and health externalities, and end-of-life recycling. System designs and functional specifications for SOFC fuel cell systems for co-generation and power applications were developed across the range of system power levels mentioned above. Bottom-up cost estimates were made using design-for-manufacturing-and-assembly (DFMA) analysis to estimate the direct manufacturing costs for key fuel cell stack components, and examination of currently installed fuel cell systems for balance of plant (BOP) costs. The development of high-throughput, automated processes achieving high yield are estimated to push the direct factory cost per kW for SOFC fuel cell CHP systems to $1000 -1500 /kW at an overall production volume of 5-50MW per year (e.g., 50kW systems at 100 to 1000 units/year). About 40-50% of stack costs are from the electrode/electrolyte assembly and material costs constitute a large fraction of fuel cell stack manufacturing costs at high production volume. However, with these assumptions, we find that balance of plant costs (BOP) dominates overall system cost, especially at higher production volumes, and that the power subsystem is the largest component of the BOP cost.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1503 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Road Truck LNG Boil-Off Converted to Battery Power by Small Planar SOFC System

Ulf Bossel
ALMUS AG
Morgenacherstrasse 2F
CH-5452 Oberrohrdorf/Switzerland
Tel.: +41-56-496-7292
ubossel@bluewin.ch

Abstract

The number of LNG (Liquefied Natural Gas) road trucks is growing in the United Kingdom and elsewhere. LNG contains much less fossil carbon than common liquid transportation fuels. However, LNG is kept at cryogenic temperatures and boil-off cannot be avoided. When the truck is in motion, the boil-off is used to fuel the engine. During longer periods of rest, the boil-off has to be vented into the atmosphere to avoid rupture of the tank system. The goal is the conversion of the boil-off into DC electricity with subsequent storage in the 24 VDC truck battery. This task is addressed by the “SAFARI” consortium of six teams from the UK, Spain, Poland and ALMUS AG of Switzerland (1,2). The project is part of the Fuel Cell and Hydrogen Joint Undertaking (FCH JU) funded by the European Union. Two different types of SOFC are simultaneously prepared for comparative evaluation. ALMUS AG is perfecting its planar approach (3) for road truck applications, while the project leader Adelan Ltd. is optimizing its tubular SOFC design (4,5,6,7,8,9) see separate conference presentation). Two stacks of 16 cells of 60 mm x 60 mm foot print are connected in series providing an OCV above 32 VDC. The stacks are directly connected to the truck battery. The operating voltage thus follows the charge-dependent voltage 24 to 26 VDC of the truck battery. Consequently, each of the 32 cells is operated under optimal conditions at about 0.75 VDC. High conversion efficiency is assured. A CPOX reformer is used to convert the methane into a mixture of H_2 and CO. The system is designed for rapid start-up with heat from the afterburner and 24 VDC electric heating elements placed near or within the stacks. The anode-supported cells provide useful power already at 600°C. The operating temperature is set at 650°C. For low heat losses and maximum conversion efficiency, the stack arrangement is surrounded by an 80 mm thick thermal jacket of the best available insulation material (calcium silicate). The arrangement is contained in a metal box for safe handling and mounting on the truck platform.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1504 (Abstract only, published elsewhere)

Electrochemical and Hydrogen Energy Technologies for Next-Generation Transportation Energy Systems

Whitney G. Colella (1, 2)
(1) Gaia Energy Research Institute, Arlington, VA, USA
(2) The Johns Hopkins University, Whiting School of Engineering, Baltimore, MD, USA
Tel.: +1 (650) 283-2701
Fax: +1 (215) 893-5171
wgc@gaia-energy-research-institute.com, wcolell1@jhu.edu

Abstract

This talk focuses on addressing transportation energy supply chain bottlenecks using advanced fuel cell, electrolysis, and hydrogen energy technologies. Within the energy supply chain for conventional automotive transport, energy supply chain bottlenecks for the highest energy losses, greenhouse gas emissions, air pollution emissions, and energy costs tend to be at the point of use of on-road fossil fuel vehicles. According to Sankey diagrams of U.S. energy flows by Lawrence Livermore National Laboratories (LLNL), automobiles consume about 16.17 EJ of primary energy, which translates into about 13.58 EJ of energy dissipated to the environment and 2.59 EJ of useful motive power energy. In other words, the U.S. automotive transportation supply chain is about 16% efficient on average on a well-to-wheels basis (2.59 EJ/16.17 EJ). Various studies have indicated that an automotive transport supply chain based on hydrogen fuel cell vehicles (FCVs) may be ~two times more efficient on a well-to-wheels basis. To address these bottlenecks in energy losses, greenhouse gas emissions, air pollution emissions, and energy costs within the transportation supply chain, this research work discusses the design, economics, and environmental impacts of technically noteworthy hydrogen FCVs, hydrogen production methods, and electrochemical hydrogen compression approaches.

One can also apply the lens of 'security of energy supply' to the automotive transport supply chain. For the U.S., the greatest lack of security of energy supply tends to be with the production, transport, and supply of crude oil. Substitution of gasoline and diesel fuel with hydrogen fuel derived from local sources of natural gas and renewables can help address this bottleneck, while also reducing air pollution and greenhouse gas emissions. In particular, one of the most efficient ways to produce hydrogen fuel for vehicles is with tri-generative stationary FCSs that produce electricity, heat, and hydrogen (H_2-FCSs). To address this bottleneck, this research discusses the thermodynamics, chemical engineering process plant design, economics, and environmental impacts of H_2-FCSs. Special attention is paid to scenarios in which H_2-FCSs are most energy efficient and recover heat from the fuel cell stack to heat the endothermic steam reforming process to generate additional hydrogen for vehicles. Other potentially low carbon and low cost hydrogen production systems include proton exchange membrane (PEM) and solid oxide electrolysis systems, for which techno-economic model results are also discussed.

Key results are discussed from both detailed thermodynamics modeling work and techno-economic-environmental impact models. Important findings are also highlighted from an independent analyses of deployed systems.

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1505 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Solid Oxide Electrolysis Development at Versa Power Systems

Tony Wood (1), Hongpeng He (1), Tahir Joia (1), Mark Krivy (1), Dale Steedman (1), Eric Tang (1), Casey Brown (1), Khun Luc (1)
(1) Versa Power Systems
4852 52nd Street SE, Calgary, Alberta, Canada, T2B 3R2
Tel.: +1-403-204-6134
Fax: +1-403-204-6101
twood@fce.com

Abstract

Versa Power Systems (VPS) is a developer of Solid Oxide Fuel Cell (SOFC) technology focused on SOFC stack development for commercial applications. In recent years VPS has been developing Solid Oxide Electrolysis (SOE) materials systems with a view to future commercial development of SOE stacks. Significant technical improvements in SOE materials technology have been made, including demonstrated cell operation up to 6 A/cm2 with <1.67 V operating voltage (>75% electrical efficiency) at 800°C. A single-cell test utilizing the same materials and components as a stack repeat unit has demonstrated stable operation for > 1000 hours at 3 A/cm^2 with 27 mV/khrs degradation rate. While further developments are ongoing with the materials technology, the materials system described has been scaled up for short-stack testing with a new, ultra-compact electrolysis stack design. Recently a 20-cell stack has achieved a current density of 3 A/cm^2 with average cell voltage of 1.493 V. The stack was using 2 kW electricity to produce more than 50 g/hour H_2 in a volume of only 200 cm^3. The stack is currently running steady-state at 2 A/cm^2 with average cell voltage of 1.38 V having operated for more than 100 hours with stable performance. Future work includes continued materials development to further lower degradation rates at these high current densities and scale-up of the compact electrolysis stack technology for larger scale demonstration of electrolysis at high current density whilst maintaining high efficiency. The ultimate objective of this work is to achieve a truly commercially viable technology for widespread hydrogen generation from renewable energy.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1506

SOEC Enabled Biogas Upgrading

John Bøgild Hansen, Majken Holstebroe, Michael Ulrik Borg Jensen, Jeppe Rass-Hansen, Thomas Heiredal-Clausen
Haldor Topsøe A/S
Nymøllevej 55
Kongens Lyngby
DK-2800 Denmark
jbh@topsoe.dk

Abstract

Electricity from wind turbines in Denmark is already in 2015 contributing more than half of the total production and there are plans to achieve 100 % renewable based production in 2035. The potential for biogas production in Denmark is also quite substantial, corresponding to 5 % of the end use energy consumption. There is thus considerable incentive to use intermittent electricity production for upgrading biogas to pipeline quality gas by methanation of the CO_2 content in the biogas with hydrogen from electrolysis.

SOEC offer strong synergy with the methanation plant, as the steam produced by the exothermal methanation reaction can be used directly as feedstock for the SOEC thus eliminating water evaporation by electricity.

A pilot plant to demonstrate the concept is built and became operational April 2016. The design capacity is 10 Nm3/h of upgraded biogas. This capacity requires approx. 50 kW SOEC, which will be provided by two Fuel Cores, each consisting of 4 SOEC stacks. Haldor Topsøe A/S has also designed the biogas cleaning unit and the methantion plant which will be located at the Agricultural Research Centre of Aarhus University at Foulum, Jutland.

The paper will outline the design of the pilot as well as full scale plants including exergy analyses. Experimental data from the SOEC unit(s) as well as the biogas cleanup and methanation pilot will be presented.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1507 (Abstract only)

Hydrogen Production Using Solid Oxide Electrolyser Cells at Shanghai Institute of Applied Physics

Guoping Xiao, Chengzhi Guan, Xinbing Chen, Jian-Qiang Wang*
Center for Thorium Molten Salt Reactor System, Shanghai Institute of Applied Physics,
Chinese Academy of Sciences,
2019 Jia Luo Road, Jia Ding District, 201800 Shangha/China
Tel.: +86-21-39194148
Fax: +86-21-39194148
wangjianqiang@sinap.ac.cn

Abstract

Hydrogen production using nuclear process heat with no greenhouse gas emission and no air pollution has been acknowledge as an effective technology to convert nuclear energy to flexible chemical energy. Since 2011, it is carried out in Shanghai Institute of Applied Physics (SINAP) that hydrogen production by high temperature steam electrolysis via solid oxide electrolyser cell using the process heat from the thorium molten salt reactor (TMSR).

A 50-cell SOC stack composed of NiO-YSZ/YSZ/GDC/LSCF-GDC with the single cell effective area of 262cm^2 (developed by Shanghai Institute of Ceramics) was tested at 750^{o}C in steam electrolysis mode for hydrogen production. The HTSE test system was established at SINAP in 2014, as illustrated in Fig.1a. Area specific resistance of the stack increased obviously at the current above 69A, derived from the slope of the I-V curve (Fig.1b). The long term stability test was carried out in galvanostatic electrolysis mode (750 ^{o}C, -0.25 A/cm^2, $p(H_2O)/p(H_2)$=0.8/0.2) for more than 500 hours(under running). The hydrogen production rate reached as high as 1.37m^3/hrs (STP), the electrolysis efficiency is higher than 90% and steam utilization is 70%. And the degradation is less than 1.5%/500hrs. The result confirms the potential of large-scale hydrogen production via HTSE by utilizing the process heat from nuclear reactors.

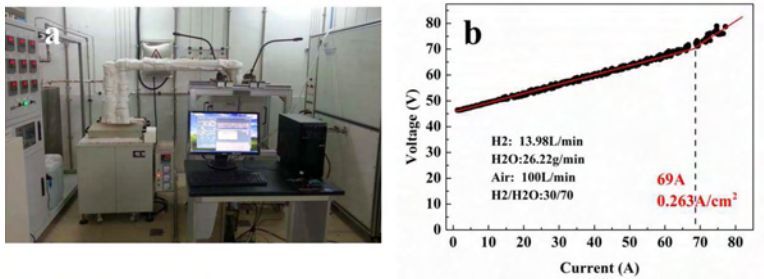


Fig.1 SOEC hydrogen production system at SINAP and the related results:
(a) the HTSE system; (b) I-V curve of the stack at 750^{o}C, $\boldsymbol{p}(H_2O)/\boldsymbol{p}(H_2)$=0.8/0.2;

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1507 (see A1502)

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1508

Topsoe Stack Platform (TSP) – a robust stack technology for solid oxide cells

Jeppe Rass-Hansen, Peter Blennow, Thomas Heiredal-Clausen, Rainer Küngas, Tobias Holt Nørby, Søren Primdahl
Haldor Topsoe A/S, Haldor Topsøes Allé 1, DK-2800 Kgs. Lyngby / Denmark
Tel.: +45 2575 4283
jerh@topsoe.dk

Abstract

Haldor Topsoe has in recent years developed a stack technology based on solid oxide cells that can successfully run in both electrolysis and fuel cell mode. The Topsoe Stack Platform (TSP) technology has been tested for durability and robustness towards simulations of stress conditions, which are likely to occur during operation of solid oxide cell systems. Such conditions include situations where the system is subjected to thermomechanical stresses or thermal cycles, as well as situations of transient electric load. The cells have Ni/YSZ fuel electrode, YSZ electrolyte, and LSCF-based oxygen electrode with a CGO barrier layer. In the stacks, the cells are separated by coated ferritic stainless steel interconnects.
The TSP technology is superior to previous Haldor Topsoe stack designs on several aspects, such as lifetime, increased number of cells per stack, increased cell active area, improved gas flow distribution, and the ease of stack manufacturability. The platform combines the stack core and external casing in one unit (see Figure 1), where manifolds and internal compression are smoothly integrated, thus simplifying system integration. TSP is a robust stack technology that can operate on multiple fuels in fuel cell mode, as well as electrolysis of H_2O, CO_2, and combinations of both. More than 12 000 h operation in SOFC mode and > 5 800 h in SOEC mode has been demonstrated, where the stacks have been exposed to multiple thermal cycles throughout the tests. These results demonstrate the versatility of the TSP technology and activities to further enhance lifetime and robustness are ongoing.

Figure 1. Topsoe Stack Platform integrating the stack core and external casing in one unit.

A1509 (Abstract only, published elsewhere)

High Temperature Electrolysis for Hydrogen Production

Whitney G. Colella (1, 2)
(1) Gaia Energy Research Institute, Arlington, VA, USA
(2) The Johns Hopkins University, Whiting School of Engineering, Baltimore, MD, USA
Tel.: +1 (650) 283-2701 Fax: +1 (215) 893-5171
wgc@gaia-energy-research-institute.com, wcolell1@jhu.edu

Abstract

This research analyzes the potential for producing hydrogen (H_2) using high temperature electrolyzers based on solid oxide electrolysis cells (SOECs). Techno-economic models are developed to analyze SOEC systems in terms of their future engineering and economic performance. Currently, most SOECs are at an early technology readiness level (TRL); i.e. individual cells and stacks, and some large scale systems, have been tested in controlled, laboratory environments. This work analyzes the best performing SOEC cells, stacks, and systems tested to-date in the laboratory and projects their performance into the future for large-scale, commercial SOEC systems.

SOEC water electrolysis can use both electricity and high temperature heat to split water (H_2O) into oxygen (O_2) and H_2. The overall, endothermic reaction is Energy + $H_2O \rightarrow H_2 + ½O_2$. A power source delivers direct current (DC) electricity to the SOEC electrodes such that electrons (e^-) flow through an external circuit. At the negative terminal (cathode), steam reacts with electrons to form negatively charged oxygen ions (O^{2-}) and H_2. The oxygen ions are conducted through the electrolyte, and, once they reach the positive terminal (anode), they release their electrons to the external circuit and form O_2. SOEC cells can generate high purity H_2 and O_2.

This research deploys a U.S. Department of Energy (DOE) techno-economic modelling tool for H_2 production, called the H2A Production Model. The H2A Production Model captures a set of standard DOE assumptions and methods. When these standards are adhered to, using the H2A Model can facilitate more even-handed techno-economic comparisons of a variety of H_2 production technologies, including, but not limited to, steam methane reforming (SMR), solar thermal production, proton exchange membrane (PEM) electrolysis, and SOEC systems. This analysis deploys the H2A Production model to evaluate H_2 generation based on SOEC electrolyzers powered by electricity from the grid and by heat from industrial processes. Models were developed to describe large-scale, 50,000 kilograms (kg) H_2/day, centralized H_2 production plants envisioned for both the near and far-term futures.

Model results indicate that, for an average electricity cost of between $0.06/kilowatt-hour (kWh) and $0.07/kWh, the levelized cost of H_2 could be as low as $4/kg H_2 in the near-term and $3/kg H_2 in the far term. The levelized cost of H_2 is most strongly influenced by the electricity price. The levelized cost of H_2 is also impacted by the price of heat, electrolyzer's capital cost, the electrolyzer's electrical conversion efficiency, and the electrolyzer's heat conversion efficiency.

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1510 (Abstract only)

Quality Evaluation and Analysis Method Development of Byproduct Hydrogen Using Gas-Chromatography

Daeic Chang*†, Jong Kuk Kim†, Jongseong Lee‡ and Hangsoo Woo‡
Fine Chemical and Material Technical Institute†
New Energy Technology Institute‡
Ulsan Technopark
15 Jongga-ro
44412 Ulsan / Republic of Korea
Tel.: +82-52-219-8743
Fax: +82-52-219-8799
daeic@utp.or.kr

Abstract

Byproduct hydrogen is produced through processes of Naphtha Cracking Process, and Chloro-Alkali process, etc. in petrochemical complexes. Byproduct hydrogen subordinately generated in the process is in use for other processes as a material, in sale through business bodies that require the collected hydrogen or boiler's heat source for energy production. Also, being affected by technology development recently according to secondary problems of environmental pollution caused by fossil energy and social needs of improving quality of life, hydrogen became the focus of attention as a new energy source, leading to the development of its high value-added utilisation measures. However, it requires hydrogen to meet the prerequisites (high purity, production, etc.) for high value-added utilisation, and quality analysis of hydrogen became an important issue in order to utilize hydrogen as an indirect energy source. Still, now that there hasn't been preparation of quality criteria and analysis methods for high purity hydrogen to operate fuel batteries in Korea, it is difficult to apply hydrogen to the industry. To cope with these problems, this study intends to prepare industrial use basics for the era of hydrogen coming in the future by developing the procedure to evaluate and systematically analyze the quality of byproduct hydrogen produced in Korea through analyzing pollution materials at ultra-trace levels based on ISO 14687-2, hydrogen testing standards for automotive fuel batteries presented by International Organisation for Standardisation.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1511 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Solid Oxide Fuel Cell application analysis

Ling-yuan Tseng
Electric Energy Express
10th Fl, No. 245, Kuang-Ming 6th Road East Sec. 1
ChuBei, Hsinchu 302
Taiwan
Tel.: +886 920-476785
Fax: +886 3 516-2723
ly.tseng@3e.com.tw

Abstract

It has been quite sometime since SOFC introduced onto the market. However, the majority of application still focused on the pure power generation, and the heat accompanied is very likely been ignored. In the energy world, more specifically the SOFC applications both electricity and heat are mixed together. Depends on the using environment and the place installed, the allocation of power and heat efficiency of the total efficiency is adjustable. The carbon dioxide generated along with power and heat is a headache to the most users. But, one's poison might be other's medicine. In some applications, CO2 becomes a necessity together with power and heat to carry out unique functions. This paper provides a general scenario of application fields that SOFC could be applied with effectiveness, efficient and lower operation cost.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

Next EFCF Events

6th European
PEFC & ELECTROLYSER
Forum 4 - 7 July 2017

13th European
SOFC & SOE
Forum 3 - 6 July 2018

Lucerne Switzerland

Show **your advertisement** or **project** and **product** info on such pages - forum@efcf.com.

Chapter 03 - Sessions A09, A12

A09: Cell design and characterisation
A12: Stack design and characterisation

Content **Page A09, A12 - ..**

A0901 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....4
Mechanics of SOFC Contacting **4**
Zhangwei Chen (1), Xin Wang (2), Nigel Brandon (3), Alan Atkinson (2) 4
A0902 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....5
Relation between shape of Ni-particles and Ni migration in Ni-YSZ electrodes – a hypothesis **5**
Mogens B. Mogensen, Anne Hauch, Xiufu Sun, Ming Chen, Youkun Tao, Sune D. Ebbesen, Peter V. Hendriksen 5
A0903 (Will be published elsewhere)....6
Cation diffusion at the CGO barrier layer region of solid oxide fuel cells **6**
M. Morales (1)*, V. Miguel-Pérez (1), A. Tarancón (1), M. Torrell (1), B. Ballesteros (2), J. M. Bassat (3), J. P. Ouweltjes (4), D. Montinaro (5), A. Morata (1) 6
A0904 (Will be published elsewhere)....7
Direct-Methane Solid Oxide Fuel Cells with Ceria-Coated Ni Layer at Reduced Temperatures **7**
Jin Goo Lee (1), Ok Sung Jeon (1), Ho Jung Hwang (2), Jeong Seok Jang (1), Yeyeon Lee (2), Sang-Hoon Hyun (3), Yong Gun Shul (1,2) 7
A0905 (Will be published elsewhere)....8
Investigation of high performance low temperature ceria-carbonate composite fuel cells **8**
Muhammad Imran Asghar (1), Ieeba Khan (2), Suddhasatwa Basu (2), Peter D. Lund (1) 8
A0906 (Will be published elsewhere)....9
1D numerical modeling of direct ammonia solid oxide fuel cells **9**
Masashi Kishimoto, Yuki Matsui, Hiroshi Iwai, Motohiro Saito, Hideo Yoshida 9
A0907 10
Electrochemical and microstructural characterization of Micro-Tubular SOFC: The effect of the operation mode **10**
M. Torrell (1), A. Hornés (1), A. Morata (1), K. Kendall (2), 10
A. Slodczyk (1), A. Tarancón (1) 10
A0908 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....11
CFY-Stacks: Progress in Development **11**
S. Megel (1), M. Kusnezoff (1), W. Beckert (1), N. Trofimenko (1), C. Dosch1, A. Weder (1), M. Jahn (1), A. Michaelis (1), C. Bienert (2), M. Brandner (2), S. Skrabs (2), W. V. Schulmeyer (2), L. S. Sigl (2) 11
A0909 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....12
New all-European high-performance stack (NELLHI): Experimental evaluation of an 1 kW SOFC stack **12**
Christoph Immisch (1), Andreas Lindermeir (1), Matti Noponen (2), Jukka Göös (2) 12
A0910 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....13
Triode Solid Oxide Fuel Cell operation under Sulphur poisoning conditions **13**
Priscilla Caliandro, Stefan Diethelm, Jan Van herle 13
A0911 (Will be published elsewhere)....14
Pressurized Operation of a 10 Layer Solid Oxide Electrolysis Stack **14**

Marc Riedel, Marc P. Heddrich, K. Andreas Friedrich 14
A0912 15
Evaluation of Zr doped $BaCe_{0.85}Y_{0.15}O_{3-\delta}$ as PCFC electrolyte **15**
Ha-Ni Im, Dae-Kwang Lim, Jae-Woon Hong, In-Ho Kim and Sun-Ju Song 15
A0913 (Will be published elsewhere)....16
Homogenization of the thermo-elastic properties of pristine and aged Ni-YSZ samples **16**
Toni Vešović (1, 2), Arata Nakajo (2), Fabio Greco (2), Pierre Burdet (2, 3), Jan Van herle (2), Frano Barbir (1) 16
A0914 17
Evaluation of H_2O/CO_2 co-electrolysis of LSCF6428-GDC Electrode SOFC on microstructural parameters **17**
Sang-Yun Jeon(1)*, Young-Sung Yoo(1), Mihwa Choi(1), Ha-Ni Im(2), Jae-Woon Hong(2), Sun-Ju Song (2)* 17
A0915 (Abstract only) 18
Temperature effect on elastic properties of SOFC layers **18**
Alessia Masini, Zdeněk Chlup, Ivo Dlouhý 18
A0917 19
Characterization of the performance and long-term degradation of fuel electrode supported multilayered tape cast Solid Oxide Cells **19**
M. Torrell (1)*, D. Rodríguez (2), B. Colldeforns (1), M. Blanes (2), A. Morata (1), F. Ramos (2), A. Tarancón (1) 19
A0918 (Abstract only, published elsewhere)....20
Hydrogen membrane fuel cell using Ni-Zr alloy membrane **20**
SungBum Park (1), Sung Gwan Hong (1), Yong-il Park (1) 20
A1201 (Will be published elsewhere)....21
Stability of SOFC cassette stacks during redox-thermal-cycling **21**
Ute Packbier (1), Tim Bause (2), Qingping Fang (1), Ludger Blum (1), Detlef Stolten (1) 21
A1202 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....22
Evaluation of a SOEC stack for hydrogen and syngas production: a performance and durability analysis **22**
Mikko Kotisaari (1), Olivier Thomann (1), Dario Montinaro (2), Jari Kiviaho (1) 22
A1203 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....23
Investigation of a 500W SOFC stack fed with dodecane reformate **23**
Massimiliano Lo Faro, Stefano Trocino, Sabrina C. Zignani, Giuseppe Monforte, Antonino S. Aricò 23
A1204 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....24
Performance Characteristics of Elcogen Solid Oxide Fuel Cell Stacks **24**
Matti Noponen, Jukka Göös, Pauli Torri, Daniel Chade, Heikki Vähä-Piikkiö, Paul Hallanoro 24
A1205 (Will be published elsewhere)....25
Performance and degradation of an SOEC stack with different air electrodes **25**
Y. Yan (1), Q. Fang (1), L. Blum (1), W. Lehnert (1, 2) 25
A1206 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....26
Fuel Distributions in Anode-Supported Honeycomb Solid Oxide Fuel Cells **26**
Hironori Nakajima(1), Tatsumi Kitahara (1), Sou Ikeda (2) 26
A1208 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....27
Potential for critically-high electrical efficiency of multi-stage SOFCs with proton-conducting solid electrolyte **27**

Yoshio Matsuzaki (1,2), Yuya Tachikawa (3), Takaaki Somekawa (1,4), Kouki Sato (2), Hiroshige Matsumoto (5), Shunsuke Taniguchi (2,3,6), Kazunari Sasaki (2,3,4,5,6) 27

A1209 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....28

Performance testing for a SOFC stack with bio-syngas 28

Ruey-Yi Lee (1)*, How-Ming Lee (1), Ching-Tsung Yu (1), Yung-Neng Cheng (1), Szu-Han Wu (1), Chien-Kuo Liu (1), Chun-Hsiu Wang (2), Chun-Da Chen (2) 28

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0901 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Mechanics of SOFC Contacting

Zhangwei Chen (1), Xin Wang (2), Nigel Brandon (3), Alan Atkinson (2)
(1) Earth Science and Engineering
(2) Department of Materials
(3) Sustainable Gas Institute
Imperial College. London SW7 2AZ UK
Tel.: +44 2075946780
alan.atkinson@imperial.ac.uk

Abstract

Assembly of a planar SOFC or SOE stack involves the lamination of cells and interconnect plates under an applied force. In most designs a pattern of ribs on the interconnector makes contact with a layer of porous ceramic current collector on the air side of the cells. These localised contacts are regions of increased stress on the cells and can cause damage if the stresses become too large. In this contribution we studied experimentally the response of an anode supported cell to a localised load applied using a spherical indenter. FIB/SEM cross sections were used to characterise the deformation of the cell and it was found that the main damage mode was through-cracking of the electrolyte due to bending of the electrolyte layer.

Similar experiments and finite element simulation were carried out to determine the mechanical response of each individual layer in the cell structure. A key feature of the FE simulations was inclusion of a sub-model to describe the collapse and densification of the porous anode support and cathode materials under the compressive loading. The FE simulations were used to analyse the indentation experiments and thus determine the critical stress for fracture of the 8YSZ electrolyte to be approximately 2 GPa, which is consistent with the defects seen in the electrolyte layer.

Finite element simulations were then carried out for a typical interconnector/cell geometry to study the stress distribution at an interconnector rib contacting the cathode side of the cell. The stiffness of the anode support was found to be a key parameter determining the likelihood of cell damage.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A0902 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Relation between shape of Ni-particles and Ni migration in Ni-YSZ electrodes – a hypothesis

Mogens B. Mogensen, Anne Hauch, Xiufu Sun, Ming Chen, Youkun Tao, Sune D. Ebbesen, Peter V. Hendriksen
Department of Energy Conversion and Storage
Technical University of Denmark (DTU)
Frederiksborgvej 399, DK-4000 Roskilde
Tel.: +45-46775726
momo@dtu.dk

Abstract

This is an attempt to explain a phenomenon of total depletion of Ni next to the electrolyte in Ni-YSZ cermet electrodes in solid oxide electrolysis cells during electrolysis at high current density/overpotential. Intuitively, we would think that Ni would always migrate down the steam partial pressure (pH_2O) gradient as previously observed [1], but in the present cases Ni seems to migrate up the pH_2O gradient. However, it is also observed that there is a preceding phase in this Ni-YSZ electrode degradation, namely that the Ni-particles closest to the YSZ electrolyte loose contact to each other. This means that the active three phase boundary (TPB) moves away from the electrolyte and causes a significant increase in the ohmic resistance as is also observed in electrochemical impedance spectra.

We hypothesize that the cause of this loss of contact is due to a change in Ni-particle shape at very negative potential due to change in surface energy with polarization and to contraction of YSZ upon reduction. Based on micrographs of the Ni-YSZ electrode structures we postulate that the original irregular, elongated shaped Ni-particles get more ball shaped with increasing negative potential, i.e. the surface energy of the Ni increases with decreasing potential. Before the loss of contact of the Ni- and YSZ-particles, the Ni will migrate towards the YSZ electrolyte during negative polarization. Depending on the exact operation conditions, the Ni-particles may lose contact before much migration has taken place. If this happens, there will be no pH_2O gradient in the volume between the active TPB (now moved away from the electrolyte) and the electrolyte. Furthermore, as the potential of the non-contacted Ni-particles will be determined simply by the steam/hydrogen ratio, while the Ni at the TPB is significantly negatively polarized, i.e. there is a clear electrochemical potential difference between them. We know that the migration of Ni takes place in form of Ni-OH complexes in the family of $Ni(OH)_x$, but maybe with Ni in a lower positive oxidation state than +2. Anyway, the activity of Ni in a positive oxidation state will be lowest at the most reducing condition, i.e. at the most active TPB some distance (max. few microns) away from the electrolyte. Consequently the Ni should diffuse, probably in the gas phase, to the active TPB and be precipitated there. This will cause the Ni-particles at the TPB (which is now a little away from the electrolyte) to grow, and this is actually observed. At some stage a significant increase in Ni-particle size at the active TPB has taken place and no loss of contact between them will then happen, but thereafter a too dense Ni-layer may form.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0903 (Will be published elsewhere)

Cation diffusion at the CGO barrier layer region of solid oxide fuel cells

M. Morales (1)*, V. Miguel-Pérez (1), A. Tarancón (1), M. Torrell (1), B. Ballesteros (2), J. M. Bassat (3), J. P. Ouweltjes (4), D. Montinaro (5), A. Morata (1)
(1) IREC, Catalonia Institute for Energy Research, Dept of Advanced Materials for Energy Applications, Jardins de les Dones de Negre 1, Planta 2, 08930, Sant Adriá del Besós, Barcelona, Spain.
(2) ICN2, Institut Catala de Nanociencia i Nanotecnologia, Campus UAB, Bellaterra, (Barcelona), Spain.
(3) CNRS, ICMCB, 87 avenue du Dr. A. Schweitzer, F-33608 Pessac, France
(4) HTceramix SA, Avenue des Sports 26, CH-1400 Yverdon-les-Bains, Switzerland
(5) SOLIDPower SpA, Viale Trento 117, 38017 Mezzolombardo, Italy.
mmorales@irec.cat

Abstract

The difficulty of achieving a long term stable operation represents one of the main hindrances for the commercialization of solid oxide fuel cells. The important progress achieved in the last years has reduced many of the major classical problems to a minimum. The remaining degradation phenomena produce subtle decreases of performance that reveal their importance at long operating times. Understanding the involved processes and assessing their relative importance in the whole degradation is a major concern.

A well-known phenomenon of degradation of SOFCs is the reaction of $La_{1-x}Sr_xCo_{1-y}Fe_yO_3$ (LSCF) cathode with the conventional 8YSZ electrolyte, forming the insulating phases $SrZrO_3$, $La_2Zr_2O_7$ and $(Co, Fe)_3O_4$ [1-3]. The solution adopted to avoid the appearance of these phases is to introduce a dense gadolinium-doped ceria (CGO) barrier layer between the cathode and the YSZ electrolyte [4]. In this work, the solid state reaction and inter-diffusion phenomena between the YSZ electrolyte, the CGO interlayer and the LSCF cathode are analysed. A non-operated reference cell is compared with one subjected to 3000 h working under real conditions in a stack. Exhaustive observations have been carried out using XRD, Raman spectroscopy, SEM-WDX and STEM-EDX-EELS. The results show that insulating phases and solid solutions are formed at both interfaces in pristine and the tested cells and throw light on the inter-diffusion mechanisms taking place.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0904 (Will be published elsewhere)

Direct-Methane Solid Oxide Fuel Cells with Ceria-Coated Ni Layer at Reduced Temperatures

Jin Goo Lee (1), Ok Sung Jeon (1), Ho Jung Hwang (2), Jeong Seok Jang (1), Yeyeon Lee (2), Sang-Hoon Hyun (3), Yong Gun Shul (1,2)
(1) Department of Chemical and Bio-molecular Engineering, Yonsei University, Seoul/Republic of Korea
(2) Department of Graduate Program in New Energy and Battery Engineering, Yonsei University, Seoul/Republic of Korea
(3) Department of Materials Science and Engineering, Yonsei University, Seoul/Republic of Korea
Tel.: +82-02-2123-2758
Fax: Not Available
shulyg@yonsei.ac.kr

Abstract

Natural gas constitutes a promising energy source in the intermediate future because of the existing supply infrastructure and ease of storage and transportation. Although a solid oxide fuel cell can directly convert chemical energy stored in the hydrocarbon fuel into electrical energy at high temperatures, carbon formations on the nickel-based anode surfaces cause serious degradation of the long-term performance. Here, we report highly coke-tolerant ceria-coated Ni catalysts for low-temperature direct-methane fuel cells. The catalyst shows the high activity for CO oxidations, which is beneficial to avoid carbon formations induced by CO disproportionation at low temperatures. When the ceria-coated Ni catalysts were applied to the solid oxide fuel cells as a catalyst layer, the cell generates a power output of 1.42 W cm^{-2} at 610 C in dry methane and operates over 1000 h at a current density of 1.2 A $cm_{-2.}$

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0905 (Will be published elsewhere)

Investigation of high performance low temperature ceria-carbonate composite fuel cells

Muhammad Imran Asghar (1), Ieeba Khan (2), Suddhasatwa Basu (2), Peter D. Lund (1)
(1) Department of Applied Physics, Aalto University, P. O. Box 15100, 00076, Finland.
(2) Department of Chemical Engineering, Indian Institute of Technology, New Delhi-110016, India.
imran.asghar@aalto.fi

Abstract

This work will be submitted to Nano Energy journal 2016, more details of this study can be found here [1]. In this work, high performance ceria-carbonate composite fuel cells (CCCFC) are fabricated and characterized using electrochemical impedance spectroscopy (EIS) and current-voltage measurements under fuel cell conditions at 550°C. The nanocomposite electrolyte of the cell consists of $Ce_{0.85}Sm_{0.15}O_2$ (65%), referred as SDC, and eutectic mixture of ternary carbonates Na_2CO_3, Li_2CO_3 and K_2CO_3 (35%) referred as NLK. The ionic conductivity of the electrolyte was obtained through EIS, which resulted in 0.44 S/cm and 0.55 S/cm at 550°C and 600°C, respectively. CCCFCs are fabricated with this electrolyte and composite electrodes (anode = NiO 50wt% and Electrolyte 50wt%) (cathode = LSCF 50wt% and Electrolyte 50wt%) through cold pressing method. The cells produced 1.04 W/cm^2 at 550°C. The EIS reveals low resistances to oxidation-reduction and hydrogen-oxidation reactions.
The CCCFC materials were further characterized by X-ray diffraction (XRD) for a wide range of temperatures (25°C – 600°C) and differential scanning calorimetry (DSC) to see the structural stability and phase changes. It was found that the carbonates were transformed into molten phase at around 393°C. The solid phases of NiO, LSCF and SDC remained stable at least up to 600°C. The CCCFCs were further characterized using Brunauer-Emmett-Teller (BET) analysis, scanning electron microscopy (SEM), and transmission electron microscopy (TEM) coupled with X-ray energy dispersive spectroscopy. Furthermore, effect of supplying CO_2 to the cathode in addition to supplying air was studied, and it was found that the open circuit voltage (OCV) of the CCCFCs improved from 1.1 V to 1.2 V. This study will provide a deeper insight into the transport mechanisms and electrode reactions in the fuel cells. Another CCCFC was manufactured using a composite electrolyte (30wt% SDC, 70wt% NKL) prepared through freeze drying method. The anodes and cathodes were prepared in a similar fashion as for the previous CCCFCs. This CCCFC produced even higher power output power 1.1 W/cm^2 at 550°C.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0906 (Will be published elsewhere)

1D numerical modeling of direct ammonia solid oxide fuel cells

Masashi Kishimoto, Yuki Matsui, Hiroshi Iwai, Motohiro Saito, Hideo Yoshida
Department of Aeronautics and Astronautics, Kyoto University
Nishikyo-ku, Kyoto 615-8540 Japan
Tel.: +81-75-383-3652
Fax: +81-75-383-3652
kishimoto.masashi.3m@kyoto-u.ac.jp

Abstract

Ammonia is receiving attention as a hydrogen carrier because of a number of advantages over other hydrogen careers, such as larger hydrogen content, easy liquefaction and no carbon emission. Mass production process of ammonia has also been fully established and well known as the Haber-Bosch process. Solid oxide fuel cells (SOFCs) are one of the candidates that can be operated with ammonia-based fuels because the excess heat generation from the cells can be effectively utilized for ammonia decomposition to produce hydrogen.

In this study we have developed a one-dimensional numerical model that predicts performance of direct ammonia SOFC cells. Catalytic decomposition of ammonia and the electrochemical reaction of hydrogen are simultaneously considered within the electrode. Microstructural parameters of the porous electrode were obtained using focused ion beam scanning electron microscopy (FIB-SEM). Empirical formula for the ammonia decomposition in the Ni-YSZ anode was developed in our group and applied to the model. The results were compared with experimental data for validation.

From a button cell experiment, the performance of an anode-supported cell with ammonia fuel at 700 °C was found to be comparable to that with fully decomposed gas (H_2:N_2=3:1). The concentration overpotential was slightly larger when the ammonia fuel was supplied.

The numerical results revealed the distribution of the ammonia decomposition and the electrochemical reaction within the anodes. In anode supported cells, most of the ammonia was decomposed before it reached the anode-electrolyte interface, with the decomposition area being ca. 200 μm from the anode surface. The electrochemical reaction occurred in the vicinity of the anode-electrolyte interface and the active thickness was 20-35 μm, which is similar to that observed when hydrogen-based fuel is supplied.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0907

Electrochemical and microstructural characterization of Micro-Tubular SOFC: The effect of the operation mode

M. Torrell (1), A. Hornés (1), A. Morata (1), K. Kendall (2), A. Slodczyk (1), A. Tarancón (1)
(1) Catalonia Institute for Energy Research (IREC), Jardins de les Dones de Negre, 1, 08930 Sant Adrià de Besòs, Barcelona, Spain
(2) Adelan, 112 Park Hill Road, Birmingham B17 9HD, UK
Tel.: +34-93-356-2615
Fax: +34-93-356-3802
atarancon@irec.cat

Abstract

Due to the excellent thermal shock and mechanical resistance of Micro-Tubular Solid Oxide Fuel Cells (mSOFC), many orders of magnitude larger than the planar SOFC, mSOFC have been applied in the transport sector market. The main objective of the SAFARI project is the development of a SOFC based system as an Auxiliary Power Unit (APU) fed by LNG for road trucks. In previous publication the authors detailed the long-term degradation of single micro-tubular SOFC operating at 700 ºC supplying 7 W.
In the present work the influence of the fuel utilization (Fu) in the degradation of the cells has been studied by means of Fu cycling experiments. Obtained results are discussed and related with the information extracted from the post-mortem microstructural characterization.
The results also evidence mass transport issues at low carrier gas flows which are ascribed to the evacuation of produced water at the anode active sites. When high Fu is employed, which means lower H_2-to-carrier ratio, this situation is prevented. An improvement of the cell performance and long term resistance is observed when the carrier gas flow is increased, even at higher Fu, identifying the carrier gas flow as a key factor for enhancing fuel efficiency of the cells.

A0908 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

CFY-Stacks: Progress in Development

S. Megel (1), M. Kusnezoff (1), W. Beckert (1), N. Trofimenko (1), C. Dosch1, A. Weder (1), M. Jahn (1), A. Michaelis (1),
C. Bienert (2), M. Brandner (2), S. Skrabs (2), W. V. Schulmeyer (2), L. S. Sigl (2)
(1) Fraunhofer Institute for Ceramic Technologies and Systems, Winterbergstrasse 28, 01277 Dresden, Germany
(2) Plansee SE, Metallwerk-Plansee Strasse 71, 6600 Reutte, Austria
Contact: Dr. Stefan Megel
Tel.: +49(0)351/25537-505,
Fax: +49(0)351/2554-187
Stefan.Megel@ikts.fraunhofer.de

Abstract

The development of electrolyte supported cells and the components for high efficient and robust stacks are in the focus of the R&D activities of Fraunhofer IKTS for a long time. Since 2010, the CFY-stack design MK351 is produced for a broad range of prototype applications. The change to the new design MK352 has advantages in operation, integration, quality and shall lead to a commercial production. In close collaboration with Plansee SE, a symmetrical design of the interconnect was developed, which allows the compensation of tolerances resulting from near-net shape pressing technology and simpler stack integration in modules. By revision of tolerance chains for all stack components, better robustness in manufacturing and performance has been achieved. The program of validation tests for cells, glass sealings, interconnects, protection and contact layers for the stack will be shown on the example of the new stack design MK352.
CFY stacks are the heart for several SOFC/SOEC systems and shows equal characteristics for a wide operating window. The background for that will be explained in this article by testing different gas compositions with local temperature measurements inside the stack.

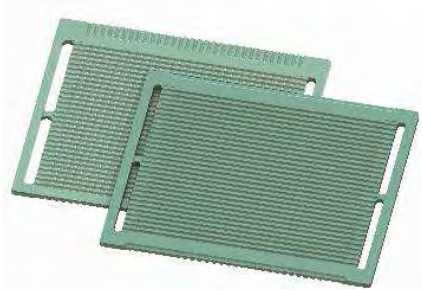


Figure 1: Different designs of interconnect plates made by Plansee SE, designed bei Fraunhofer IKTS (top/back MK351, bottom/front MK352)

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0909 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

New all-European high-performance stack (NELLHI): Experimental evaluation of an 1 kW SOFC stack

Christoph Immisch (1), Andreas Lindermeir (1), Matti Noponen (2), Jukka Göös (2)
(1) Clausthaler Umwelttechnik-Institut GmbH
Leibnizstrasse 21+23, D-38678 Clausthal-Zellerfeld, Germany
Tel.: +49-5323-933-209
Fax: +49-5323-933-100
christoph.immisch@cutec.de
(2) Elcogen Oy
Niittyvillankuja 4, FIN-01510 Vantaa, Finland
Tel.: +358-40-732-9696
matti.noponen@elcogen.com

Abstract

The NELLHI project, supported by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), combines European know-how in single cells, coatings, sealing, and stack design to produce a novel 1 kW SOFC stack with improved electrical efficiency, robustness and considerable cost reductions by establishing mass production pathways. Elcogen stacks are optimized for reduced operating temperatures of 600 to 700 °C and based on products of industrial partners. Elcogen AS supplies the cells, AB Sandvik Materials Technology produces interconnector plate material and coating, Borit manufactures the interconnector plates and Flexitallic Ltd addresses the sealing issue. All components merge together at Elcogen Oy for the design and assembly of the stack. By this, a complete high-quality industrial supply chain is set-up in Europe.
Within the NELLHI project, three stack generations shall be developed and evaluated at CUTEC and VTT to proof their performance and long-term stability. Results of tests done at CUTEC with a 15 cell stack of the 1st generation are very promising and a detailed performance map of the stack at different operating parameters like temperature, anode feed gas composition and flow rate was recorded. Additional test gave deeper insight in the capabilities of the stack under aggravated conditions. Current cycle tests were executed over a total time under load of more than 140 h. The presentation shows the status of stack performance within the NELLHI project and gives an outlook on the ongoing developments.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A0910 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Triode Solid Oxide Fuel Cell operation under Sulphur poisoning conditions

Priscilla Caliandro, Stefan Diethelm, Jan Van herle
FUELMAT, École Polytechnique fédérale de Lausanne
1951 Sion, Switzerland
Tel.: +41-21-693-3549
priscilla.caliandro@epfl.ch

Abstract

The Triode SOFC is a three electrodes configuration. The third electrode, so called auxiliary, is connected in a way to run in electrolysis mode, while cathode and anode operate in normal fuel cell mode. This mixed operation allows to reach anode–cathode potential differences which are not accessible in normal operation. In this work, the benefits of triode operation under S-poisoning conditions are shown. In particular, the difference between conventional and triode operation mode under 2ppm of H_2S in H_2 are analyzed. The partial reversibility of sulphur poisoning is investigated and the observed regeneration processes are discussed for both the conventional and triode operation. After each sequence of exposure and regeneration, IV and EIS characteristics are taken. The electrochemical impedance spectra are further processed by computing the distribution of relaxation times (DRT). During triode operation, less degradation during exposure and faster stabilization after exposure and regeneration with respect to conventional operation mode are observed.

Keywords
Triode SOFC; Degradation; Sulphur poisoning; DRT; EIS.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0911 (Will be published elsewhere)

Pressurized Operation of a 10 Layer Solid Oxide Electrolysis Stack

Marc Riedel, Marc P. Heddrich, K. Andreas Friedrich
German Aerospace Center (DLR)
Institute of Engineering Thermodynamics
Pfaffenwaldring 38-40
70569 Stuttgart
Germany
Tel.: +49-711-68628205
marc.riedel@dlr.de

Abstract

Solar and wind energy are becoming the fundament of the power supply system. However, the increasingly significant amount of renewable electrical power associated with natural intermittency due to varying weather conditions requires flexible storage options. One promising path is the solid oxide electrolysis cells (SOECs) technology which can provide hydrogen or derived hydrocarbons as fuel in transport, as chemical in industry or for repowering or heating.

SOECs offer a great potential for a highly efficient energy conversion due to their high operating temperature that may lead to reduced electrochemical losses. Previous studies have shown that the efficiency of solid oxide fuel cells (SOFCs) can be significantly improved by operating at elevated pressure. Similar effects on the electrochemistry can also influence the cell when operated in electrolysis mode and may also cause improved performance. Another reason for pressurization is the use of pressurized hydrogen in downstream processes like storage or fuel synthesis, e.g. methanation or Fischer-Tropsch synthesis in co-electrolysis.

Preliminary experimental results of water electrolysis in a pressurized SOEC stack are presented in this paper. More results are presented at the poster presentation. The stack consists of ten electrolyte supported cells. The pressure ranges from 1 to 8 bar. Reactant gas composition (0.80 - 0.98), steam utilization (0.60 - 0.85) and temperature (750 - 850 °C) are the experimental parameters that are varied. Pressure influence on open circuit voltage (OCV) and power density is examined. Furthermore current voltage characteristics and impedance spectroscopy are performed to investigate the influence of pressure on the stack performance.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0912

Evaluation of Zr doped $BaCe_{0.85}Y_{0.15}O_{3-\delta}$ as PCFC electrolyte

Ha-Ni Im, Dae-Kwang Lim, Jae-Woon Hong, In-Ho Kim and Sun-Ju Song
Ionics Laboratory, School of Materials Science and Engineering
Chonnam National University, Gwang-Ju 61186, Republic of Korea
*Tel: +82-62-530-1706, Fax: +82-62-530-1699,
song@chonnam.ac.kr

Abstract

Fuel cells as an energy conversion device have generated paramount importance in ensuring the efficient way of utilizing the limited resource of hydrocarbon-based fuels. Among various fuel cell configurations, oxygen ion-conducting electrolyte based solid oxide fuel cells (SOFCs) operating at temperatures >800◦C have been widely studied and utilized for power generation because of advantage of fuel flexibility. However, the mechanical and economic constraints arising from the requirement of high temperature operations so far have been limiting factors in widespread commercialization of these SOFCs. Consequently, over the years great efforts have been made to develop new electrolyte and electrode materials which can bring down the operating temperature of high temperature fuel cells to the intermediate temperature range. Recently, proton-conducting oxide materials have been expected to be potential electrolytes for the new fuel cell configurations operating in intermediate temperature range. A number of cathode material for BCFC, the hydration/dehydration kinetics of $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (BSCF5582) have reported protonic conductivity on humidify the BSCF5582 bulk phase. This observation has broadened the scope of BSCF5582 being used as cathode in intermediate temperature proton-conducting ceramic-electrolyte fuel cells (IT-PCFCs) as well, as the protonic conduction in BSCF5582 would be helpful in PCFCs because of the possibility of extending three-phase boundary deep into cathode during the PCFC operation. Otherwise, the use of LSM as cathode in PCFC would limit the cathode reaction at the three phase boundary (TPB) and keep the TPB close to the electrolyte, thus compared both cathode material we can identified electrochemical active area.
In this work, we have fabricated two type of PCFC 1)$BaCe_{0.85}Y_{0.15}O_{3-\delta}$ (BCY15) electrolyte with LSM cathode to confirm of sub-process, 2) $BaCe_{0.45}Zr_{0.4}Y_{0.15}O_{3-\delta}$ electrolyte with BSCF5582 cathode which enhanced chemical stability of electrolyte.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0913 (Will be published elsewhere)

Homogenization of the thermo-elastic properties of pristine and aged Ni-YSZ samples

Toni Vešović (1, 2), Arata Nakajo (2), Fabio Greco (2), Pierre Burdet (2, 3), Jan Van herle (2), Frano Barbir (1)
(1) Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, Split, Croatia
(2) Fuelmat Group, Faculty of Engineering Sciences and Technology STI, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
(3) Interdisciplinary Centre for Electron Microscopy, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
Tel.:+385-91-174-6059
toni.vesovic@epfl.ch
tvesovic@fesb.hr

Abstract

Solid oxide fuel cell (SOFC) materials are exposed to varying types of mechanical loads and degradation processes during operation and the malfunction of a single cell can cause the end of service of the whole stack. The knowledge of the mechanical properties of the materials is essential to predict the lifetime of the SOFC stack. Several of the thin SOFC layers are heterogeneous materials. The measurement of their properties by mechanical testing is challenging. Methods based on 3-D imaging and computational homogenization are of interest to overcome these difficulties.

This study is focused on the evolution of the thermo-elastic properties of nickel-yttria stabilized zirconia (Ni-YSZ) electrode upon SOFC operation. Focused ion beam-scanning electron microscopy (FIB-SEM) serial sectioning has been performed to obtain 3-D reconstructions of the anode material in the pristine state and after short stack operation for 4700 *h*. The coefficient of thermal expansion (CTE) and elastic constants have been computed using homogenization.

The analysis started with the validation of the developed image processing and numerical procedure. A grid and volume independence study have been first performed to estimate the spatial resolution and minimum volume required for characterizing the investigated Ni-YSZ material. The computed thermo-elastic properties have been then compared to measurements of the pristine anode from dilatometry and four-point bending tests. After these validation steps, the changes in the properties caused by operation have been characterized and the relationship with the evolution of the metric and topological properties discussed.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0914

Evaluation of H_2O/CO_2 co-electrolysis of LSCF6428-GDC Electrode SOFC on microstructural parameters

Sang-Yun Jeon(1)*, Young-Sung Yoo(1), Mihwa Choi(1), Ha-Ni Im(2), Jae-Woon Hong(2), Sun-Ju Song (2)*
(1) Renewables & ESS Group, Energy New Business Lab., Korea Electric Power Research Institute (KEPRI), Korea Electric Power Corporation (KEPCO)
105, Munji-Ro, Yuseong-Gu, Daejeon, 43056, Republic of Korea
(2) Ionics Lab., School of Materials Science and Engineering, Chonnam National University, 77 Yongbong-Ro, Buk-gu, Gwang-Ju, 61186, Republic of Korea
Tel.: +82-62-530-1713
Fax: +82-62-530-1699
*song@chonnam.ac.kr

Abstract

High temperature co-electrolysis of steam and CO_2 based on solid oxide electrolysis cell (SOEC) to produce syngas as a feedstock for the well-known Fischer-Tropsch process is the main aim of the present research. Here Ni-8YSZ/8YSZ/LSCF6428-GDC button cells were fabricated and the effect of the different microstructural parameters like fuel electrode porosities and thermodynamic parameters like gas composition, temperature, on the performance of SOEC has been investigated thoroughly. The SOEC with air electrode and fuel electrode having 20 vol% PMMA contents, addition of YSZ-GDC adhesion layer gives the better performance in overall results and the voltage obtained for this SOEC at current density of 0.8 $A.cm^{-1}$ is ~ 1.3 V. To identify the electrochemical processes occurring at the electrodes of SOEC, distribution function of relaxation time (DRT) analysis of the electrochemical impedance (EIS) data is carried out. The optimized microstructural composition of the SOEC is conceded forward to study effect of thermodynamic parameters. By controlling the upstream gas composition, I-V and EIS performance of SOEC is evaluated.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0915 (Abstract only)

Temperature effect on elastic properties of SOFC layers

Alessia Masini, Zdeněk Chlup, Ivo Dlouhý
Institute of Physics of Materials (IPM)
22 Zizkova
616 62 Brno / Czech Republic
Tel.: +420-774-98-2727
masini@ipm.cz

Abstract

The goals EU set by year 2020 include the saving of fossil fuels and the decrease of carbon dioxide emissions; hence, more environmentally friendly and efficient means of energy conversion are needed. Solid oxide fuel cells (SOFCs) and reversible solid oxide electrolyser cells (SOECs) are two of them; thanks to their ability to directly convert chemical energy of fuels into electricity, they are attracting considerable attention nowadays. In order to make these devices competitive in the energy market, it is necessary to improve their durability and reliability. Further development of SOCs requires the simulation of their operational behavior by thermo-mechanical models, which in turn require reliable values for the thermal and mechanical properties of the materials involved.
It is known that mechanical damage caused by thermal loading is the most serious problem that may cause degradation or even destruction of the cell and consequently lower the lifetime and efficiency of whole system. Thus, it is of high importance to understand mechanical properties of SOFC and SOEC components, especially under long term operating conditions.
This study is targeted to the behaviour of individual cell, as it is the main component and its failure compromise the operation of the whole stack. Although exist several literature sources dealing with mechanical properties of the most common electrolytes and electrodes, the knowledge is usually limited to the behaviour of single layers. The effects of interfaces and layers co-sintering effects are up to now not well understood. In this contribution we have investigated the overall behavior of the cell, focusing on the role that interface between layers plays in the changing of resulting elastic properties. For this purpose, the effects of added layers were analysed using high temperature impulse excitation technique. The relationship of Young's modulus and presence of various combinations of layers was measured from the room temperature up to a temperature lying above the service one. Obtained trends allowed us to extract the elastic behaviour of individual layers suitable as input for simulations.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0917

Characterization of the performance and long-term degradation of fuel electrode supported multilayered tape cast Solid Oxide Cells

M. Torrell (1)*, D. Rodríguez (2), B. Colldeforns (1), M. Blanes (2), A. Morata (1), F. Ramos (2), A. Tarancón (1)
(1) IREC, Catalonia Institute for Energy Research, Dept of Advanced Materials for Energy Applications, Jardí de les Dones de Negre 1, Planta 2, 08930, Sant Adriá del Besós, Barcelona
(2) FAE, Francisco Albero SAU, L'Hospitalet de Llobregat, Spain
(*) mtorrell@irec.cat

Abstract

After the efforts of the scientific community focused on the development and optimization of the Solid Oxide Cells (SOC) carried out during past years, nowadays their final implementation depends mainly on the long term stability of the systems. Improving the durability and characterize the aging mechanisms is shown as key factor for the final introduction of SOC systems as real alternative energy devices. The market penetration of SOC will probably be promoted not only as power generator systems, working as Solid Oxide Fuel Cells (SOFC) but also as Solid Oxide Electrolyzer Cells (SOEC) for chemical energy storage for power to gas and power to liquid routes [1-3].
In the present work, anode supported cells (ASC) have been fabricated by an innovative multilayer tape casting process at industrial scale at FAE S.A.U facilities. NiO-YSZ and YSZ tapes have been cast and jointly sintered to produce the cell supports (fuel electrode and electrolyte). $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_3$ (LSCF) oxygen electrode has been deposited by screen printing with a $Gd_{0.2}Ce_{0.8}O_2$ (CGO) diffusion barrier to avoid the generation of insulator secondary phases such as $SrZrO_3$ [4]. A complete microstructural characterization of the cells has been carried out. The cells have been electrochemically characterized under SOFC and SOEC mode in terms of performance and long term stability. Results are discussed analyzing EIS spectra obtained under different operation modes and conditions. Power densities above 700mW/cm^2 have been achieved under wet hydrogen at 750ºC in SOFC mode showing more than 2000h of stability. In addition, current densities of 1A/cm^2 have been injected to the same cell operating as electrolyzer at 850ºC. SOEC aging test for 150h has been carried out at voltages above the thermoneutral.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0918 (Abstract only, published elsewhere)

Hydrogen membrane fuel cell using Ni-Zr alloy membrane

SungBum Park (1), Sung Gwan Hong (1), Yong-il Park (1)
(1) Kumoh National Institute of Technology
61 Daehak-ro, Gumi, Gyeongbuk, Korea
Tel.: +82-54-478-7753
parksungbum@kumoh.ac.kr

Abstract

The purpose of this study is to develop HMFC (hydrogen membrane fuel cell), a new concept fuel cell different from the existing thin membrane type SOFC, by utilizing the high-degree of mechanical stability of metal complex electrolyte including metal hydrogen separation membrane. In the case of metal separation membrane mainly used for hydrogen separation membrane, it is excessively dependent upon Pd with effective hydrogen storage and transmission performances and an alternative material has not been found. Accordingly, there is a need for studies on non-Pd system hydrogen permeable membrane that can be used in high temperatures with hydrogen permeable rate similar to existing Pd. This study fabricated and analyzed the characteristics of Ni-Zr system hydrogen separation membrane with high selectivity and permeability of hydrogen while substituting existing Pd that has been used as hydrogen separation membrane.
In addition, HMFC was composed by using the Ni-Zr system metal hydrogen permeable membrane fabricated to evaluate its performance.

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1201 (Will be published elsewhere)

Stability of SOFC cassette stacks during redox-thermal-cycling

Ute Packbier (1), Tim Bause (2),
Qingping Fang (1), Ludger Blum (1), Detlef Stolten (1)
(1) Forschungszentrum Jülich GmbH
Institute of Energy and Climate Research
Electrochemical Process Engineering (IEK-3)
Wilhelm-Johnen-Straße, 52428 Jülich, Germany
(2) ElringKlinger AG, Max-Eyth-Straße 2 72581 Dettingen, Germany
Tel.: +49-2461-615170
Fax: +49-2461-616695
u.packbier@fz-juelich.de

Abstract

At Forschungszentrum Jülich measurements regarding redox-stability of anode supported cells integrated in 5-layer cassette design stacks were performed. In potential SOFC system applications like off-grid power generators the anode side of these stacks may be exposed to air during system start and/or stop. During the stack tests combined thermal and redox cycles were performed in order to determine the temperature at which the cells are irreversibly damaged.
Two 5-layer cassette design stacks provided by ElringKlinger AG were thermal-cycled in a temperature range between 300 to 750 °C. While cooling down, the anode side was flushed with 100 $mlmin^{-1}$ air as soon as the stack reached a certain temperature. At a temperature of 300 °C air was replaced by 4% H_2 in Ar and the stack was heated back to operation temperature. During the stack test the temperature at which flushing with air was started was increased stepwise from 500 to 700 °C for the first stack, and up to 630 °C for the other one. Within each cycle cell voltages at 0.3 A/cm² were recorded at defined conditions for comparison. OCVs under dry atmosphere were measured for detecting possible leakage in each cell. After testing the stacks were examined regarding damages related to redox-cycling by post-mortem analysis.
Up to a redox temperature of 600 °C no decrease in cell performance and OCV was observed. At higher redox temperatures starting from 620 °C a noticeable decrease in performance and OCV was measured. At a redox temperature of 700 °C the decrease in OCV indicated a severe damage of the cells.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1202 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Evaluation of a SOEC stack for hydrogen and syngas production: a performance and durability analysis

Mikko Kotisaari (1), Olivier Thomann (1), Dario Montinaro (2), Jari Kiviaho (1)
(1) VTT Technical Research Centre of Finland Ltd., Biologinkuja 5, 02150 Espoo, Finland
(2) SOLIDpower SpA, Viale Trento 115/117, 38017 Mezzolombardo, Trento, Italy
Tel.: +358-40-483-7715
Fax: +358-20-722-7048
mikko.kotisaari@vtt.fi

Abstract

Solid oxide electrolysers (SOE) are gaining growing interest in research because they can convert electricity into a chemical fuel with high efficiency. The present work investigates the performance of a 6-cell SOE stack (80 cm^2 active area) in electrolysis and co-electrolysis modes for the purpose of producing synthetic fuel. Initially, the stack was operated and characterized in fuel cell mode at 750 °C. Operation was then changed to electrolysis mode and the stack performance was characterized with a test matrix consisting of four different inlet gas compositions of various ratios of inlet steam and carbon dioxide at temperatures of 700, 750 and 800 °C. It was found that the stack performance depends primarily on the operation temperature and only to a small extent on the inlet gas composition. Finally, a steam electrolysis durability test of 1500 hours was performed at a current density of -0.775 A/cm^2 (50 % of reactant utilization) and at a temperature of 750 °C. The voltage trend showed that no degradation could be measured, which is a very promising result. In conclusion, the investigated stack appears suitable for syngas production. In the future, co-electrolysis durability tests will be conducted to evaluate the effect of addition of carbon dioxide on the stack durability.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1203 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Investigation of a 500W SOFC stack fed with dodecane reformate

Massimiliano Lo Faro, Stefano Trocino, Sabrina C. Zignani, Giuseppe Monforte, Antonino S. Aricò
CNR-ITAE, Via Salita S. Lucia sopra Contesse 5, 98126 Messina, Italy
Tel.: +39-090-624231
Fax: +39-090-624247
lofaro@itae.cnr.it

Abstract

A proof-of-concept Solid Oxide Fuel Cell (SOFC) system of 500 W_{el} fed with n-dodecane reformate was realized in order to prove the reliability of SOFC technology for naval uses. The cells used for the prototype consisted of Ni-YSZ/YSZ/YDC/LSFC whereas the catalyst for the reformer of n-dodecane was Rh-CeO_2-ZrO_2. At the preliminary stage and as to a propaedeutic approach, a microplant consisting of a reformer for the treatment of 7 Wh of dodecane and a single button cell were coupled in order to determinate the proper conditions of operation and the degradation effects occurring during 300 h of stressed tests. Then, a single large area cell and a stack were fed with n-dodecane reformate to determinate the performance achievable under practical conditions.
Electrochemical ac-impedance spectra (EIS) and polarizations curves were carried out to study the systems above mentioned. As well, post-operation scanning electron microscopy analysis (SEM) on the cell and thermal analysis on the catalyst were conducted in order to demonstrate the ageing effect observed during the operation of the coupled system.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1204 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Performance Characteristics of Elcogen Solid Oxide Fuel Cell Stacks

Matti Noponen, Jukka Göös, Pauli Torri, Daniel Chade, Heikki Vähä-Piikkiö, Paul Hallanoro
Elcogen Oy
01510 Vantaa, Finland
Tel.: +358-40-732-9696
matti.noponen@elcogen.com

Abstract

Elcogen E1000 and E3000 stacks were characterized according to IEC 62282-7-2 for their electrochemical performance including rated power tests, current-voltage characteristics tests, effective fuel utilization dependency tests, long term durability tests, and internal reforming performance tests. Stacks show similar performance characteristics at equivalent testing conditions indicating repeatable quality of the stack design, components, assembly and conditioning process. Stack durability has been tested with reformate gas over 7300 h. Elcogen stacks enable high system efficiencies as stack gross efficiency was measured to reach 72 %-LHV with below 5 mbar pressure drops both for fuel and air side at 650 °C.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1205 (Will be published elsewhere)

Performance and degradation of an SOEC stack with different air electrodes

Y. Yan (1), Q. Fang (1), L. Blum (1), W. Lehnert (1, 2)
(1) Forschungszentrum Jülich GmbH
Institute of Energy and Climate Research
Wilhelm-Johnen-Straße
52425 Jülich/ Germany
(2) RWTH Aachen University, Modeling in Electrochemical Process Engineering
52072 Aachen/ Germany
Tel.: +49 2461 61-5487
Fax: +49-2461-616695
y.yan@fz-juelich.de

Abstract

High temperature water electrolysis with Solid Oxide Electrolysis Cell (SOEC) is a promising method for hydrogen production. In order to study the performance and degradation behavior of different air electrodes under electrolysis mode, a 4-cell stack was assembled in JÜLICH's F10-design with two types of air electrodes based on $La_{0.6}Sr_{0.4}CoO_{3-\delta}$ (LSC) and $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$ (LSCF). The performance of the stack was characterized in both SOFC and SOEC modes in the temperature range of 700~800 °C. The durability of the stack was first investigated by conducting a long-term stationary operation with a constant current density of -0.5 Acm^{-2} and steam conversion rate of 50% at 800 °C. Electrochemical Impedance Spectroscopy (EIS) was utilized in the study of the electrochemical performance of the stack, as well as the degradation behavior during the long-term electrolysis operation. To improve the quality and reliability of the equivalent circuit fitting, the Distribution of Relaxation Times (DRT) analysis was applied.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1206 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Fuel Distributions in Anode-Supported Honeycomb Solid Oxide Fuel Cells

Hironori Nakajima(1), Tatsumi Kitahara (1), Sou Ikeda (2)
(1) Department of Mechanical Engineering, Faculty of Engineering, Kyushu University
(2) Department of Hydrogen Energy Systems, Graduate School of Engineering, Kyushu University
744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan
Tel.: +81-92-802-3161
Fax: +81-92-802-3161
nakajima@mech.kyushu-u.ac.jp

Abstract

An anode-supported honeycomb solid oxide fuel cell can achieve high volumetric power density and improve thermo-mechanical durability at high temperatures. We have so far fabricated the honeycomb cell with conventional materials for a cathode layer (LSM) and an electrolyte layer (8YSZ) on a porous anode honeycomb substrate of Ni/8YSZ. The anode-supported honeycomb cell exhibited promising volumetric power densities [1]. Effect of flow channel configurations on the cell performance was investigated in terms of the hydrogen partial pressure distributions in the cell under operation as well [1]. In this study, we compare the differences of measured current-voltage and current-power density curves among the honeycomb cells having different porous substrate thicknesses shown in and different flow channel configurations under different inlet hydrogen flow rates. Hydrogen partial pressure distributions associated with the anode-substrate thickness and the flow channel configuration on the cell performance possibly give the performance differences.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1208 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Potential for critically-high electrical efficiency of multi-stage SOFCs with proton-conducting solid electrolyte

Yoshio Matsuzaki (1,2), Yuya Tachikawa (3), Takaaki Somekawa (1,4), Kouki Sato (2), Hiroshige Matsumoto (5), Shunsuke Taniguchi (2,3,6), Kazunari Sasaki (2,3,4,5,6)
(1) Fundamental Technology Department, Tokyo Gas Co., Ltd.,
1-7-7 Suehiro-cho, Tsurumi-ku, Yokohama City, Kanagawa 230-0045, Japan
(2) Next-generation Fuel Cell Research Center, Kyushu University,
744 Motooka, Nishi-ku, Fukuoka City, Fukuoka 819-0395, Japan
(3) Center for Co-Evolutional Social Systems (CESS), Kyushu University,
744 Motooka, Nishi-ku, Fukuoka City, Fukuoka 819-0395, Japan
(4) Faculty of Engineering, Kyushu University,
744 Motooka, Nishi-ku, Fukuoka City, Fukuoka 819-0395, Japan
(5) International Institute for Carbon-Neutral Energy Research (WPI-I2CNER),
744 Motooka, Nishi-ku, Fukuoka City, Fukuoka 819-0395, Japan
(6) International Research Center for Hydrogen Energy, Kyushu University,
744 Motooka, Nishi-ku, Fukuoka City, Fukuoka 819-0395, Japan
Tel.: +81-806-5418-9431
Fax: +81-3-5604-8285
matuzaki@tokyo-gas.co.jp

Abstract

Recently we developed and reported a conceptual design that has a potential to realize a critically-high fuel-to-electricity conversion efficiency of up to as high as 85% (LHV, gross DC), in which a high-temperature multi-stage electrochemical oxidation is combined with a proton-conducting solid oxide electrolyte. In the conceptual design a protonic transport number of a proton-conducting electrolyte was assumed to be unity.
However, the protonic transport number of the proton-conducting solid oxide electrolyte depends on the material and operating conditions such as temperature, partial pressures of oxygen and steam, and so on, and would affect the electrical efficiency.
In this study, the influence of the conductivities of oxide-ion as well as electron and hole in the proton-conducting solid electrolyte with multi-stage configuration on the electrical efficiency has been investigated. The existence of measurable conductions of electron and/or hole was found to cause leakage current resulting in obvious deterioration of the electrical efficiency.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1209 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Performance testing for a SOFC stack with bio-syngas

Ruey-Yi Lee (1)*, How-Ming Lee (1), Ching-Tsung Yu (1), Yung-Neng Cheng (1), Szu-Han Wu (1), Chien-Kuo Liu (1), Chun-Hsiu Wang (2), Chun-Da Chen (2)
(1) Institute of Nuclear Energy Research
No. 1000 Wenhua Road,
Longtan District, Taoyuan City / Taiwan (R.O.C.)
(2) China Steel Corporation
No. 1 Chung-Kang Road,
Hsiao Kang District, Kaohsiung / Taiwan (R.O.C.)
*Tel.: +886-3-471-1400 Ext. 6761
Fax: +886-3-471-3980
rylee@iner.gov.tw

Abstract

The purpose of this study is to assess the adaptability of the bio-syngas as a fuel for a SOFC power system. The eucalyptus wood chips, provided by China Steel Corporation, were fed into a Plasma-Assisted Gasification System at INER to obtain the bio-syngas. Subsequently, it was passed through a set of cleanup processes to remove gaseous impurities and particulates, and then compressed and preserved in the storage tanks. Performance testing was conducted for 3-cell stacks fuelled with the cleaned bio-syngas. In the first run, the stack experienced fluctuations of open circuit voltage (OCV), a relatively high degradation rate as well as severe carbon deposition onto the catalysts of reformer. The situation was significantly improved for the 2nd run, while a series of deep cleanup processes were employed to reduce impurities of the bio-syngas to below ppm levels. The results indicate: (1) the bio-syngas is successfully produced through the plasma-assisted gasification system, the total concentration of hydrogen and carbon monoxide is higher than 50%, the lower heating value of the syngas is around 7~8 MJ/Nm^3. (2) the concentration of hydrogen sulfide is below 1.0 ppm after the deep cleanup processes, while the total concentration of sulfur, phosphorus, and chlorine is below 0.01 ppm, 0.01 ppm, and 0.30 ppm, respectively. (3) OCV of the 3-cell stack is 2.89 V, power output 77 W (power density 317 mW/cm^2, @ 32 A, 750 ^{o}C), and an overall degradation is around 0.6 % for a test period of 103 hours. (4) it is experimentally proved that SOFC can be fuelled with well purified bio-syngas.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

Chapter 04 - Session A13

Development of systems and balance of plant components

Content **Page A13 - ..**

A1301 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....3
Development of highly efficient SOFC power generating system using fuel concentration recovery process **3**
Kazuo Nakamura, Takahiro Ide, Shumpei Taku, Tatsuya Nakajima, Marie Shirai, Tatsuki Dohkoh, Takao Kume, Yoichi Ikeda, Takaaki Somekawa, Takuto Kushi, Kei Ogasawara, Kenjiro Fujita 3
A1302 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....4
Prognostics-oriented simulation of an MSR fuel processor for SOFCs **4**
Federico Pugliese (1), Andrea Trucco (2), Paola Costamagna (1) 4
A1303 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....5
A Planar Steam Reformer Designed for 60,000 h Operation **5**
Yves De Vos (1), Jean-Paul Janssens (1) 5
A1304 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....6
Proof of concept for solid oxide electrolysis systems **6**
DI Richard Schauperl, Bsc Beppino Defner, Bsc Dominik Dunst, DI Jürgen Rechberger 6
A1305 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....7
SchIBZ – application of large diesel fuelled SOFC systems for seagoing vessels and decentralized onshore applications **7**
Keno Leites 7
A1306 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....8
Development of a SOFC/Battery-Hybrid System for Distributed Power Generation in India **8**
Thomas Pfeifer, Mathias Hartmann, Markus Barthel, Jens Baade, Ralf Näke, Christian Dosch 8
A1307 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....9
Sulfur Tolerant WGS-Catalysts **9**
Thorsten Dickel (1), André Weber (1) Michael Scharrer (2), Claus Peter Kluge (2) 9
A1309 (Will be published elsewhere).....10
Control strategy for a SOFC gas turbine hybrid power plant **10**
Moritz Henke (1), Mike Steilen (1), Ralf Näke (2), Marc Heddrich (1), K. Andreas Friedrich (1) 10
A1312 (Will be published elsewhere).....11
rSOC plant concept for renewable energy storage **11**
Matthias Frank (1), Roland Peters (1), Van Nhu Nguyen (1), Robert Deja (1), Ludger Blum (1), Detlef Stolten (1,2) 11
A1313.....12
Investigation of a novel catalytic partial oxidation and pre-reforming radial reactor of a micro-CHP SOFC-system with anode off-gas recycle **12**
Timo Bosch (1), Maxime Carré (1), Angelika Heinzel (2), 12
Michael Steffen (2), François Lapicque (3) 12
A1315 (Abstract only).....13
Performance evaluation of solid oxide carbon fuel cells operating on steam gasified carbon fuels **13**
Tak-Hyoung Lim(*), Jong-Won Lee, Seung-Bok Lee, Seok-Joo Park, Rak-Hyun Song 13

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1316 (Abstract only, published elsewhere) 14
Methane Steam Reforming Reaction over Ni/CeO_2-ZrO_2 Catalysts Loaded on Metallic Monolith **14**
Jong Dae Lee (1) 14
A1317 (Will be published elsewhere).....15
System validation tests for a SOFC power system at INER **15**
Shih-Kun Lo*, Wen-Tang Hong, Hsueh-I Tan, Huan-Chan Ting, Ting-Wei Liu and Ruey-Yi Lee 15
A1319 (Will be published elsewhere).....16
A Global Reaction Model of Carbon Gasification with K_2CO_3 in the External Anode Media of a DCFC **16**
Shinae Song, Jun Ho Yu, Kyungtae Kang, Jun Young Hwang 16
A1320 (Will be published elsewhere).....17
Experimental study on the fuel ejector for solid oxide fuel cell system **17**
Kanghun Lee (1), Sanggyu Kang (1, 2), Youngduk Lee (1), Kook-Young Ahn (1,2) 17

A1301 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Development of highly efficient SOFC power generating system using fuel concentration recovery process

Kazuo Nakamura, Takahiro Ide, Shumpei Taku, Tatsuya Nakajima, Marie Shirai, Tatsuki Dohkoh, Takao Kume, Yoichi Ikeda, Takaaki Somekawa, Takuto Kushi, Kei Ogasawara, Kenjiro Fujita
Tokyo Gas Co., Ltd., Fundamental Technology Dept.;
1-7-7, Suehiro-cho, Tsurumi-ku, Yokohama 230-0045 / Japan
Tel.: +81-45-500-8772
Fax: +81-45-500-8790
kzo_naka@tokyo-gas.co.jp

Abstract

Although a large number of residential fuel cell systems have been installed, the market for business-use fuel cell systems is at an initial stage in Japan. We believe that the realization of highly efficient power generation is the key issue in creating the market for business-use fuel cell systems. In view of the above, we aim to develop a highly efficient power generation system using the solid oxide fuel cell (SOFC).

In order to realize the SOFC module with highly efficient power generation, we have laid out a two-stage SOFC stack configuration with a fuel concentration recovery process between the stacks. The fuel concentration recovery process is designed to remove 96% of the H_2O content in the anode off-gas from the first SOFC stack. Since the fuel utilization rate of the second SOFC stack using the fuel from the process can be raised to about the same level as that of the first SOFC stack (for example 70%), a total fuel utilization rate above 91% can be achieved. Therefore, the module can generate power with high electric efficiency using this configuration.

In order to demonstrate highly efficient power generation, the SOFC module using the configuration was manufactured and operated. The power generation test was carried out successfully, and thermally self-sustainable operation was confirmed. The total output power was DC 2.27 kW and the power generation-end efficiency was DC 69.2% (lower heating value, LHV) at the total fuel utilization rate of 86.3%. Taking inverter loss (5%) and auxiliary devices loss (6%) into consideration, the AC electrical efficiency was estimated to be 61.8% (LHV). We have established the method of achieving highly efficient power generation using the SOFC module with the two-stage SOFC stacks and the fuel regeneration process.

In order to realize even higher power generation efficiency, it is required to remove the CO_2 content by the fuel regeneration process and to also prevent heat from escaping outside the system. In the future, we aim to develop SOFC systems with high power generation efficiency above AC 65% (LHV) by improving the SOFC module and integrating it into the system.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1302 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Prognostics-oriented simulation of an MSR fuel processor for SOFCs

Federico Pugliese (1), Andrea Trucco (2), Paola Costamagna (1)
(1) Department of Civil, Chemical and Environmental Engineering (DICCA)
(2) Department of Electrical, Electronics and Telecommunications Engineering (DITEN)
University of Genoa
Via Opera Pia 15, 16145 Genoa, Italy.
Tel.: +39-010-353-2922
Fax: +39-010-353-2586
paola.costamagna@unige.it

Abstract

In solid oxide fuel cell (SOFC) plants, failure of the methane steam reforming (MSR) fuel processor can result in increased levels of methane being fed into the fuel cell stack, with possible consequent damage. In view of this, diagnostics and prognostics of the MSR reactor is of utmost importance. The development of methods for early prediction and detection of faults in chemical reactors is based on numerical tools for the steady-state and transient simulation.

In the present work, we investigate in detail the problem of carbon deposition in an MSR reactor for application in SOFC power plants, through a first-principle model based on microscopic mass balances embedding a local chemical kinetics. The partial differential and algebraic equations (PDAEs) are integrated numerically using a finite element method, implemented through COMSOL Multiphysics. The results allow to identify the areas where carbon deposition is expected to occur, and show that, even with a steam-to-carbon (S/C) ratio of 3, carbon deposition can occur in some specific operating conditions.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1303 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

A Planar Steam Reformer Designed for 60,000 h Operation

Yves De Vos (1), Jean-Paul Janssens (1)
(1) Bosal ECS NV
Dellestraat 20, B-3560 Lummen/Belgium
Tel.: +32-13-530-971
Fax: +32-13-531-411
yves.devos@eur.bosal.com

Abstract

A planar steam reformer is designed for meeting 60,000 h lifetime. The component is designed as a plate heat exchanger, whereby the reaction heat for the steam reforming is extracted from the hot cathode flow through thin, catalytically coated heat exchanging foils. The surface wall reactions were modeled in a periodic CFD domain, consisting of a coated foil, and periodic half anode and cathode channels on the opposing sides of the foil. The flow parameters, heat exchange and wall surface reactions were solved by the CFD. The catalyst aging by deactivation was determined by reactivity measurements on washcoat powder. The washcoat mass loss by flaking was obtained using SEM/EDX. Aging was simulated in CFD by partly deactivating the reactions at wall temperatures > 800°C. The reaction zone and the temperature profile shifted as a result. Washcoat redundancy was validated by calculating the overall performance. Redundancy parameters were drafted, so that the designed component proved unaffected by catalyst aging. The measured performance of new and aged reformers was in line with the calculations.
Oxide scale growth, and scale flaking was determined by post-mortem analysis at 20,000 h. A stable Cr oxide scale was measured, 20 - 40 μm thick. Locally, Cr / Fe oxide scale was present, resulting in flaking, and reduction of the bulk plate thickness. Iron oxides contributed for 40 to 85% of the collected flake mass, as determined using x-ray diffraction (XRD). The Cr evaporation was modeled by CFD at the cathode path, using rate parameters as measured on steel sample plates in an inert reactor.
Optimization for both Cr evaporation and scale flaking was achieved by reducing the hotspots, and optimizing the material grade and component cost.

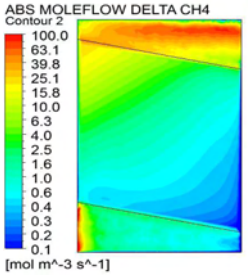


Fig 1: Contour plot of the gas composition in the planar steam reformer.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1304 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Proof of concept for solid oxide electrolysis systems

DI Richard Schauperl, Bsc Beppino Defner, Bsc Dominik Dunst, DI Jürgen Rechberger
AVL List GmbH
Hans-List-Platz 1
A-8020 Graz, Austria
Tel.: +43-316-787-2168
richard.schauperl@avl.com

Abstract

Today's energy supply systems are not very suitable for highly stochastic energy production from renewable sources (wind, PV). The availability of wind and solar power is not sufficiently predictable and the storage of this excess energy is not possible in quantities based on today's technologies. Solid oxide electrolysis offer an efficient and scalable energy storage technology with the potential to contribute in finding solutions for the typical issues of renewable electricity production and in developing carbon neutral fuels. A third opportunity is to use the products, including O_2, for further chemical synthesis, for example in the pharmaceutical or plastic industry.

Electrical energy can be stored in chemical energy by producing molecular hydrogen or syngas. This happens via electrolysis of steam or co-electrolysis of steam and carbon dioxide. These energy carriers can either be used as a buffer for fluctuating energy production, or used as transport fuels. The synthetic fuels are potentially carbon neutral, when the electricity comes from renewable energy production.

Within the project "HydroCell" various advantageous system concepts for hydrogen production, including all components which are necessary to operate the electrolysis stacks, were identified. Furthermore, several electricity storage technologies where taken into comparison, with the goal to investigate the high temperature electrolysis technology's potential for the energy sector.
Two system concepts where identified, reaching electrical to chemical energy conversion efficiencies up to 79%. [(1)] Based on these results, two system concepts were developed, downscaled into "Proof-of-Concept" systems and analyzed on a test rig. Furthermore, suitable operating strategies were developed for an efficient and safe operation. The presentation will explain the theoretical background and will show the Proof-of-Concept system design and measurements performed in the project "HydroCell".

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1305 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

SchIBZ – application of large diesel fuelled SOFC systems for seagoing vessels and decentralized onshore applications

Keno Leites
thyssenkrupp Marine Systems GmbH
Hermann-Blohm-Str. 3, 20457 Hamburg, Germany
Tel.: +49-431-700-1466
Fax: +49-431-700-16001466
keno.leites@thyssenkrupp.com

Abstract

Under the project name SchIBZ thyssenkrupp Marine Systems and 6 partners from industry and science developed a fuel cell system for seagoing vessels. The unique feature of this system is the use of low sulphur diesel oil as fuel.
The system is based on solid oxide fuel cells coupled with a unique reforming unit for the diesel fuel and connected with an energy buffer. The components are modular to realize power outputs roughly between 50 and 500 kW per system.
The advantages of the system are a high electrical efficiency, around 50%, very low gaseous emissions without exhaust gas treatment, low heat radiation and noise, very low maintenance due to few active components, possibility for heat recovery for further energy efficiency, high intrinsic redundancy and the potential to reduce the power installed on board.
Additionally the availability of energy supply can be increased by decentralized installation of the units on board of oceangoing ships. Furthermore, the system offers advantages for transportable, remote power supply when installed in container.
The consortium is right now in the phase of the construction of a 50 kW demonstrator which is going to be installed on-board a merchant vessel for several months for sea trials in 2016. It is planned to offer the system commercially after that successful test.
Further development activities will comprise adaption to other fuels, improvements at the electrical side and scaling.
This paper will present the results of tests as well as an outlook for further development of the technology and application.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1306 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Development of a SOFC/Battery-Hybrid System for Distributed Power Generation in India

Thomas Pfeifer, Mathias Hartmann, Markus Barthel, Jens Baade, Ralf Näke, Christian Dosch
Fraunhofer IKTS
Winterbergstraße 28
D-01277 Dresden / Germany
Tel.: +49-351-2553-7822
Fax: +49-351-2554-302
thomas.pfeifer@ikts.fraunhofer.de

Abstract

In recent years India faces demanding challenges in covering an aggressively increasing electricity consumption through economic growth and progressive consumer requirements. Renewable sources and small distributed power generators have been identified as one of the options to establish a diversified power supply infrastructure. The present situation offers promising opportunities for fuel cell systems, as “grid-parity” is not the common measure of competitiveness, but rather the installation speed and availability of reliable power sources.
Contracted by the company h2e Power Systems Pvt. Ltd. based in Pune, India, Fraunhofer IKTS has developed a 1 kW(el) SOFC power generator during a three-year system engineering and technology transfer project. The fuel cell system is based on the CFY stack technology by Plansee SE and IKTS, incorporating state-of-the-art ESC with Scandia-doped Zirconia electrolytes. CFY-stacks have proven to be robust and reliable, showing power degradation rates below 0.6 % per 1.000 hours during endurance operation over 20.000 hours and a cyclization capability of more than 120 near-system cycles under full RedOx-conditions.
For the SOFC power generator a CFY stack is integrated with a pre-reformer, a tail-gas oxidizer and heat exchangers into a HotBox-module following a novel concept for least-space-demanding reactor integration and flow distribution. Aside from compactness, a simple and robust, yet highly efficient system concept was set as the primary development goal for the project. To meet these requirements, two major design decisions have been introduced in the process layout, i.e. a rated fuel utilization in the stack of 85 % as well as a POX-air pre-heater for reducing the reformer air flow to lowest possible values. This approach leads to a water-less SOFC system with a net electrical efficiency above 40 %.
In 2015, two Proof-of-Concept (PoC) prototype systems were commissioned and tested at IKTS. One of the PoC-prototypes was installed later at the customer’s laboratory in Pune, India, for test and demonstration purposes. In Project Phase II, three improved prototype systems were built at IKTS and shipped to India in May 2016 for initial demonstration projects and field trials. At the same time, the technology transfer to the customer was initiated, in order to enable for a local manufacturing and deployment of SOFC systems in India. By completion of the prototype delivery and technology transfer, the initial development project was successfully finished. Various follow-up activities are currently under negotiation between h2e Power Systems and Fraunhofer IKTS.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1307 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Sulfur Tolerant WGS-Catalysts

Thorsten Dickel (1), André Weber (1)
Michael Scharrer (2), Claus Peter Kluge (2)
(1) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT),
Adenauerring 20b, D-76131 Karlsruhe/Germany
Tel.: +49-721-608-47494
Fax: +49-721-608-47492
thorsten.dickel@kit.edu

(2) CeramTec GmbH
CeramTec-Weg 1
D-95615 Marktredwitz

Abstract

The sulfur content in fuels as reformed natural gas or diesel results in a severe power loss of state of the art anode supported SOFCs. Previous studies showed that the performance loss is related to a sulfur poisoning of the Ni/YSZ-cermets resulting in a deactivation of (i) the catalytic watergas-shift-reaction (WGS) at the nickel surfaces and (ii) the electro-oxidation of hydrogen at the triple phase boundaries (TPB).
In a first step towards a sulfur tolerant SOFC different ceria and nickel/ceria catalysts were investigated with respect to sulfur poisoning of the WGS-reaction. The catalysts were applied onto dense zirconia substrates and tested in a single cell test bench that enables in-operando gas analysis along the gas channel. A model fuel consisting of 50% CO and 50% H_2O was applied. To study sulfur poisoning 2 ppm of H_2S was added.
The experiments revealed that pure ceria exhibits a low catalytic activity but a good sulfur tolerance. Nickel showed a significantly higher initial catalytic activity but strong poisoning effects. In case of Ni/ceria cermets exhibiting an appropriate microstructure and layer thickness high catalytic activity and excellent sulfur tolerance can be achieved. The results indicate that the sulfur tolerance is increasing with the density of TPBs between ceria, nickel and the fuel. The conversion rate and its stability in sulfur containing fuels increases with the thickness of the catalyst layer. The applicability of such Ni/ceria catalyst layer was validated by performance tests of state of the art anode supported cells operated with a sulfur containing diesel reformate. Due to the additional hydrogen generated by the WGS-reaction in this sulfur tolerant catalyst layer the cell performance was increased by 32%.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1309 (Will be published elsewhere)

Control strategy for a SOFC gas turbine hybrid power plant

Moritz Henke (1), Mike Steilen (1), Ralf Näke (2), Marc Heddrich (1), K. Andreas Friedrich (1)
(1) German Aerospace Center (DLR),
Pfaffenwaldring 38-40, 70569 Stuttgart, Germany
(2) Fraunhofer IKTS,
Winterbergstraße 28, 01277 Dresden, Germany
Tel.: +49-711-6862-795
moritz.henke@dlr.de

Abstract

Today, gas steam combined cycle plants are the most efficient power plants converting chemical energy into electrical energy with installed powers of usually several hundred MW. They are technologically mature reaching electrical efficiencies of 60 % (based on the lower heating value). Hybrid power plants consisting of solid oxide fuel cells (SOFC) and a gas turbine (GT) can reach higher electrical efficiencies and can be built at lesser installed power.

The general concept of a SOFC/GT hybrid power plant is to use the hot SOFC exhaust gases to drive a gas turbine. High electrical efficiencies are achieved if SOFC and gas turbine match well. In the past few years a hybrid power plant with an electrical power output of 30 kW has been designed and is currently under construction at DLR.

One challenge concerning the operation of the hybrid power plant is the control of the hybrid system. Stand-alone gas turbines can react comparatively fast to load changes and quickly reach a new stationary operating point. SOFC system temperatures react much slower due to their large thermal capacity. The operating strategy of the hybrid system needs to ensure a safe and reliable operation and allow for high electrical efficiency in a wide power range. Furthermore, dynamic operation like start-up, load changes, shut-down and emergency procedures are also considered. This work will give an overview of the control concept and show how the requirements are met.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1312 (Will be published elsewhere)

rSOC plant concept for renewable energy storage

Matthias Frank (1), Roland Peters (1), Van Nhu Nguyen (1), Robert Deja (1), Ludger Blum (1), Detlef Stolten (1,2)
(1) Juelich Research Center
IEK-3: Electrochemical Process Engineering
52428 Juelich/Germany
(2) RWTH Aachen University
Lehrstuhl für Brennstoffzellen, Fakultät für Maschinenwesen
52072 Aachen/Germany
Tel.: +49-2461-614394
Fax: +49-2461-616695
ma.frank@fz-juelich.de

Abstract

Since 2015, a reversible solid oxide cells plant (rSOC) in the kW-class has been developed at Forschungszentrum Jülich. Based on steam, hydrogen and air; the rSOC plant is environmentally friendly. One of the major benefits of an rSOC plant is that it can be operated in either electrolysis (SOEC) or fuel cell mode (SOFC). This is ideal system to deal with the time discrepancy occurring between energy demand and supply in most renewable energy resources (wind, solar…). At times of high energy surplus, the plant can run in SOEC mode, thereby electrolyzing water into a storable gaseous fuel, H_2. At a later time of energy demand, the rSOC plant can be run in fuel cell (SOFC) mode, producing electricity from the hydrogen. The plant requires a single stack which can be used for both modes.
Based on data of previous solid oxide cells stacks carried out at Jülich, a model of an rSOC plant was developed. A balance of plant able to supply the stack with gas compositions required for the two modes was established. Importantly the saturated steam needed for SOEC mode is generated inside the rSOC plant. Different plant concepts were examined and compared, especially in order to increase the overall efficiency of the plant. Concerning heat management, in-depth analysis and optimization of waste heat recovery was carried out. Off-gas recycling was also implemented both in SOFC and SOEC modes. In SOFC mode, anode off-gas recirculation enables the system to reach higher fuel utilizations than of the fuel cell stack alone. In SOEC mode, hydrogen recirculation makes it possible to limit the use of the gas tank to the start-up phase only.
The final concept will be discussed. Benchmark data of the developed rSOC plant, as well as the process flow sheet, will be presented. Additionally, simulation results of the rSOC plant will be shown.

The Authors did not wish to publish their full contribution in this proceeding. Full contribution most probably published in the International Journal of Hydrogen and Energy. Please Contact the Authors directly for further Information.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1313

Investigation of a novel catalytic partial oxidation and pre-reforming radial reactor of a micro-CHP SOFC-system with anode off-gas recycle

Timo Bosch (1), Maxime Carré (1), Angelika Heinzel (2), Michael Steffen (2), François Lapicque (3)
(1) Robert Bosch GmbH
Robert-Bosch-Campus 1, DE-71272 Renningen
(2) Zentrum für BrennstoffzellenTechnik GmbH
Carl-Benz-Strasse 201, DE-47057 Duisburg
(3) Laboratoire Réactions et Génie des Procédés, CNRS-Univ. Lorraine
1 rue Grandville, FR-54000 Nancy
Tel.: +49-711-811-27652
Fax: +49-711-811-5193290
timo.bosch@de.bosch.com

Abstract

A new radial reactor design using a precious metal catalyst coated wire mesh has been developed. This reactor has been tested standalone by emulating the total micro-combined heat and power (micro-CHP) solid oxide fuel cell (SOFC) system ($P_{el,AC}$= 1000 W) interfaces by an inlet gas conditioning system and external reactor heating representing the thermal boundary conditions. During startup the total system runs on catalytic partial oxidation (CPOX) mode with internal electric heating at an oxygen to carbon ratio (O/C) of 1.2 and on pre-reforming during SOFC nominal operation (O/C= 2.2) overlaid by anode off-gas recycle in both cases. This reactor is investigated for several operation points by means of nondispersive infrared (NDIR) for CO, CO_2 and CH_4, a thermal conductivity detector (TCD) for H_2, a paramagnetic sensor for O_2 and a dew point mirror for H_2O, radial and axial temperature distributions and pressure losses.

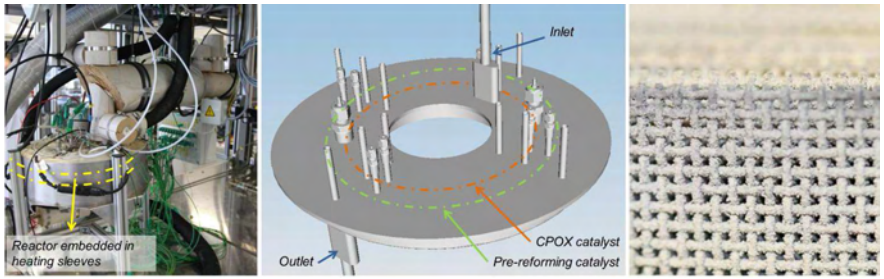


Fig. 1: Reactor test rig (left); radial reactor 3D CAD image (middle) [1]; installed wire-mesh catalyst (right)

A1315 (Abstract only)

Performance evaluation of solid oxide carbon fuel cells operating on steam gasified carbon fuels

Tak-Hyoung Lim(*), Jong-Won Lee, Seung-Bok Lee, Seok-Joo Park, Rak-Hyun Song
Fuel Cell Research Laboratory, Korea Institute of Energy Research (KIER)
152 Gajeong-ro, Yuseong-gu, Daejeon 34129, Korea
Tel.: +82-42-860-3608
Fax: +82-42-860-3297
ddak@kier.re.kr

Abstract

We investigated the operating characteristics of solid oxide carbon fuel cells (SO-CFCs) integrated with a steam gasifier that used carbonaceous fuels, including activated carbon and biomass driven charcoal. Steam gasification was carried out in a specially designed gasifier, which was directly integrated with a solid-oxide based carbon fuel cell. We studied the effect of gasification temperature, steam flow rate and catalyst addition on the electrochemical performance of SO-CFC, and the results showed that among the three tested fuels, activated carbon with a K_2CO_3 catalyst performed the best. At 850°C, the maximum power density 108mW/cm^2, 161mW/cm^2 and 181mW/cm^2 was achieved when the SO-CFC operated on activated carbon, biomass driven charcoal and activated carbon with a K_2CO_3 catalyst, respectively. The SO-CFC operated continuously for 100h and it showed relatively stable performance. This study suggests that by using a catalytic steam gasifier integrated with the SO-CFC, the solid carbon fuel resources can be used for power generation with higher efficiency and minimal carbon footprint.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1316 (Abstract only, published elsewhere)

Methane Steam Reforming Reaction over Ni/CeO_2-ZrO_2 Catalysts Loaded on Metallic Monolith

Jong Dae Lee (1)
(1) Department of Chemical Engineering, Chungbuk National University.
1 Chungdea-ro, Seowon-gu Cheong-ju, Chungbuk 28644, Korea
Tel.: +82-43-261-2375
Fax: +82-43-269-2370
jdlee@chungbuk.ac.kr

Abstract

In recent years, the over consumption of fossil fuels leads to critical environmental problems and arises a great concern on energy security. Great research effort has been focused on the production of hydrogen and the fuel cell systems. Hydrogen has been proposed as a clean and renewable energy. Among the hydrocarbon fuels, methane is a commercial gas that is easily transported and stored. Some typical fuel reforming technologies are steam reforming, partial oxidation, autothermal reforming and CO_2 reforming etc. In general, steam reforming has the advantage of producing a higher H_2 concentration than catalytic partial oxidation.

Currently, steam reforming process by precious metal catalysts (e.g., Ru, Pd, and Pt) has generally been used to convert CH_4 to H_2. In this study, the catalytic behaviors of Ni $Ni/Ce_xZr_{1-x}O_2$ loaded on the metallic monolith were investigated for the steam reforming reaction of CH_4. Ni, Pd and Ru were loaded on the Al_2O_3-MgO supports by the impregnation method after dissolving in 5M-HNO_3 and then these catalysts were thermally treated at 800 ℃ for 2h. Metallic monolith with diameter of 2.5 cm and height 2 cm was prepared by winding a combination of flat plate and flexural plate of 50 μm thickness. Before loading the catalyst to metallic monolith, alumina sol was coated on the surface of metallic monolith for improvement of catalyst adhesion, and pre-heated at 900 ℃. The catalyst slurrys were washcoated on the metallic monolith of honeycomb structure that has excellent heat conductivity. Prepared supports and catalysts were analyzed by XRD, SEM and BET.

The effect of Ni content on the $Ni/Ce_{0.80}Zr_{0.20}O_2$ catalysts was also investigated and the catalyst loaded with 15wt% Ni had the highest activity for the steam reforming reaction. Also, the effect of temperature, GHSV and H_2O/CH_4 ratio, was investigated to find optimum operating conditions for each processes. As GHSV decreased and H_2O/CH_4 ratio increased, CH_4 conversion and H_2 yield were increased. Among the catalysts, the Ni(15wt%)/$Ce_{0.80}Zr_{0.20}O_2$ and Ni(15wt%)-Ru(0.5wt%)/$Ce_{0.80}Zr_{0.20}O_2$ catalysts showed high CH_4 conversion at 800℃ for the steam reforming reaction. The optimum operating conditions of both catalysts were GHSV under 10,000h^{-1} and H_2O/CH_4 ratio over 3 at 800℃. Catalytic activity of Ni(15wt%)-Ru(0.5wt%)/$Ce_{0.80}Zr_{0.20}O_2$ loaded on the metal monolith was tested at 800℃ for 10 h and the activity of the catalyst remained stable in steam reforming reaction for mono and double layer metallic monolith catalysts.

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1317 (Will be published elsewhere)

System validation tests for a SOFC power system at INER

Shih-Kun Lo*, Wen-Tang Hong, Hsueh-I Tan, Huan-Chan Ting, Ting-Wei Liu and Ruey-Yi Lee
Institute of Nuclear Energy Research
No. 1000 Wenhua Road, Longtan District
Taoyuan City / Taiwan (R.O.C.)
*Tel.: +886-3-471-1400 Ext. 6787
Fax: +886-3-471-3980
jackon@iner.gov.tw

Abstract

This research presents the results of system validation tests for a SOFC power system. In the study, the system was heated up without electric device, i.e., the fuel providing the required thermal energy through an integrated balance of plant (BOP). The ex-situ experiments, without a SOFC stack installed in the system, were first conducted to investigate the operability of a BOP apparatus. It was found that the BOP possessed high conversion efficiencies for both steam reforming and water gas shift reactions. The total fuel concentration of hydrogen and carbon monoxide from the reformer was 91.2 %.
The system validation tests showed that, with the natural gas as fuel, the output power from the stack reached to 1060 W, while the fuel utilization efficiency and electrical efficiency were 67.16 % and 45.0 %, respectively. A steady 600-hour system operation test was carried out at an average system temperature of 694 °C. Of which, a 36-cell stack was employed for the test. Meanwhile, the current, voltage and output power were 26 A, 32.3 V and 840 W, respectively, and its electrical efficiency was 33.4 %.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1319 (Will be published elsewhere)

A Global Reaction Model of Carbon Gasification with K_2CO_3 in the External Anode Media of a DCFC

Shinae Song, Jun Ho Yu, Kyungtae Kang, Jun Young Hwang
Korea Institute of Industrial Technology
Ansan, 426-173, South Korea
Tel.: +82-31-8040-6434
Fax: +82-31-8040-6430
jyhwang@kitech.re.kr

Abstract

The present study was conducted to develop a practical reaction model for high temperature gasification based on the mechanism of the key elementary reactions, considering its applications to the external anode media of a direct carbon fuel cell (DCFC). The characteristics of gasification reactions were experimentally investigated for carbon black-K_2CO_3 mixtures in carbon dioxide ambient atmosphere at high temperatures up to 900 °C. Changes in the exit gas composition were monitored during the heating process (Fig. 1). Based on the experimental observations, a simplified reaction model for a global gasification reaction was suggested in the form of a linear combination of the Boudouard reaction, carbonate-catalysed reactions, and metal-catalysed reactions. The correlation between the equilibrium concentrations of carbonates and oxides in the mixture media was also given, where the ratio of the carbonate concentration to the oxide concentration was proportional to the CO_2 concentration.

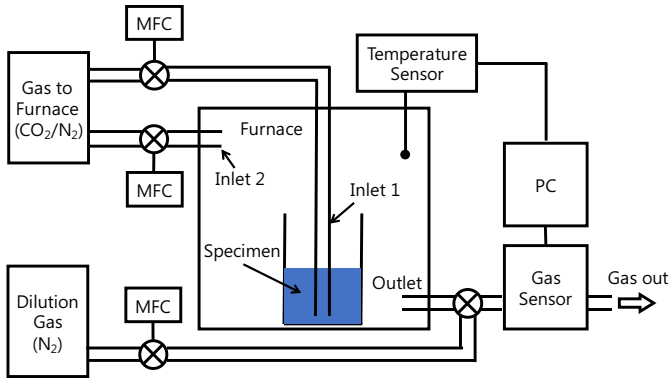


Fig. 1 Schematic drawing of exit-gas measurement system.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A1320 (Will be published elsewhere)

Experimental study on the fuel ejector for solid oxide fuel cell system

Kanghun Lee (1), Sanggyu Kang (1, 2), Youngduk Lee (1), Kook-Young Ahn (1,2)
(1) Korea Institute of Machinery and Materials (KIMM); Gajeongbukro 156; Daejeon/Republic of Korea
(2) University of Science and Technology (UST), Gajeongro 217; Daejeon/Republic of Korea
Tel.: +82-42-868-7267
Fax: +82-42-868-7284
kyu2613@kimm.re.kr

Abstract

The anode-off gas from the solid oxide fuel cell (SOFC) stack can be reutilized to improve the system efficiency. That is, because the anode-tail gas from the SOFC is including the unreacted fuel as well as high amount of steam, which can be reused as a fuel for SOFC stack and steam for methane steam reforming reaction (MSR), respectively. Recirculation of the SOFC anode-off gas can obtain the benefit from its high operating temperature. Ejector is one promising way for the recirculation of the SOFC anode-off gas due to robustness at high temperature and low cost. However, the amount of suction flow is not controlled easily compared to the regenerative blower.

In this study, one SOFC system using the fuel ejector has been developed. And the fuel ejector has been designed, manufactured, and evaluated its performance. The effects of the operating pressure and temperature on the ejector performance are identified. Furthermore, the effect of geometric parameter of nozzle exit position on the ejector characteristics has been investigated. This study is useful to optimize the design of the ejector and establish the optimal operating scheme of ejector.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

Next EFCF Events

6th European
PEFC & ELECTROLYSER
Forum 4 - 7 July 2017

13th European
SOFC & SOE
Forum 3 - 6 July 2018

Lucerne Switzerland

Show **your advertisement** or **project** and **product** info on such pages - forum@efcf.com.

Chapter 05 - Session B03

State of the art & novel processing routes

Content **Page B03 - ..**

B0301 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....3
Development of tubular proton conducting electrolysers **3**
M.-L. Fontaine (1), C. Denonville, R. Strandbakke (2), E. Vøllestad (2), J.M. Serra (3), D.R. Beeaff (4), C. Vigen (4), T. Norby (2) 3
B0302 (Will be published elsewhere).....4
Silicon-supported Nano Thin Film Solid Oxide Fuel Cell Array with Superior Mechanical Stability **4**
Jong Dae Baek, Yong-Jin Yoon, Pei-Chen Su* 4
B0303 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....5
Anode with Ni-YSZ Nanostructures Infiltrated into YSZ Pillars **5**
Keisuke Nagato (1,2), Lei Wang (1), Takaaki Shimura (3), Masayuki Nakao (1), Naoki Shikazono (3,4) 5
B0304 (Will be published elsewhere).....6
Influence of Process Parameters on Microstructure and Permeability of Axial Suspension Plasma Sprayed Electrolytes in SOFCs **6**
Mohit Gupta (1), Joel Kuhn (2), Olivera Kesler (2), Nicolaie Markocsan (1) 6
B0305 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....7
Multilayer and Co-sintering Ni/8YSZ for SOFC by Aqueous Tape Casting **7**
Nor Arifin (1), Robert Steinberger-Wilckens (1), Tim Button (2) 7
B0306 (Will be published elsewhere).....8
On the optimization of $(Mn,Co)_3O_4$ suspensions for electrophoretic deposition **8**
Sophie Labonnote-Weber (1), Hilde Lein (2), Guttorm Syvertsen-Wiig (1), Andreas Richter (1) 8
B0310 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....9
Development and characterization of electroless- electrodeposited SOFC anodes with engineered microstructures **9**
Zadariana Jamil (1,2), Enrique Ruiz-Trejo (1), Nigel P Brandon (1) 9
B0314 10
Development of Solid Oxide Fuel Cell Electrolyte Coating Process using YSZ solution **10**
Kunho Lee(1), Juhyun Kang(1), Sanghun Lee(1), and Joongmyeon Bae(1) 10
B0315 11
Tape Casting of Lanthanum Chromite **11**
Diego Rubio (1,2), Crina Suciu (1), Ivar Waernhus (1), Arild Vik (1), Alex C. Hoffmann (2) 11
B0316 12
Characterization and testing of the SOECs prepared from water based slurries by the tape casting method **12**
Filip Karas, Martin Paidar, Karel Bouzek 12
B0317 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....13
Cellulose as a Pore Former in Electroless Co-Deposited Anodes for Solid Oxide Fuel Cells **13**
Rob Turnbull, Alan Davidson, Neil Shearer, Callum Wilson 13
B0318 (Will be published elsewhere).....14
Optimization of ultrasonic-assisted electroless plating process for Ni-YSZ anode fabrication for SOFCs **14**
Juhyun Kang (1), Hoyong Shin (1), Kunho Lee (1), Joongmyeon Bae (1) 14
B0319 (Will be published elsewhere).....15
Micro-structured, Multi-channel Hollow Fibers for Micro-tubular Solid Oxide Fuel Cells (MT-SOFCs) **15**
Tao Li (1), Xuekun Lu (2), Paul Shearing (2), Kang Li* (1) 15
B0320 (Will be published elsewhere).....16
Prospect of Electrochemical Deposition Technique for Fuel Cell and Electrolysis Cell Applications **16**
Mark K. King Jr.(1), Nik S. Jindal (1), Prabhakar Singh (2), Manoj K. Mahapatra, (1)* 16
B0321 17
Scalable synthetic method for IT-SOFCs compounds **17**
A. Wain, A. Morán-Ruiz, K. Vidal, A. Larrañaga, M. I. Arriortua 17

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0301 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Development of tubular proton conducting electrolysers

M.-L. Fontaine (1), C. Denonville, R. Strandbakke (2), E. Vøllestad (2), J.M. Serra (3), D.R. Beeaff (4), C. Vigen (4), T. Norby (2)
(1) SINTEF Materials and Chemistry, Forskningsveien 1, NO-3014 Oslo, Norway
(2) University of Oslo, SMN, FERMiO, Gaustadalleen 21, NO-0349 Oslo, Norway
(3) ITQ UPV-CSIC, Av. Naranjos s/n, E-46022 Valencia, Spain
(4) CoorsTek Membrane Sciences AS, Gaustadalleen 21, NO-0349 Oslo, Norway
Tel.: +47-93-479-555
Fax: +47-22-067-350
marie-laure.fontaine@sintef.no

Abstract

The project "ELECTRA FCH-JTI 621244" (2014-2017) addresses the development of tubular proton ceramic electrolyser cells (PCECs) to be assembled in a 1 kW multi-tube module to produce pure dry pressurised H_2 at temperatures up to 600 °C. To date, we have developed innovative tubular segmented-in-series cells along two main lines of production integrating a porous Ni Y-doped $Ba(Zr,Ce)O_3$ (BZCY) cermet cathode and a thin dense BZCY-based electrolyte of 15 to 40 microns thickness. The 1st generation technology is based on solid state reactive co-sintering of BZCY based electrolyte film spray-coated or dip-coated on a slip-cast or extruded tube of NiO based composite. The anode is then dip-coated and fired. The manufacturing protocols were successfully applied to the production of 25 cm length half-cells with various Ce dopants (fig. 1). In the 2nd generation technology, the BZCY tubes are cut and stacked in series with Pt interconnect wire to build voltage and reduce overall current to improve the current collection along the tube. Example of two-segment-in-series half-cells is shown in fig. 1. A number of anode materials were screened for their compatibility with BCZY based electrolyte and stability as PCEC anode. These include $La_2NiO_{4+\delta}$, LSM, BSCF, $Ba_{1-x}Gd_{0.8}La_{0.2+x}Co_2O_{6-\delta}$ (x = 0-0.5) (BGLC) and LSCF. The screening indicated that LSM is potential candidate electrode material with respect to its stability in reducing conditions and BGLC (x ≥ 0.3) as a candidate material stable under oxidizing conditions and high steam pressures. BGLC (x = 0.5) tested as oxygen / steam electrode has a total area specific polarization resistance of 1 Ωcm^2 over both electrodes at 600 °C in 5 % H_2 in Ar / 2.5 % H_2O in 1 atm O_2.

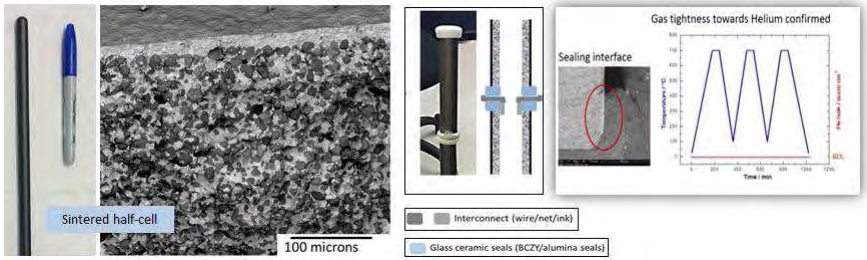


Figure 1: Pictures of sintered half-cells in 1st and 2nd gen. with temperature cycling test.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0302 (Will be published elsewhere)

Silicon-supported Nano Thin Film Solid Oxide Fuel Cell Array with Superior Mechanical Stability

Jong Dae Baek, Yong-Jin Yoon, Pei-Chen Su*
School of Mechanical and Aerospace Engineering
Nanyang Technological University
50 Nanyang Avenue, Singapore, 639798
Tel.: +65-6790-5586
Fax: +65-6792-4062
peichensu@ntu.edu.sg

Abstract

A micro-solid oxide fuel cell (μ-SOFC) array with nanoscale-thick electrolyte membranes embedded in a thin silicon supporting membrane was fabricated using simple silicon micromachining processes. The fuel cell array has a large number of yttria-stabilized zirconia (YSZ) electrolyte membranes with thicknesses of only 80 nm, all supported by the 20 μm-thick single crystalline silicon supporting layer. The silicon supporting membrane was reinforced by leaving the silicon thicker at the edges after the through-wafer etching, which effectively improved mechanical stability of the entire fuel cell array. From a 1.6 mm diametral μ-SOFC array having a total number of 413 single fuel cells, a peak power density of 134 mW/cm^2 was obtained at low temperature of 400 °C using pure H_2 as fuel and air as the oxidant. The corresponding total power output was in the microwatt range of 1.08 mW, which is higher than most of the reported nano thin film μ-SOFCs operating at temperatures below 400 °C.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0303 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Anode with Ni-YSZ Nanostructures Infiltrated into YSZ Pillars

Keisuke Nagato (1,2), Lei Wang (1), Takaaki Shimura (3), Masayuki Nakao (1), Naoki Shikazono (3,4)
(1) Graduate School of Engineering, The University of Tokyo;
7-3-1 Hongo, Bunkyo-ku, 113-8656 Tokyo / Japan
(2) JST PRESTO; 4-1-6 Honcho, Kawaguchi-shi, 332-0012 Saitama / Japan
(3) Institute of Industrial Science, The University of Tokyo;
4-6-1 Komaba, Meguro-ku, 153-8505 Tokyo / Japan
(4) JST CREST; 4-1-6 Honcho, Kawaguchi-shi, 332-0012 Saitama / Japan
Tel.: +81-3-5841-6361
Fax: +81-3-5800-6997
nagato@hnl.t.u-tokyo.ac.jp

Abstract

In order to decrease polarization resistance in anode of solid oxide fuel cells (SOFCs), a yttria stabilized zirconia (YSZ) pillar based electrode is proposed. With YSZ pillars, the resistance of oxide ion transport and the activation overpotential can be reduced. In our previous report, it was demonstrated that YSZ pillars were fabricated by a laser-ablation technique and nickel (Ni) particles were infiltrated by screen printing in a vacuum (K. Nagato, et al., *ECS Trans.*, **68**, 1309-1314, 2015). However, the Ni particles were agglomerated during the operation. In this study, we infiltrated Ni-YSZ composite in the trenches among the YSZ pillars so that the agglomeration of Ni is avoided by the YSZ nanostructure. The 7.5-μm-pitch and 5-μm-depth YSZ pillars were fabricated by an excimer laser. The infiltration was carried out by screen printing and sputtering technologies. After the infiltration of Ni or Ni-YSZ, the anodes were annealed at 800°C in a reduced condition. It was preliminarily found that replacement by 25 vol.%-YSZ formed the finest triple phase boundary (TPB) structure using flat YSZ substrates. The YSZ pillars infiltrated by YSZ:Ni = 25:75 vol.% resulted in lower resistance than that infiltrated by only Ni. Furthermore, the resistance of anode with Ni-YSZ infiltrated by sputtering was lower than that infiltrated by screen printing.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0304 (Will be published elsewhere)

Influence of Process Parameters on Microstructure and Permeability of Axial Suspension Plasma Sprayed Electrolytes in SOFCs

Mohit Gupta (1), Joel Kuhn (2), Olivera Kesler (2), Nicolaie Markocsan (1)
(1) University West
461 86 Trollhättan/Sweden
(2) University of Toronto
27 King's College Circle, Toronto, Ontario M5S 1A1/Canada
Tel.: +46-520-223282
mohit-kumar.gupta@hv.se

Abstract

Solid oxide fuel cells (SOFC) are a promising technology for producing electricity by clean energy conversion through an electrochemical reaction of fuel and air. High production costs of the cells are still a major obstacle in the widespread commercialization of SOFCs. Plasma spraying has been investigated extensively during past fifteen years by several research groups as an alternative to conventional manufacturing of single cells as well as stacks. It is a rapid and cost-effective technology for deposition of ceramic layers for both low and high production volumes. Recent developments in plasma spraying techniques, particularly for atmospheric plasma spraying (APS) of suspension feedstocks, suspension plasma spraying (SPS), have brought improvements in the ability to produce coatings with low thickness (from a few microns to tenths of microns) and/or coatings with a high degree of gas tightness. These characteristics which were not achievable several years ago, and they are of key importance in producing high performance SOFCs. The axial injection of feedstock during SPS compared to radial injection in conventional systems ensures better control of coating microstructure and quality as well as process repeatability.

The objective of this work was to evaluate the effect of process parameters on microstructure and gas tightness of axial SPS electrolytes in metal-supported SOFCs in order to achieve high-performing electrolytes. The porous metal supports used in this study were made of ferritic stainless steel. The anode layer material used in this study was nickel/yttria partially stabilized zirconia, which was deposited by APS using dry powder feedstock. The electrolyte material was yttria stabilized zirconia. Deformation of metal substrate occurs during the spraying process due to high temperature gradients, especially when using thin substrates, which are desirable for high performance SOFCs. Therefore, the effect of substrate-torch relative velocity and substrate temperature during the deposition process on deformation of substrates as well as coating microstructure was studied in this work. Other plasma spray parameters varied during this study were, for example, plasma current and gas composition and flow rate. The effect of varying these parameters on electrolyte properties will be discussed in this work. The results show that axial SPS with relative substrate-torch velocities > 3.8 m s^{-1} can be used to fabricate dense SOFC electrolytes without introducing substrate deformation.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0305 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Multilayer and Co-sintering Ni/8YSZ for SOFC by Aqueous Tape Casting

Nor Arifin (1), Robert Steinberger-Wilckens (1), Tim Button (2)
(1) Centre of Fuel Cell and Hydrogen Research,
Chemical Engineering Department,University of Birmingham.
Edgbaston, Birmingham B15 2TT United Kingdom
(2) School of Metallurgy and Material,
University of Birmingham.
Edgbaston, Birmingham B15 2TT United Kingdom
Tel.: +44(0)1214145283
Fax: +44 (0)121 414 5324
NAA335@student.bham.ac.uk

Abstract

Ni/8YSZ SOFC half-cell consisting of electrolyte, anode functional layer and anode substrate were successfully fabricated using a multilayer aqueous tape casting route and co-sintering between the layer application. Zeta potential and sedimentation tests were carried out prior to the slurry optimisation. The optimisation and conditioning focused on the anode substrate since the thick cast substrates show more problems with cracking and pinholes. For the substrate, the cermet powders were mixed with distilled water, PAA, PVA, PEG, glycerol, antifoam 204 and tapioca starch in the roles of solvent, dispersant, binder, plasticisers, antifoam agent, and pore former, respectively. For thick slurries, de-gassing followed by slow rolling was essential to avoid pin-holes and keep the slurry homogenous during storage. Drying at constant humidity as well as the amount of organics used was found to be very critical to avoid cracking. The smooth multi-layered green tapes produced were cut into button cell size and co-sintered at 1350°C without pre-sintering during intermediate steps and the half-cell then characterised by Scanning Electron Microscopy (SEM).

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0306 (Will be published elsewhere)

On the optimization of $(Mn,Co)_3O_4$ suspensions for electrophoretic deposition

Sophie Labonnote-Weber (1), Hilde Lein (2), Guttorm Syvertsen-Wiig (1), Andreas Richter (1)
(1) Ceramic Powder Technology AS
Kvenildmyra 6, N-7093 Tiller, Norway
(2) Department of Materials Science and Engineering,
Norwegian University of Science and Technology, N-7491 Trondheim, Norway
Tel.: +47 941 58 842
sophie.weber@cerpotech.com

Abstract

In order to achieve sufficient power levels, solid oxide fuel cells (SOFCs) are stacked up, separated by interconnects. Recent development within fuel cell technology resulted in a decrease of SOFC operating temperatures, allowing the use of cheap and easy to manufacture high-Cr ferritic steel interconnects [1]. However, the lifetime and performance of SOFC stacks is today greatly limited by oxidation of the steel interconnects. To hinder chromia formation and to prevent chromium evaporation, $(Mn,Co)_3O_4$ spinel has been identified as a promising coating material [2].

Synthesis and dispersion of $(Mn,Co)_3O_4$ powders are addressed in this study for further deposition by electrophoretic deposition (EPD). The powders synthesized by spray pyrolysis with particles in the submicron range exhibit suitable microstructural, chemical, thermal and electrical properties. Two types of colloidal suspensions are prepared for so-called anodic and cathodic EPD, and optimized via design of experiment in terms of solvent, solid loading and type and quantity of surfactant by evaluating particle surface charge, size evolution, and colloidal system rheological response.

Butanol and triethanolamine is a successful solvent-surfactant system for positively charging the manganese cobaltite particles, and the stability of the cathodic suspensions is confirmed by zeta potential measurements (Figure 1) for coating deposition. An ethanol and citric acid-triethylamine, solvent-surfactant system, is shown effective for negatively charging the $MnCo_2O_4$ particles. The anodic suspensions present better short-term stability than the cathodic suspensions, whereas the long-term stability is lower. The most stable suspensions are subsequently deposited on ferritic steel and both anodic and cathodic EPD types, with corresponding suspensions, produce coatings with the desired thickness and microstructure. However, the best deposition method seems to be the anodic type, in terms of processing and coating microstructure.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0310 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Development and characterization of electroless-electrodeposited SOFC anodes with engineered microstructures

Zadariana Jamil (1,2), Enrique Ruiz-Trejo (1), Nigel P Brandon (1)
(1) Department of Earth Science and Engineering
Imperial College London, SW7 2AZ, UK
(2) Faculty of Civil Engineering
Universiti Teknologi MARA Pahang
26400 Bandar Pusat Jengka, Pahang, Malaysia
Tel.: +44 (0) 7512202200
z.jamil13@imperial.ac.uk

Abstract

Decoupling scaffold fabrication and metal incorporation for SOFC electrode fabrication allows independent control of metal particle size, porosity and TPB density. In this study, a novel electroless and electrodeposition technique is employed to fabricate Ni/GDC scaffold anodes. The desired GDC scaffold microstructures were obtained by engineering GDC inks with pore formers, and screen printing onto 8YSZ electrolytes (290 μm). Ag was added electrolessly to provide an electronically conductive layer on the GDC scaffold prior to Ni electrodeposition. From the cyclic voltammetric study, a well-ordered and controlled amount of Ni can be deposited on the Ag/GDC scaffolds from a Watts bath under controlled conditions (T= 55°C, E= -0.75 to -1.0 V vs Ag/AgCl, pH 4 ± 0.2, agitation rate at 500rpm, SDS as the additive). The microstructure of Ni deposits and the porous scaffolds was examined using scanning electron microscopy and energy dispersive X-ray analysis.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0314

Development of Solid Oxide Fuel Cell Electrolyte Coating Process using YSZ solution

Kunho Lee(1), Juhyun Kang(1), Sanghun Lee(1), and Joongmyeon Bae(1)
(1) Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, Yuseong-Gu, Daejeon 305-701, Republic of Korea
Tel.: +82-42-350-3085
Fax: +82-42-350-8207
kunpu@kaist.ac.kr

Abstract

Solid Oxide Fuel Cells (SOFCs) have been focused on as an eco-friendly energy conversion device that can directly convert chemical energy into electricity. SOFCs are composed of different layers of porous electrodes and a dense electrolyte layer. Typically, in order to deposit the dense electrolyte on a porous substrate, the electrolyte coated substrate has been fabricated by co-sintering process. However, during this co-sintering process, some critical defects such as warpage and fractures may form in the SOFC single cell due to different shrinkage rates of the two different layers. Furthermore, high viscosity slurry or paste has to be used for the coating electrolyte, and this can result in a thick electrolyte thickness. Therefore, in this study, in order to suppress defects that can form during sintering of two different layers, the electrolyte layer was coated via solution coating process on a porous anode substrate that was completely sintered at 1350 °C. Then, the surface of the electrolyte was observed using SEM to determine whether the electrolyte layer was sufficiently dense. After this observation, IVP and EIS of single cell tests were conducted. The electrolyte surface was found to be dense; the OCV result was 1.09 V at 750 °C. This implies that the electrolyte layer was definitely dense and defect free.

B0315

Tape Casting of Lanthanum Chromite

Diego Rubio (1,2), Crina Suciu (1), Ivar Waernhus (1), Arild Vik (1), Alex C. Hoffmann (2)
(1) Prototech AS
Fantoftvegen 38, 5072 Bergen/Norway
(2) Faculty of Physics and Technology, University of Bergen
Allegaten 55, 5007 Bergen/Norway
Tel.: +4755582876
Fax: +4755589440
nfyah@uib.no

Abstract

The experimental study presented in this paper is aimed at achieving and optimizing laminated tape casting of lanthanum chromite. The main aim of the experiments was to produce dense, ceramic interconnects for SOFCs, the densification involving all steps in the production process. The starting material is a powder with the composition $La_{0.8}Ca_{0.2}CrO_3$. This powder was characterized and used to prepare an aqueous suspension, which was optimized by studying its rheological behavior and the effects of process additives. The optimized formulation of the suspension for tape casting was found to be: 50 wt.% of solids loading, 22 wt.% of WB4101 (binder, dispersant and plasticizer), 25 wt.% of DI water, 0.45 wt.% of Ammonium Hydroxide and 2.5 wt.% of DF002 (defoamer). This solution was ball-milled in two stages for 24 h and 1 h respectively, these times were also optimized to mitigate excessive effects of thixotropy during the tape casting. The influence of the tape casting parameters was studied to obtain uniform, thick (>700 μm) and dense green tapes. A number of lamination techniques were used on the green tapes. Several sintering conditions were studied and, in the end, high relative densities were achieved (92%). The obtained results demonstrate that the tape casting process is feasible for the production of lanthanum chromite interconnects. Furthermore, they prove that tape casting is capable of producing sintered samples with higher densities than many processes currently used. Detailed procedures and data for achieving optimal results are given in the paper.

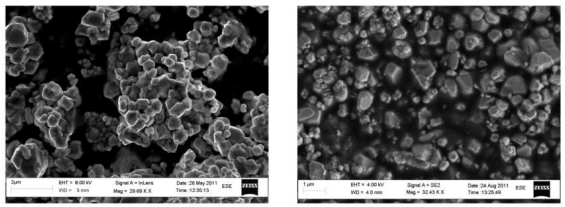


Illustration of how high density is achieved by dispersion. Left: agglomerated state of the suspension before tape casting. Right: after dispersion of the particles in the suspension before tape casting.

B0316

Characterization and testing of the SOECs prepared from water based slurries by the tape casting method

Filip Karas, Martin Paidar, Karel Bouzek
University of Chemistry and Technology Prague
Department of Inorganic Technology
Technická 5, Praha 6 - Dejvice
166 28, Czech Republic
Tel.: +420-22-044-4009
Fax: +420-22-044-4410
karasf@vscht.cz

Abstract

High temperature steam electrolysis is considered as a prospective technology for industrial scale hydrogen production as a valuable chemical for utilization e.g. in energetics, transportation or chemical industry. Through the intensive research in the past decade, significant progress has been achieved in matureness of this technology. However, there are still important obstacles to be overcome before reaching its large scale industrialization. Utilization of huge amounts of organic solvents during series solid oxide cells (SOCs) production can be given as a typical example. This problem becomes recently increasingly important due to the strong emphasis on the environmental issues.
Due to the above mentioned reason, this study has focused on development of SOCs by tape casting method from water based slurries. In these slurries beside demineralized water used as solvent, gelatin was used as a natural water soluble binder. The hydrogen electrode supported planar “button” cells were successfully prepared in this way. The commonly accepted NiO/YSZ – YSZ – LSM/YSZ – LSM system was used. The electrochemical characteristics of SOCs prepared were determined by means of voltammetry and impedance spectroscopy under steam electrolysis conditions. Durability tests were accomplished as well. Beside electrochemical characteristics, morphology of the SOCs was analyzed by means of scanning electron microscopy. The main problem represented inhomogeneity of electrolyte layer thickness which, in turn, can lead to the problems with homogeneity of distribution of local current density across the active cell area. The solution of this problem consisting in modification of YSZ slurry preparation procedure was proposed. It was proved that well performing cells can be prepared by tape casting method using slurries prepared. Current densities up to 250 mA cm^{-2} were reached at a cell voltage of 1.2 V and temperature of 800 °C. These values are fully comparable to the SOCs prepared by means of traditional solvents.

Acknowledgement: Financial support of this research by FCH JU within framework of the project SElySOs, grant agreement No. 671481 is gratefully acknowledged.

B0317 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Cellulose as a Pore Former in Electroless Co-Deposited Anodes for Solid Oxide Fuel Cells

Rob Turnbull, Alan Davidson, Neil Shearer, Callum Wilson
Edinburgh Napier University Edinburgh EH10 5DT, Scotland, U.K.
R.Turnbull@napier.ac.uk

Abstract

A study was conducted to investigate the feasibility of cellulose as a pore former in the manufacture of Solid Oxide Fuel Cell (SOFC) anodes using Electroless Co-Deposition (ECD). Previous work into the use of ECD to produce SOFC anodes has found that the lack of porosity restricted the maximum power density of the cell. Studies have also shown that an anode produced by ECD using rice starch as a pore former has nearly doubled the power density of a cell. Therefore by increasing the anode porosity, the cell's power density should also increase and lead to greater performance of SOFCs for the power generation market.

As the choice of pore former is closely related to the size and shape of pores produced, a whisker pore former will produce a more cylindrical pore once removed. These cylindrical pores will increase the chances of producing an interconnected pore network compared with more spherical pores, and will improve the gas diffusion through the anode. Therefore cellulose whiskers were used to not only improve the porosity of the anode but improve the gas diffusion capabilities throughout the electrode.

Coatings were produced using ECD with different types of cellulose added to act as a pore former using a constant bath loading. A range of 4 cellulose pore formers were selected to reflect different morphologies and sizes available. A fifth coating was also produced using the same methods but, without pore formers, to act as a comparison and determine any improvement produced by the addition of cellulose as a pore former.

The coatings were characterized using and a Scanning Electron Microscope with Electron Dispersive Spectroscopy capabilities. This was used to determine the pore structure which had been produced via a cross sectional analysis. A mercury porosimeter was used to determine the pore content and size in the ECD coatings.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0318 (Will be published elsewhere)

Optimization of ultrasonic-assisted electroless plating process for Ni-YSZ anode fabrication for SOFCs

Juhyun Kang (1), Hoyong Shin (1), Kunho Lee (1), Joongmyeon Bae (1)
(1) Korea Advanced Institute of Science and Technology (KAIST)
KAIST 291, Daehak-ro, Yuseong-gu, Daejeon/Republic of Korea
Tel.: +82-42-350-3045
Fax: +82-42-350-8207
wneodfk@kaist.ac.kr

Abstract

A solid oxide fuel cell (SOFC) consists of a ceramic component, and it operates in a relatively high temperature region (above 500 ^{o}C) compared to other fuel cell types. Because SOFCs operate at high operating temperature, there afford several advantages. Above all, it is possible to use nickel (Ni) as an anode material in place of platinum, which is used as an electrode material for low temperature fuel cells. Nickel is used as a composite mixed with electrolyte materials, and Ni-YSZ (a composite of Ni metal and yttria-stabilized zirconia ceramic materials) is typically used as a SOFC anode.
Recently, there have been reports that nanoscale catalysts can improve the performance of anodes, and an impregnation process is widely used to fabricate nanoscale catalysts. However, when impregnating catalysts into the thick substrate, there are severe problems such as poor catalyst uniformity and the requirement of repetitive work.
In this study, a nickel electroless plating process is applied to replace the impregnation process. First, plating baths with various molarities of reducing agent are prepared to identify the effect of the reducing agent on the characteristics of nickel electroless plating. As a result, it is shown that the molarity of the reducing agent has a significant impact on the plating rate. Furthermore, suppression of cavitation behavior inside the porous substrate is important when plating nickel onto a thick and porous YSZ substrate. To suppress the cavitation behavior, an ultrasonicator is adopted throughout the electroless plating process. By adopting the ultrasonicator, Pd activation is carried out inside the thick substrate properly. As a result, ultrasonic-assisted nickel electroless plating is performed on the substrate after Pd activation, and nickel particles are plated inside the thick substrate.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0319 (Will be published elsewhere)

Micro-structured, Multi-channel Hollow Fibers for Micro-tubular Solid Oxide Fuel Cells (MT-SOFCs)

Tao Li (1), Xuekun Lu (2), Paul Shearing (2), Kang Li* (1)
(1) Department of Chemical Engineering, Imperial College London, London SW7 2AZ
(2) Electrochemical Innovation Lab, Department of Chemical Engineering, University College London, London, WC1E 7JE
Tel.: +44 2075945676
kang.li@imperial.ac.uk

Abstract

Micro-tubular SOFCs have been considered as a promising technology for sustainable energy generation. However, this technology is yet to be commercially applied due to some major bottlenecks, such as the lack of a cost-effective manufacturing route and problematic robustness.

The feasibility and benefits of fabricating micro-tubes via a phase inversion-assisted process have been well demonstrated in our previous work [1]. In this study, a new micro-structured, multi-channel design has been attempted (Fig.1), integrating advantages of micro-structure tailoring and enhanced mechanical property. An asymmetric structure has been obtained for the interior anode substrate, including micro-channels and a thin sponge-like region, which leads to more uniform distribution of fuel gases and reduced concentration polarization. The fracture load measured via 3-point bending illustrated that the resistance towards external impact of multi-channel design is several times better compared with single-channel counterpart, without compromising gas transport property. More systematic studies of electrochemical performances and multi-scale X-ray tomography will be conducted in the near future.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0320 (Will be published elsewhere)

Prospect of Electrochemical Deposition Technique for Fuel Cell and Electrolysis Cell Applications

Mark K. King Jr.(1), Nik S. Jindal (1), Prabhakar Singh (2), Manoj K. Mahapatra, (1)*
(1) Department of Materials Science and Engineering, University of Alabama at Birmingham, Birmingham, Alabama- 35294
(2) Center for Clean Energy Engineering, Materials Science and Engineering, University of Connecticut, Storrs, Connecticut - 06269
* Phone: 2059754666
mkmanoj@uab.edu

Abstract

Electrochemical deposition technique is being used for various commercial applications due to ease of processing, versatility, and low-cost. This technique, however, has not been well explored for fuel cells and electrolysis cells applications. The crucial processing parameters to obtain uniform functional coatings and subsequent implications on fuel cells and electrolysis cells will be identified. We will discuss the current state-of-the-art, prospects, and challenges of the electrochemical deposition technique using specific examples from existing literature.

Keywords: Electrochemical deposition, fuel cell, electrolysis cell

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0321

Scalable synthetic method for IT-SOFCs compounds

A. Wain, A. Morán-Ruiz, K. Vidal, A. Larrañaga, M. I. Arriortua
Universidad del País Vasco/ Euskal Herriko Unibertsitatea (UPV/EHU). Facultad de Ciencia y Tecnología. Sarriena s/n, E-48940 Leioa, Spain
Tel.: +34-94-601-5984
Fax: +34-94-601-3500
aritza.wain@ehu.es

Abstract

Economically competitive SOFC systems appear ready for commercialization, but widespread market penetration will require a broad inventory of key starting materials and fabrication processes to enhance systems and reduce costs. These requirements are originated from the demands for large scale SOFC industrial production. For these reason, we have synthesized different parts of a fuel cell, on a large scale, by the glycine-nitrate combustion method.

It have been synthesized interconnector protective coatings ($MnCo_{1.9}Fe_{0.1}O_4$), contact layers ($LaNi_{0.6}Fe_{0.4}O_3$), cathodes ($La_{0.6}Sr_{0.4}FeO_3$), interlayers ($Sm_{0.2}Ce_{0.8}O_{1.9}$), electrolytes $(ZrO_2)_{0.92}(Y_20_3)_{0.08}$ and anode $(Ni_{0.3}O\text{-}(ZrO_2)_{0.92}(Y_20_3)_{0.08})$ materials, obtaining reproducible pure samples and amounts up to 12 g for each batch, being able to increase easily this amount to lots of hundred of grams.

The obtained materials have been characterized compositionally by inductively coupled plasma atomic emission spectroscopy (ICP-AES) and X-ray fluorescence (XRF), structurally by X-ray diffraction (XRD) and microstructurally by scanning electron microscopy (SEM).

Next EFCF Events

6th European
PEFC & ELECTROLYSER
Forum 4 - 7 July 2017

13th European
SOFC & SOE
Forum 3 - 6 July 2018

Lucerne Switzerland

Chapter 06 - Sessions B05, A08, A11

B05: Lifetime: Materials and cells
A08: Lifetime: Cells and stacks
A11: Lifetime: Stacks and systems

Content **Page B05, A08, A11 - ..**

B0501 5
Quantitative review of degradation and lifetime of solid oxide cells and stacks **5**
Theis L. Skafte (1,2), Johan Hjelm (2), Peter Blennow (1), Christopher Graves (2) 5
B0502 (Will be published elsewhere) 6
Electrochemical Analysis of Sulfur Poisoning in Ni/8YSZ Cermet Anodes **6**
Sebastian Dierickx, André Weber and Ellen Ivers-Tiffée 6
B0503 (Will be published elsewhere) 7
Phase decomposition of $La_2NiO_{4+\delta}$ under Cr-and Si-poisoning conditions **7**
N. Schrödl (1), A. Egger (1), E. Bucher (1), C. Gspan (2), T. Höschen (3), F. Hofer (2) W. Sitte (1) 7
B0504 8
Evaluation of the effect of sulfur poisoning on the performance of Ni/CGO based SOFC anodes **8**
Matthias Riegraf (1), Vitaliy Yurkiv (1), Rémi Costa (1), Günter Schiller (1), Andreas Mai (2), K. Andreas Friedrich (1) 8
B0507 (Will be published elsewhere) 9
Sulfur-Tolerance of Ceria-based Anodes **9**
André Weber (1), Thorsten Dickel (1) and Ellen Ivers-Tiffée (1) 9
B0508 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 10
Carbon removal from the fuel electrode of ASC-SOFC and regeneration of the cell performance **10**
Vanja Subotić (1), Christoph Schluckner (1), Bernhard Stoeckl (1), Hartmuth Schroettner (2), Christoph Hochenauer (1) 10
B0509 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 11
Quantitative correlation of Cr-deposition from the gas phase with chemical origin of electrolytes in SOFCs **11**
Xiaomei Zhang, Yushan Hou, Elena Konysheva 11
B0510 (Will be published elsewhere) 12
New challenges for steel interconnects: lower temperature and dual atmosphere effect **12**
Patrik Alnegren, Mohammad Sattari, Jan-Erik Svensson, Jan Froitzheim 12
B0511 (Will be published elsewhere) 13
Assessment of limiting steps and degradation processes of an advanced metals supported cell with LST based anode **13**
Vitaliy Yurkiv (1), Laurent Dessemond (2,3), Feng Han (1), Patric Szabo (1), Robert Semerad (4), Rémi Costa (1) 13
B0512 14
The effect of polarization on SOFC seal ageing **14**
Stéphane Poitel (1,3), Yannik Antonnetti (2), Zacharie Wuillemin (2), Jan Van Herle (1), Cécile Hébert (3) 14
B0513 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 15
Evolution of oxidation of SOFC interconnect alloys in dry and wet air **15**
Manuel Bianco, Maxime Auchlin, Stefan Diethelm, Jan Van herle 15

B0514 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 16
Experiments on metal-Glass-metal samples simulating the fuel inlet/outlet manifolds in SOFC stacks **16**
Paolo Piccardo (1,2), Maria Paola Carpanese (3), Andrea Pecunia (1), Roberto Spotorno (1,2), Simone Anelli (1) 16
B0515 (Will be published elsewhere) 17
Silver as a current collector for SOFC **17**
Artur J. Majewski, Aman Dhir 17
B0516 (Will be published elsewhere) 18
Improvement of interface between electrolyte and electrodes in solid oxide electrolysis cell **18**
Nikolai Trofimenko, Mihails Kusnezoff, Alexander Michaelis 18
B0517 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 19
Local Evolution of Three-dimensional Microstructure of Ni-YSZ Anode in Solid Oxide Fuel Cell Stack after Long-term Operation **19**
Grzegorz Brus (1), Hiroshi Iwai (2), Yuki Otani (2) Motohiro Saito (2), Hideo Yoshida (2), Janusz S. Szmyd (1) 19
B0518 20
Fuel heterogeneity in solid oxide carbon fuel cells: according to the internal gasification of carbon **20**
Hansaem Jang (1), Youngeun Park (1), Jaeyoung Lee (1,2) 20
B0519 (Abstract only) 21
Anomalous Shrinkage of Ni-YSZ Cermet during Low Temperature Oxidation **21**
Keiji Yashiro, Fei Zhao, Shinichi Hashimoto and Tatsuya Kawada 21
B0520 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 22
Time-dependent Degradation of Nickel-infiltrated ScSZ Anodes **22**
Jingyi Chen (1), Xin Wang (1), Enrique Ruiz-Trejo (2), Alan Atkinson (1), Nigel P Brandon (2) 22
B0521 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 23
Impact of redox cycling on microstructure related properties of Ni-YSZ Solid Oxide Fuel Cell anodes **23**
Bowen Song, Enrique Ruiz-Trejo, Zhangwei Chen, Kristina Maria Kareh, Farid Tariq 23
and Nigel P Brandon 23
A0801 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 24
20 000 Hours Steam Electrolysis with Solid Oxide Cell Technology **24**
Annabelle Brisse, Josef Schefold, Julian Dailly 24
A0802 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 25
Post-test analysis on a Solid Oxide Cell stack operated for 10700 hours in steam electrolysis mode **25**
Giorgio Rinaldi (1), Stefan Diethelm (1), Pierre Burdet (1), Emad Oveisi (1), Jan Van herle (1), Dario Montinaro (2), Qingxi Fu (3), Annabelle Brisse (3) 25
A0803 (Will be published elsewhere) 26
Degradation analysis of an SOEC stack operated for more than 10,000 h **26**
Qingping Fang, Ludger Blum, Norbert H. Menzler 26
A0804 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 27
Long-term operation of a solid oxide cell stack for co-electrolysis of steam and CO_2 **27**
Karsten Agersted (1), Ming Chen (1), Peter Blennow (2), Rainer Küngas (2), Peter Vang Hendriksen (1) 27
A0807 (Abstract only, published elsewhere) 28

Cr Poisoning of (La,Sr)(Co,Fe)O3-δ SOFC Cathodes at the Micrometre to Nanometre Scale **28**
Na Ni (1), Samuel Cooper (1), Stephen Skinner (1), Robert Williams (2), David W. McComb (2) 28
A0808 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 29
SOFC Operation on Biogas: Impurity Threshold Levels **29**
Hossein Madi (1), Christian Ludwig (2) and Jan Van herle (1) 29
A0809 (Will be published elsewhere) 30
$La_2NiO_{4+\delta}$ as SOEC anode material **30**
Andreas Egger, Nina Schrödl and Werner Sitte 30
A0810 (Will be published elsewhere) 31
Chromium and silicon poisoning of $La_{0.6}Sr_{0.4}CoO_{3-\delta}$ IT-SOFC cathodes at 800°C **31**
E. Bucher (1), N. Schrödl (1), C. Gspan (2), T. Höschen (3), F. Hofer (2), W. Sitte (1) 31
A0812 32
Study of variables for accelerating lifetime testing of SOFCs **32**
Alexandra Ploner, Anke Hagen, Anne Hauch 32
A0813 (Will be published elsewhere) 33
SOFC Anode Protection Using Electrolysis Mode During Thermal Cycling **33**
Young Jin Kim, Seon Young Bae, Hyung-Tae Lim 33
A0814 34
Degradation analysis of SOFC performance **34**
Tohru Yamamoto, Kenji Yasumoto, Hiroshi Morita, Masahiro Yoshikawa, Yoshihiro Mugikura 34
A0815 35
Development of protective coatings on SOFC metallic interconnects fabricated by powder metallurgy **35**
V. Miguel-Pérez (1), M. Torrell (1)*, M. Morales (1), B. Colldeforns (1), A. Morata (1), M.C. Monterde (2), J.A. Calero (2), A. Tarancón (1) 35
A0816 (Will be published elsewhere) 36
Low carbon gases direct feeding to SOFC: operative strategies to reduce anode degradation **36**
Arianna Baldinelli (1), Linda Barelli (1), Gianni Bidini (1) 36
A0817 37
Degradation of the SOFC anode by contaminants in biogenic gaseous fuels **37**
Michael Geis (1), Stephan Herrmann (1), Sebastian Fendt (1), Hartmut Spliethoff (1) 37
A0818 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 38
Mechanical properties of $La_{0.6}Sr_{0.4}M_{0.1}Fe_{0.9}O_{3-\delta}$ (M: Co and Ni) perovskites as electrode material for SOFCs **38**
Ali Akbari-Fakhrabadi, Marcelo Orellana, Viviana Meruane 38
A1101 39
Post-Test Analysis of a Solid Oxide Fuel Cell Stack Operated for 35,000h **39**
Norbert H. Menzler (1), Peter Batfalsky (2), Alexander Beez (1), Ludger Blum (1), Sonja-Michaela Groß-Barsnick (2), Leszek Niewolak (1), Willem J. Quadakkers (1), Robert Vaßen (1) 39
A1102 40
Understanding lifetime limitations in the Topsoe Stack Platform using modeling and post mortem analysis **40**
Peter Blennow, Jeppe Rass-Hansen, Thomas Heiredal-Clausen, Rainer Küngas, Tobias Holt Nørby, Søren Primdahl 40
A1103 (Will be published elsewhere) 41

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

Understanding of SOEC Degradation Processes by means of a Systematic Parameter Study **41**
Michael P. Hoerlein, Vitaliy Yurkiv, Günter Schiller, K. Andreas Friedrich 41
A1104 42
Durability assessment of SOFC stacks with several types of structures for thermal cycles during their lifetimes on residential use **42**
Koki Sato (1), Takaaki Somekawa (1), Toru Hatae (1), Shinji Amaha (1), Yoshio Matsuzaki (1), Masahiro Yoshikawa (2), Yoshihiro Mugikura (2), Hiroshi Sumi (3), Makoto Ohmori (4), Harumi Yokokawa (5) 42
A1107 (Will be published elsewhere) 43
Performance Modelling of anode supported cells on a SOFC stack layer level **43**
Helge Geisler (1)*, Jochen Joos (1), André Weber (1) and Ellen Ivers-Tiffée (1) 43
A1108 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 44
An environmental and energetic performance assessment of an integrated power-to-gas concept system **44**
Dimitrios Giannopoulos* (1), Marianna Stamatiadou (1), Manuel Gruber (2), Maria Founti (1), Dimosthenis Trimis (2) 44

Lifetime: Materials and cells,
Lifetime: Cells and stacks,
Lifetime: Stacks and systems

B0501

Quantitative review of degradation and lifetime of solid oxide cells and stacks

Theis L. Skafte (1,2), Johan Hjelm (2), Peter Blennow (1), Christopher Graves (2)
(1) Haldor Topsoe A/S
Haldor Topsøes Allé 1, 2800 Kgs. Lyngby/Denmark
(2) Department of Energy Conversion and Storage, Technical University of Denmark
Risø campus, Frederiksborgvej 399, 4000 Roskilde/Denmark
Tel.: +45-2552-9534
Fax: NA
tlsk@dtu.dk

Abstract

A comprehensive review of degradation and lifetime for solid oxide cells and stacks has been conducted. Based on more than 50 parameters from 150 publications and 1 000 000 hours of accumulated testing, this paper presents a quantitative analysis of the current international status of degradation and lifetime in the field. The data is used to visualize specific trends regarding choice of materials, operating conditions and degradation rates. The average degradation rate reported is decreasing and is quickly approaching official targets. The database is published online for open-access and a continued updating by the community is encouraged. Furthermore, the commonly reported test parameters and degradation indicators are discussed. The difficulty in standardizing testing due to variations in cell and stack design, materials and intended purpose of the system is acknowledged. A standardization of reporting of long-term single-cell- and stack-tests is proposed.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0502 (Will be published elsewhere)

Electrochemical Analysis of Sulfur Poisoning in Ni/8YSZ Cermet Anodes

Sebastian Dierickx, André Weber and Ellen Ivers-Tiffée
Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT),
Adenauerring 20b, D-76131 Karlsruhe/Germany
Tel.: +49-721-608-47570
Fax: +49-721-608-47492
sebastian.dierickx@kit.edu

Abstract

The impact of sulfur on the electrochemical performance of anode supported SOFCs is analyzed via Electrochemical Impedance Spectroscopy (EIS). The performance limiting loss processes become accessible with a physically motivated equivalent circuit model (ECM) established in our previous studies, which makes a distinction between four major polarization processes: (i) the gas diffusion of hydrogen and steam through the anode substrate at low frequencies (4 to 20 Hz) described by a Warburg element, (ii) the cathode electrochemistry at intermediate frequencies (10 to 500 Hz) described by a Gerischer element and (iii) two processes associated with the coupled anode electrochemistry at high frequencies (2 to 8 kHz, 12 to 25 kHz) described by two RQ-elements [1].
However, these two RQ-elements represent four individual sub-processes: (a) the ion transport through the 8YSZ-matrix, (b) the electron transport through the Ni-matrix, (c) the gas diffusion through the pores and (d) the electrochemical oxidation of hydrogen at the triple phase boundary. The latter strongly affects performance of Ni/YSZ cermet anodes and is primary hindered by sulfur poisoning. During exposure sulfur chemisorbs on catalytically active Ni sites and thus dramatically lowers the reaction rate of the electrochemical hydrogen oxidation followed by a considerable extension of the penetration depth of all electrochemical processes [2].
We will introduce a physically meaningful extension of the ECM model by applying a modified transmission line model (TLM) [3], parametrized with microstructural data obtained from FIB tomography. We will present a detailed study on the development and parameterization of the TLM model, as well as the temporal evolution of the abovementioned processes (a) to (d) and the corresponding penetration depth during durabilty tests with sulfur.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0503 (Will be published elsewhere)

Phase decomposition of $La_2NiO_{4+\delta}$ under Cr-and Si-poisoning conditions

N. Schrödl (1), A. Egger (1), E. Bucher (1), C. Gspan (2), T. Höschen (3), F. Hofer (2) W. Sitte (1)
(1) Chair of Physical Chemistry, Montanuniversitaet Leoben,
Franz-Josef-Straße 18, 8700 Leoben, Austria
(2) Institute for Electron Microscopy and Nanoanalysis (FELMI), Graz University of Technology & Graz Centre for Electron Microscopy (ZFE)
Steyrergasse 17, 8010 Graz, Austria
(3) Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany
Tel.: +43-3842-402-4809
Fax: +43-3842-402-4802
nina.schroedl@unileoben.ac.at

Abstract

Poisoning of the air electrode by impurities released from stack-components like interconnects and sealing materials is still regarded a severe issue limiting the life time of SOFC-stacks. Recently, the mixed ionic-electronic conductor $La_2NiO_{4+\delta}$ (LNO) has received much attention as a potential cathode material for intermediate temperature solid oxide fuel cells (IT-SOFCs) due to its high catalytic activity for the oxygen exchange reaction. LNO has been considered to be more chromium tolerant because it does not contain alkaline earth elements like Sr and Ba which are known to segregate from the bulk towards the surface forming insulating or catalytically inactive secondary phases with Cr. In the present work, the long-term stability of LNO in dry and humid Cr- and Si-containing atmospheres was investigated at 800°C using the dc-conductivity relaxation method. Dense samples of LNO were exposed to dry and humid Cr- and Si-containing atmospheres while monitoring the degradation process via the chemical surface exchange coefficient (k_{chem}) of oxygen for a total duration of 3500 h. To determine chemical as well as morphological changes extensive post-test analyses using X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy (SEM-EDXS), analytical scanning transmission electron microscopy (STEM) with EDXS and electron energy loss spectroscopy (EELS) as well as high resolution transmission electron microscopy (HRTEM) were applied. In dry atmospheres (pO_2 = 0.10 bar) no degradation was observed in the presence of a Cr- and a Si-source over a period of 1300 h. Humidification of the test gas (pO_2 = 0.1 bar, 30-60% relative humidity), however, resulted in a significant decrease of k_{chem}. After the degradation experiment, XPS depth profiles, SEM-EDXS and STEM confirm the presence of an approximately 1.5 µm thick layer of Cr- and Si-containing compounds on the LNO surface. The main Si- and Cr-containing phases were identified by means of HRTEM selected area diffraction.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0504

Evaluation of the effect of sulfur poisoning on the performance of Ni/CGO based SOFC anodes

Matthias Riegraf (1), Vitaliy Yurkiv (1), Rémi Costa (1), Günter Schiller (1), Andreas Mai (2), K. Andreas Friedrich (1)
(1) German Aerospace Center (DLR)
Pfaffenwaldring 38-40, GER-70569 Stuttgart
(2) Hexis Limited
Zum Park 5, CH-8404 Winterthur
Tel.: +49-711-6862-8027
Fax: +49-711-6862-747
Matthias.Riegraf@dlr.de

Abstract

Even though the commonly used Ni/YSZ-based cermet for Solid Oxide Fuel Cell (SOFC) anodes shows high catalytic activity towards the oxidation of a variety of fuels and good long-term stability, it still faces high sensitivity towards exposure to chemical impurities such as sulfur, siloxane and phosphorus. In this regard, Ni/CGO anodes have been shown to display higher resistance to poisoning by chemical impurities than Ni/YSZ anodes. To allow for a deeper understanding of the processes leading to sulfur poisoning in Ni/CGO-based SOFC anodes, this study presents a detailed analysis of SOFC operating on H_2/H_2O gas mixtures with trace amounts of hydrogen sulfide (H_2S).
The short-term poisoning behavior of electrolyte-supported Ni/CGO40-based cells provided by Hexis and commercial Ni/CGO10-based cells was systematically investigated by means of transient voltage stability experiments and electrochemical impedance measurements for a wide range of operating conditions with varying H_2S concentrations, temperatures, current densities and gas phase compositions. The poisoning behavior was shown to be completely reversible for short exposure times in all cases. By means of impedance spectroscopy it was observed that the sulfur-affected processes show significant different relaxation times depending on the Gd-doping level of the CGO-based anode indicating possible differences in the underlying hydrogen oxidation mechanisms.
Furthermore, in order to evaluate long-term degradation of the cells, voltage stability tests of 900 h were conducted for different H_2S concentrations. Long-term stability was demonstrated for the low H_2S concentrations. Throughout these long-term experiments, the degradation processes were monitored by means of impedance spectroscopy. In addition, post-mortem analyses were carried out in order to identify the nature and location of the occurring microstructural changes.

B0507 (Will be published elsewhere)

Sulfur-Tolerance of Ceria-based Anodes

André Weber (1), Thorsten Dickel (1) and Ellen Ivers-Tiffée (1)
(1) Institute for Applied Materials (IAM-WET)
Karlsruhe Institute of Technology (KIT), D-76131 Karlsruhe, Germany
Tel.: +49-721-608-47572
Fax: +49-721-608-47492
andre.weber@kit.edu

Abstract

The sulfur content in fuels as reformed natural gas or diesel results in a severe power loss of state of the art anode supported SOFCs. Previous studies showed that the performance loss is related to a sulfur poisoning of the Ni/YSZ-cermets resulting in a deactivation of (i) the catalytic watergas-shift-reaction (WGS) at the nickel surfaces and (ii) the electro-oxidation of hydrogen at the three phase boundaries.
As ceria and nickel/ceria are well known as sulfur tolerant catalysts, in a first step towards a sulfur tolerant anode different ceria and nickel/ceria anode layers were investigated with respect to their performance and sulfur tolerance. The anodes were produced by screen printing and sintering ceria respectively nickel/ceria-cermet layers onto 8YSZ-substrates. In addition nickel, ceria and nickel/ceria electrocatalysts were infiltrated into some of the porous anode layers. Electrochemical tests were performed using full cells with a LSCF-cathode.
The sulfur poisoning was analyzed by electrochemical impedance spectroscopy in a $H_2/H_2O/N_2$ fuel-mixture at 750 °C. The investigations revealed that the ceria and nickel/ceria anodes exhibited a lower performance than a state-of-the-art nickel zirconia anode in H_2S-free fuel. This has to be at least partially attributed to the non-optimized composition and microstructure. On the other hand nickel/ceria anodes showed a better sulfur tolerance. In case of a similar fuel with 1 ppm H_2S a total polarization resistance of the cell as low as 208 mΩ·cm² was achieved.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0508 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Carbon removal from the fuel electrode of ASC-SOFC and regeneration of the cell performance

Vanja Subotić (1), Christoph Schluckner (1), Bernhard Stoeckl (1), Hartmuth Schroettner (2), Christoph Hochenauer (1)
(1) Institute of Thermal Engineering, Graz University of Technology
Inffeldgasse 25b/4, 8010 Graz, Austria
(2) Institute for Electron Microscopy and Nanoanalysis of the TU Graz (FELMI), Graz University of Technology, Steyrergasse 17, 8010 Graz, Austria
Tel.: +43-316-873-7319
Fax: +43-316-873-7305
vanja.subotic@tugraz.at

Abstract

Formation and deposition of deleterious carbonaceous species on the fuel electrode due to feeding with carbon-containing fuels can cause unwanted performance degradation and even mechanical damage of solid oxide fuel cells (SOFC). This phenomenon represents a major challenge towards the commercialization of this fuel cell type. The prevention of carbon formation is possible by diluting the fuel with steam, but this significantly worsens the cell performance. In order to ensure the regular cell operation with various fuels, such as diesel reformate different regeneration methods for the cell-protecting carbon removal and the improvement of the cell performance have been investigated and applied. For this purpose anode-supported SOFCs with Ni-YSZ anode have been used. Diverse tests showed that some methods applied ensure complete cell regeneration while some theoretically possible strategies only further deteriorate the cell performance and mutate the cell microstructure. Detection of carbon deposition before irreversible cell degradation occurs can be advantageous for the fast cell regeneration.

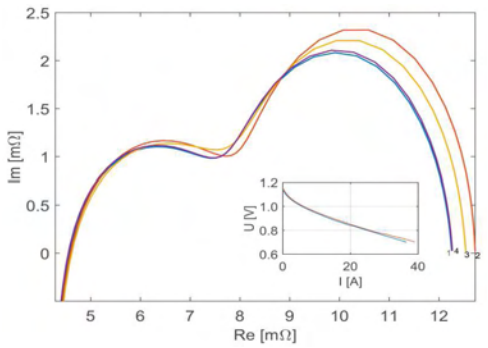


Fig. 1 Electrochemical impedance spectra of the "healthy" cell (1) and the cell during the carbon removal (2 – 3 – 4) and polarization curves before (blue) and after (red) the applied regeneration method

The tested SOFC cells have been characterized by several electrochemical methods, gas analysis and different temperature measurements. To investigate the microscopic topography of the cells used before and after the executed experiments microscopic examinations were performed. Post-mortem analysis of the cells included scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX).

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0509 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Quantitative correlation of Cr-deposition from the gas phase with chemical origin of electrolytes in SOFCs

Xiaomei Zhang, Yushan Hou, Elena Konysheva
Department of Chemistry, Xi'an Jiaotong-Liverpool University
111 Ren'ai Road, Suzhou, 215123 China
Tel.: +86-512-88161435
Fax: +86-512-81880440
elena.konysheva@xjtlu.edu.cn

Abstract

Quantitative analysis of Cr-deposition from a gas phase on the surface of Gd-doped CeO_2 (CGO10), 10 mol % Sc_2O_3 and 1 mol % CeO_2 stabilized ZrO_2 (ScCSZ), pure and doped $BaCeO_3$ was carried out at 700 and 840 ^oC. Cr-deposition on the surface of CGO10 and ScCSZ is noticeably lower compare to pure and doped $BaCeO_3$. Application of electrochemical impedance spectroscopy demonstrates that even a small quantity of the deposited chromium effects strongly the total conductivity of CGO10. Raman spectroscopy, X-ray powder diffraction and scanning electron microscopy were applied to identify the presence of chromium on the surface and its chemical form. The results obtained indicate that the chemical origin of electrolytes will influence the chromium deposition rate and make an impact on the evolution of their transport properties.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0510 (Will be published elsewhere)

New challenges for steel interconnects: lower temperature and dual atmosphere effect

Patrik Alnegren, Mohammad Sattari, Jan-Erik Svensson, Jan Froitzheim
Energy and Materials, Chalmers University of Technology
Kemivägen 10, 41296 Gothenburg, Sweden
Tel.: +46-31 772 2828
alnegren@chalmers.se

Abstract

Ferritic stainless steel samples of AISI 441 were exposed to dual atmosphere conditions of hydrogen on side and air on the other. An inverse temperature effect was observed at an interval of 600-800 °C. After exposure to 600 °C, break away oxidation was found at the air side of the samples, but at higher temperature a much thinner, more protective chromium rich oxide was formed. This effect was clearly caused by the migration of hydrogen through the steel sample towards the air side, since the reference samples, exposed to air on both sides, formed thin protective chromia scales at all temperatures.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0511 (Will be published elsewhere)

Assessment of limiting steps and degradation processes of an advanced metals supported cell with LST based anode

Vitaliy Yurkiv (1), Laurent Dessemond (2,3), Feng Han (1), Patric Szabo (1), Robert Semerad (4), Rémi Costa (1)
1) German Aerospace Center (DLR)
Pfaffenwaldring 38-40, GER-70569 Stuttgart
(2) Université Grenoble Alpes, Laboratoire d'Electrochimie et de Physico-Chimie des Matériaux et des Interfaces, FR-38000 Grenoble
(3) CNRS, Laboratoire d'Electrochimie et de Physico-Chimie des Matériaux et des Interfaces, FR-38000 Grenoble
(4) Ceraco Ceramic Coating GmbH
Rote-Kreuz-Str. 8, GER-85737 Ismaning
Tel.: +49-711-6862-8044
Fax: +49-711-6862-747
Vitaliy.Yurkiv@dlr.de

Abstract

In this contribution we present the combined modeling and experimental study of electrochemical hydrogen oxidation at an alternative perovskite based mixed-conducting SOFC anode. A SOFC with $La_{0.1}Sr_{0.9}TiO_{3-\alpha}$-CGO anode functional layer, CGO electrolyte and $La_{1-x}Sr_xCo_{1-y}Fe_yO_{3-\alpha}$ (LSCF) cathode were produced. In addition, at the anode side a thick substrate made of NiCrAl metal foam impregnated with LST ceramic was employed. The cells were electrochemically characterized by means of polarization curve and impedance measurements in H_2/H_2O fuel mixture varying applied potentials and operating temperatures.
In order to interpret the electrochemical measurements, an elementary kinetic model was developed and applied to explore the performance of LST based SOFC. A detailed multi-step heterogeneous chemical and electrochemical reaction mechanism was established taking into account transport of ions in all ionic phases, and gas transport in channel and porous media. It was found that four physico-chemical processes contribute to the overall polarization resistance with different impact depending upon operating conditions. The gas transport in the supply chamber (gas conversion) is significant and appears at all temperatures in the lowest frequencies, it follows by the anode surface charge-transfer reaction. The cathode charge-transfer electrochemistry impacting impedance curves in the intermediate frequencies and the oxygen anions transport throughout ionic phase is observable in high frequency. It was identified that degradation of the cathode after redox cycling together with YSZ degradation are among the main degradation phenomena of the cells.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0512

The effect of polarization on SOFC seal ageing

Stéphane Poitel (1,3), Yannik Antonnetti (2), Zacharie Wuillemin (2), Jan Van Herle (1), Cécile Hébert (3)
(1) SCI-STI-JVH FUELMAT Group, Faculty of Engineering Sciences (STI), Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1951 Sion, Switzerland.
(2) SOLIDpower, CH-1400 Yverdon-Les-Bains
(3) Interdisciplinary Centre for Electron Microscopy (CIME), Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland
Tel.: +41-78-825-45-63
poitel.st@gmail.com

Abstract

Seals in SOFC stacks have to cope with harsh conditions during their service. Their degradation leads to performance loss of the stack. Perhaps less known is the effect of polarization on the seals, when they are applied between positive and negative metal interconnect plates. This influence was studied in this work by ageing a series of seals for 1000 hours in dual atmosphere under different applied voltages of 0V, 1V and 6V: the first two to cover the normal operating range across a cell (or a pair of neighbor interconnects), the third (6V) to study an extreme case and provide a trend. The influence of polarization on the seals degradation was evidenced with optical microscopy and SEM-EDX. Barium chromate formation was found on the exposed part of the seals. Obvious color changes in the seals were seen by optical microscopy depending on cathodic or anodic polarization. SEM analysis confirmed a clear change in microstructure in these colored areas of the seals. EDX analysis did not evidence an important ion migration. A marked porosity was formed at the interface between seals and metallic interconnect and strongly depended on the polarization.

B0513 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Evolution of oxidation of SOFC interconnect alloys in dry and wet air

Manuel Bianco, Maxime Auchlin, Stefan Diethelm, Jan Van herle
FUELMAT group, École Polytechnique Fédérale de Lausanne
17 Rue de l'Industrie, CH-1950 Sion
Tel.: +41-56-987-1234
manuel.bianco@epfl.ch

Abstract

Crofer 22 APU, Crofer 22 H and CFY alloy substrates were evaluated as SOFC interconnect materials. Coated sandwich coupons, spaced by perovskite contact layers ($La_{1-x}Sr_xMnO_3$) underwent exposure tests for different durations (300h, 1000h, 2000h, 3000h), air condition (dry, 3% wet) and polarization (current, no current). After test, cross sections of all samples have been studied by SEM-EDS. Scale thickness, microstructure morphology, and Cr retention of the ceramic protective layer on the steel coupons were the principal investigated parameters. In the study, the correlation between these properties and the ASR results is described, together with the comparison between dry and wet air tested specimens.
Results show that the 3% air humidity leads to lower ASR values. This could be correlated to the thinner scale found in the wet samples. In particular, in the first 3000 hours the scale growth for CFY alloy in dry condition is twice that in wet condition. This in turn could be mainly due to enhanced revolatisation of the scale in wet air compared to dry air exposure.

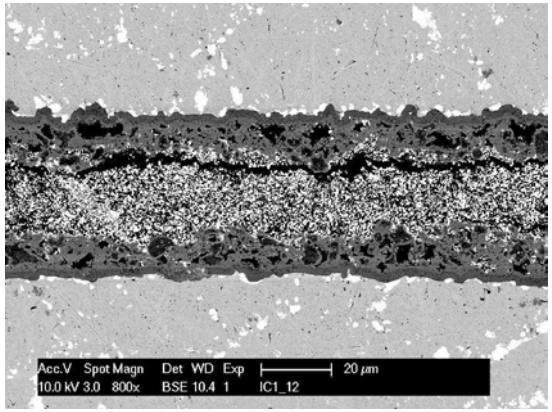


***Figure 1**. Cross section of Crofer 22 H samples exposed for 3000 h at 800°C*

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0514 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Experiments on metal-Glass-metal samples simulating the fuel inlet/outlet manifolds in SOFC stacks

Paolo Piccardo (1,2), Maria Paola Carpanese (3), Andrea Pecunia (1), Roberto Spotorno (1,2), Simone Anelli (1)
(1) Laboratory of Metallurgy and Materials, DCCI, University of Genoa, Genoa, Italy
(2) Institute for Energetics and Interphases, National Council of Research, Genoa, Italy
(3) Dept. of Civil, Chemical and Environmental Engineering, University of Genoa, Genoa, Italy
Tel.: +39-010-353-6145
paolo.piccardo@unige.it

Abstract

The investigations performed on state-of-the-art SOFC stacks operated at various electrical load for several thousand hours have underlined the importance to better understand how the sealant materials evolve during the operation period. The opportunity to operate a stack and to have access to post-experiment samples is quite unique and opened the possibility to design and operate in a suitable rig samples replicating the metal-glass-metal of a stack manifold.
Samples prepared with the same materials and manufacturing method as for stacks have been aged at operating conditions of the fuel inlet and outlet for 500h under a polarization of 0.8V and a temperature of 700°C in dual atmosphere (i.e. air, fuel).
The evolution of the glass properties has been followed in by Electrochemical Impedance Spectroscopy (EIS) with measurements performed at Open Circuit Voltage (OCV) and under polarization.
EIS measurements allowed to monitor the behaviour of the investigated system during the ageing process. The bulk resistance of the glass was measured and related to the evolution of the microstructural features investigated by post experiment characterization on the cross-sections. The combination of different fuel stream composition and temperature resulted in a quite stronger evolution of the glass at the outlet.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0515 (Will be published elsewhere)

Silver as a current collector for SOFC

Artur J. Majewski, Aman Dhir
School of Chemical Engineering
University of Birmingham
B15 2TT Birmingham, UK
Tel.: +44-121 414 5081
a.j.majewski@bham.ac.uk
a.dhir@bham.ac.uk

Abstract

In this paper the behaviour of silver as cathode conductive material, interconnect wire, and sealing for anode lead connection for micro-tubular solid oxide fuel cells (μSOFC) is reported. The changes in silver morphology were examined by scanning electron microscopy, on cells that had been operated under reformed methane. It was found that using silver in an SOFC stack can significantly improve the cell performance. However, it was also concluded that silver may also be responsible for cell degradation. The results demonstrate that silver is unstable in both interconnect and cathode environments. It was found that the difference in thermal expansion of silver and sealant resulted in damage to the glass. It was concluded that when silver is exposed to a dual atmosphere condition, high levels of porosity formation was seen in the dense silver interconnect. The relevance of application of silver in SOFC stacks is discussed.

Keywords: silver, SOFC, micro-tubular SOFC, SOFC stacks

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0516 (Will be published elsewhere)

Improvement of interface between electrolyte and electrodes in solid oxide electrolysis cell

Nikolai Trofimenko, Mihails Kusnezoff, Alexander Michaelis
Fraunhofer Institute for Ceramic Technologies and Systems
Winterbergstrasse 28, 01277 Dresden, Germany
Tel.: +49-351-255-37-787
Fax: +49-351-255-41-59
Nikolai.Trofimenko@ikts.fraunhofer.de

Abstract

Durability of solid oxide electrolyte supported cells was investigated under stack relevant operating conditions at -300 mA/cm^2 and -500 mA/cm^2 for high temperature steam electrolysis. To improve electrochemical and mechanical stability, especially during long-term operation, an additional layer was introduced between electrolyte and multilayer oxygen electrode based on strontium doped lanthanum manganite with additional transition metal on B-site. Different materials for this interlayer have been tested. Electrochemical testing combined with detailed microstructural analysis were carried out. The changes in polarization resistance of single cells under different operating conditions as well as during durability tests were performed and discussed on basis of analysis of impedance spectra. Microstructure observations at the interfaces in both electrodes were carried out after long-term tests to understand the reasons for degradation. The technological aspects of cell production are discussed.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0517 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Local Evolution of Three-dimensional Microstructure of Ni-YSZ Anode in Solid Oxide Fuel Cell Stack after Long-term Operation

Grzegorz Brus (1), Hiroshi Iwai (2), Yuki Otani (2)
Motohiro Saito (2), Hideo Yoshida (2), Janusz S. Szmyd (1)
(1) AGH University of Science and Technology, Faculty of Energy and Fuels, Dept. of Fundamental Research in Energy Engineering, Krakow, Poland
(2) Kyoto University, Department of Aeronautics and Astronautics, Kyoto, Japan
Tel.: +41-56-987-1234
Fax: +41-56-987-1235
brus@agh.edu.pl

Abstract

In this research a 100 W solid oxide fuel cells stack was tested. After 3700 hours of continuous operation a subsequent post-test analysis of the anodes' microstructure was conducted using a combination of focused ion beam and scanning electron microscopy. The obtained data was reconstructed into three-dimensional images, based on which the microstructure parameters were obtained. The microstructure parameters were quantified at nine different locations in the stack. The obtained results indicate strong non-homogeneous microstructure morphology changes after long-term operation.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0518

Fuel heterogeneity in solid oxide carbon fuel cells: according to the internal gasification of carbon

Hansaem Jang (1), Youngeun Park (1), Jaeyoung Lee (1,2)
(1) Electrochemical Reaction and Technology Laboratory,
School of Environmental Science and Engineering,
Gwangju Institute of Science and Technology (GIST), Gwangju 61005, South Korea
(2) Ertl Center for Electrochemistry and Catalysis,
Research Institute for Solar and Sustainable Energies,
GIST, Gwangju 61005, South Korea
Tel.: +82-62-715-2440
Fax: +82-62-715-2434
jaeyoung@gist.ac.kr

Abstract

In solid oxide carbon fuel cell, provided oxygen gas (O_2) to a cathode turns into the form of oxide ion (O^{2-}), which later reaches an anode surface through defects within a solid oxide electrode. Basically, the resultant electrochemical reaction with carbon on anode surface happen. In fact, within an anode chamber, various further oxidizable gas molecules could be produced with the aid of internal gasification, and the further oxidizable gas molecules can be employed as fuel in solid oxide carbon fuel cells. The further oxidizable gas molecules could take part in the electrochemical reaction and a gas-state oxidizable material is more readily reachable to triple phase boundary (TPB), and hence rendering higher performance. In this sense, it is crucial and important to know how gaseous molecules are generated and what kind of molecules are produced. According to the origination of the generation of gas molecules, gasification reactions can be classified into two: internal gasification around solid fuel within an anode chamber without the contact to anode surface *and* internal gasification occurring near TPBs. The former is attributed to various gas molecules within an anode chamber. Apart from the ideal case, having extremely high carbon purity and perfect air-seal, in fact, an anodic atmosphere is not only governed by carbon-oxygen speciation but also with partial pressure of H_2, steam, hydrocarbons, etc. This partial pressure could either be utilized as fuel or initiate further internal gasification. The latter occurs due generally to reverse Boudouard reaction (RBR), which substantially fosters the generation of CO at the elevated temperature. This study shows the evidences of two different gasification reactions and demonstrates a mechanism.

B0519 (Abstract only)

Anomalous Shrinkage of Ni-YSZ Cermet during Low Temperature Oxidation

Keiji Yashiro, Fei Zhao, Shinichi Hashimoto and Tatsuya Kawada
Graduate School of Environmental Studies, Tohoku University
6-6-01 Aramakiaoba, Aoba-ku
9808579 Sendai / Japan
Tel.: +81-22-795-6976
Fax: +41-22-795-4067
yashiro@ee.mech.tohoku.ac.jp

Abstract

Microstructure of Ni-YSZ cermet is a critical factor for electrochemical performance as well as mechanical stability of SOFCs. Recently, a typical cell configuration is anode support cell. It is known that microstructure of the cermet changes upon reduction and oxidation of nickel; and that nickel sintering takes place during long-term operation. The robustness of Ni-YSZ cermet is important to ensure long term reliability of SOFCs.
Upon oxidation of Ni to NiO, crystal volume increases. However, we recently observed anomalous shrinkage of Ni-YSZ under low temperature oxidation: As shown in Fig. 1, Ni-YSZ cermet (with 30vol% pore former) was unexpectedly shrunk during the oxidation in the temperature range less than 500 °C; While Ni-YSZ cermet was dense, no shrinkage was observed. This shrinkage behavior depends on porosity of Ni-YSZ cermet. To clarify this phenomenon, thermal expansion behavior of sintered nickel metal was measured in oxidizing atmosphere by a dilatometry. Oxygen partial pressure varied from 10^{-3} to 0.2 bar. The shrinkage behavior was again observed in temperature range between 300-500 °C even without YSZ. Therefore, this anomalous shrinkage is attributed to nickel. The amount of shrinkage depended on oxygen partial pressure and temperature ramp. Maximum shrinkage of 1% was observed in 20%O2-N2 at heating rate of 1 °C/min. Comparing the nickel microstructure before and after low temperature oxidation, it seemed that nickel sintering was accelerated by oxidation of nickel.

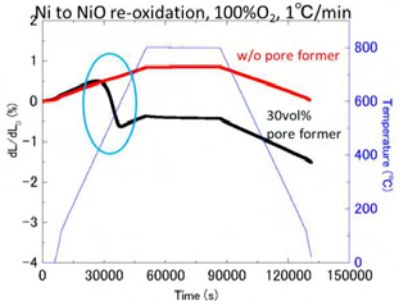


Fig. 1 Dilatometry measurement of Ni-YSZ cermet with/without a pore former.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0520 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Time-dependent Degradation of Nickel-infiltrated ScSZ Anodes

Jingyi Chen (1), Xin Wang (1), Enrique Ruiz-Trejo (2), Alan Atkinson (1), Nigel P Brandon (2)
(1) Imperial College London
Department of Materials
SW7 2AZ London/United Kingdom
(2) Imperial College London
Department of Earth Science and Engineering
SW7 2AZ London/United Kingdom
Tel.: +44-07876335662
jingyi.chen12@imperial.ac.uk

Abstract

The stability of the solid oxide fuel cell under high temperature operation is a significant concern for commercialisation. The coarsening of Ni in the anode is a contributor to the degradation, as it causes disruption in the electronically conductive path and a reduction in the density of active triple phase boundaries. Nickel infiltration of an ionically conducting scaffold often shows better electrochemical performance than conventional cermet anodes due to its finer Ni particle size, and in addition the lower volume fraction of Ni improves tolerance to redox cycling. However, degradation of infiltrated nickel anodes has not been fully studied and understood. In this work, anodes formed by infiltrating scandia-stabilised zirconia scaffolds with 40 wt% nickel are studied. Electrochemical impedance spectra were monitored over time at temperatures of 800 °C and 950 °C. The degradation in performance is explained by changes in the nickel microstructure seen in secondary electron images. A significant increase in area specific resistance was observed in the first 500 - 1000 minutes. The in-plane conductivity of the infiltrated electrodes as a function of time was measured by the van der Pauw method and compared with values calculated from the general effective media theory. A trend of rapid decrease in the first 500 minutes was shown in in-plane conductivities. The resistance increases both in-plane and cross-plane were attributed to the interplay between Ostwald ripening of nickel and constraint from the zirconia backbone

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0521 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Impact of redox cycling on microstructure related properties of Ni-YSZ Solid Oxide Fuel Cell anodes

Bowen Song, Enrique Ruiz-Trejo, Zhangwei Chen, Kristina Maria Kareh, Farid Tariq and Nigel P Brandon
Department of Earth Science and Engineering
Imperial College London
SW7 2AZ London, UK
Tel.: +447984808868
b.song15@imperial.ac.uk

Abstract

Nickel yttria stabilised zirconia (Ni-YSZ) cermets are widely used as anode materials for Solid Oxide Fuel Cells (SOFCs). Upon cyclic reduction and oxidation, the anode material degrades. In this study, the effect of anode reduction and oxidation cycling for a typical electrolyte supported cell (ESC) has been investigated. The electrochemical degradation was followed by impedance spectroscopy and conductivity measurements.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0801 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

20 000 Hours Steam Electrolysis with Solid Oxide Cell Technology

Annabelle Brisse, Josef Schefold, Julian Dailly
European Institute for Energy Research (EIFER)
Emmy-Noether-Str. 11, D-76131 Karlsruhe, Germany
Tel.: +49-2461-61051317
brisse@eifer.de

Abstract

High temperature steam electrolysis with solid oxide cells (SOCs) can play an important role in the transition to sustainable energy sources, e.g. by converting renewable electricity into synthetic fuels. It can accelerate that transition by offering solutions to the transport and industrial sectors, which depend on fuels of high energy density, such as the fossil fuels kerosene and gasoline.

SOC are operated at, or slightly above, the thermal neutral voltage (~1.3 V at 800°C). In the 1980's tubular cells tested in the frame of the project HOTELLY reached that voltage value for current densities of -0.3 to -0.4 Acm^{-2}. Present solid oxide electrolyser cells, commonly based on the planar SOFC technology, can be operated at higher magnitude of the current density (0.8 to 1 Acm^{-2}) with still lower cell voltage. Typical voltage values amount to about 1 V for H_2 electrode supported cells and 1.1 to 1.2 V for electrolyte supported cells. A voltage margin therefore exists which may be used for a further increase in current density and/or for degradation compensation, e.g. by temperature adjustment. The latter approach means zero voltage/power degradation as long as temperature remains in the tolerable window.

The focus of this work is on long-term operation of SOC in the electrolysis mode. A solid oxide cell from the German company KERAFOL was operated over 22,500 hours with a current density of -0.9 Acm^{-2} and a low voltage degradation of 7.5 mV/1000 h. Performance and lifetime were moreover evaluated with a 7,000 hours test of a 5 cell stack from the company SUNFIRE (Germany), using a high steam-to-hydrogen conversion rate of ca. 80%. Finally, the experimental results, which are relevant for practical operation, were implemented in a technical and economic analysis in order to compare the hydrogen production cost as function of electrolysis key performance indicators defined by the European commission in the Multi Annual Work Plan 2014 – 2020.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A0802 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Post-test analysis on a Solid Oxide Cell stack operated for 10700 hours in steam electrolysis mode

Giorgio Rinaldi (1), Stefan Diethelm (1), Pierre Burdet (1), Emad Oveisi (1), Jan Van herle (1), Dario Montinaro (2), Qingxi Fu (3), Annabelle Brisse (3)
(1) École polytechnique fédérale de Lausanne Valais/Wallis,
Rue de l'Industrie 17, Sion 1950, Switzerland
giorgio.rinaldi@epfl.ch
(2) SOLIDpower
Viale Trento 115, Mezzolombardo 38017, Italy
(3) European Institute for Energy Research (EIFER)
Emmy-Noether-Strasse 11, D-76131 Karlsruhe, Germany

Abstract

A solid oxide short stack composed of 6 Ni-cermet supported cells with LSC oxygen electrodes (6x48 cm^2 of active area) has been tested for 10700 h in steam electrolysis mode, in the temperature range of 710-730°C, with 9.3 Nml/min/cm^2 (90% steam, 10%H_2) feed flow. 12 Nml/min/cm^2 Air flow was used as a sweep gas on the O_2 side. The stack has been operated at -0.6 A/cm^2 during the first 3200 hours (Steam Conversion 50%) and, after an accidental interruption of the steam supply, the current density was lowered to -0.5 A/cm^2 for the remaining of the test (SC 42%). Severe initial degradation (8% in the first 2000 hours) was followed by a global stabilization of the performance after lowering the current density, with a degradation rate below 0.5%/kh.
Post-test analysis has been conducted on 2 repeating unit using scanning electron microscopy (SEM). Focused Ion Beam (FIB) technique has been applied to highlight the most significant microstructure alterations. Impurities contamination and material migration were investigated with Energy Dispersive X-ray analysis (EDX). The repeating units were cut in 8 samples to analyse the cross-section at locations of interest.
Nickel depletion was observed in the hydrogen electrode close to the interface with the electrolyte, followed by Ni agglomeration further away from the interface. The formation of small pores in the electrolyte was detected along the grain boundaries. A consequent detachment related to this phenomenon was observed in proximity of the GDC compatibility layer, probably enhanced by the sample preparation. In the oxygen electrode, the formation of a ~1 µm dense mixed layer of GDC and YSZ was observed. Strontium from the LSC electrode migrated through GDC pores and reacted with YSZ, forming $SrZrO_3$. In addition, sulphur traces contained in the sweep air were identified especially along cracks, likely as $SrSO_4$.
Despite this range of alterations observed, the stack degradation (apart from the initial loss) remained limited, testified from the fact that performance decay between 4000 and 10'000 h of operation was virtually nil.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0803 (Will be published elsewhere)

Degradation analysis of an SOEC stack operated for more than 10,000 h

Qingping Fang, Ludger Blum, Norbert H. Menzler
Forschungszentrum Jülich GmbH
Institute of Energy and Climate Research
Wilhelm-Johnen-Straße
D-52428 Jülich / Germany
Tel.: +49-2461-611573
Fax: +49-2461-616695
q.fang@fz-juelich.de

Abstract

A Solid Oxide Electrolysis (SOE) short stack consisting of anode-supported cells (ASCs in fuel cell mode) was assembled in JÜLICH's F10-design. ASCs are based on Ni/8YSZ (8 mol-% yttria-stabilized zirconia) with an LSCF air electrode ($La_{0.58}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$) and 8YSZ electrolyte. A gadolinium-doped ceria (GDC) ($Ce_{0.8}Gd_{0.2}O_{1.9}$) barrier layer was deposited between 8YSZ and LSCF by means of physical vapor deposition (PVD).
The stack performance was characterized in a furnace environment in both fuel cell and electrolysis modes between 700 and 800 °C with 50% humidified H_2. Electrolysis operation was first carried out at three temperatures (i.e. 700, 750 and 800 °C) with a current density of -0.5 Acm^{-2} and steam conversion rate of 50%. Operation time of each period was more than 500 h. Long-term electrolysis operation was then carried out at 800 °C with the same current density and steam conversion rate. The possible effect of the reversible operation on SOEC degradation was investigated by operating the stack in fuel cell mode for more than 1000 h in between the long-term electrolysis operation. Electrochemical impedance spectroscopy (EIS) and analysis of the distribution function of relaxation times (DRT) were performed for degradation analysis. After more than 10,000 h of operation, the stack showed an average voltage degradation rate of 0.7%/kh, which was primarily due to the increase in ohmic resistance.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0804 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Long-term operation of a solid oxide cell stack for co-electrolysis of steam and CO_2

Karsten Agersted (1), Ming Chen (1), Peter Blennow (2), Rainer Küngas (2), Peter Vang Hendriksen (1)
(1) Department of Energy Conversion and Storage, Technical University of Denmark, Frederiksborgvej 399, DK-4000 Roskilde/Denmark
(2) Haldor Topsoe A/S, Haldor Topsøes Allé 1, DK-2800 Kgs. Lyngby/Denmark
Tel.: +45-46775757
Fax: +45-46775858
minc@dtu.dk

Abstract

High temperature electrolysis based on solid oxide electrolysis cells (SOECs) is a promising technology for production of synthetic fuels. The SOEC units can be used for co-electrolysis of steam and CO_2 to produce synthesis gas (syngas, $CO+H_2$), which can be further processed to a variety of synthetic fuels such as methane, methanol or DME. Previously we have reported electrolysis operation of solid oxide cell stacks for periods up to about 1000 hours. In this work, operation of a Haldor Topsoe 8-cell stack (stack design of 2014) in co-electrolysis mode for 6000 hours is reported. The stack consists of Ni/YSZ electrode supported SOEC cells with a footprint of 12X12 cm^2. The co-electrolysis operation was carried out by supplying a mixture of 45 % CO_2 + 45 % H_2O + 10 % H_2 to the stack operating with a fixed conversion of 39 % for steam and CO_2. The stack was operated at different conditions. Initial operation at 700 °C and -0.25 A/cm^2 lasted for only 120 hours due to severe degradation of the bottom cell. Regaining the stack performance was realized by increasing the operation temperature to 750 °C. After reactivation, the stack showed negligible degradation at 750 °C and -0.25 A/cm^2 and about 1.4 %/1000 h performance degradation at 750 °C and -0.5 A/cm^2. This study demonstrates feasibility of long-term co-electrolysis operation via SOEC stacks and of careful temperature variation as a tool to regain the stack performance.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0807 (Abstract only, published elsewhere)

Cr Poisoning of (La,Sr)(Co,Fe)O3-δ SOFC Cathodes at the Micrometre to Nanometre Scale

Na Ni (1), Samuel Cooper (1), Stephen Skinner (1), Robert Williams (2), David W. McComb (2)
(1) Imperial College London, Exhibition road, SW7 2AZ London UK
Tel.: +44(0)2075895111, extension 51176
(2) Center for Electron Microscopy and Analysis, Ohio State University, 1305 Kinnear Road, Columbus, OH 43212, USA
n.ni@imperial.ac.uk

Abstract

For developing solid oxide fuel cells (SOFCs) operating at intermediate temperatures, metallic materials have become a preferential choice for the interconnect due to their low cost and excellent physical and chemical properties. However the presence of chromium in all commonly used metallic alloys has been found to cause poisoning of the cathode leading to rapid electrochemical performance degradation of the cathodes including one of the most promising (La,Sr)(Co,Fe)$O_{3-\delta}$ (LSCF) perovskite oxides [1-3]. Despite the extensive research on the chromium deposition and poisoning processes, careful microstructural studies at multi-scale lengths are rare, which can provide valuable information for the fundamental understanding of the Cr poisoning mechanisms required for developing Cr tolerant cathode materials.

In this paper, we examine the Cr poisoning mechanisms in LSCF materials by correlating the bulk electrochemical properties of the cell with their structural and chemical change at multi-scales down to the nanometer level. Cells with LSCF cathodes were prepared, and the effect of Cr poisoning on the electrochemical behavior of the cell was assessed by impedance spectroscopy. The change in nano/microstructure and chemistry due to poisoning were studied in parallel by a combination of several advanced electron microscopy techniques including focus ion beam (FIB) tomography, high resolution (scanning) transmission electron microscopy ((s)TEM) and analytical STEM. Our results show that Cr poisoned samples with an increase in the total polarization resistance by one order of magnitude exhibit multiscale changes especially at the nanoscle including formation of nanometer size Cr rich phases, Cr segregation at LSCF grain boundaries and alternation of LSCF bulk stoichiometry. This nanoscale evolution correlates well with the impedance results obtained from the same samples, which shows that the area specific resistance of poisoned sample increased due predominantly to the increase of the oxygen reduction component related with a decrease both in the oxygen exchange rate at the LSCF internal surface and the oxygen diffusion in the electrode.

References

[1] M.C. Tucker, H. Kurokawa, C.P. Jacobson, L.C. De Jonghe, S.J. Visco, *J. Power Sources* **160** (2006) (1) 130.
[2] S.P. Jiang, X.B. Chen, *Int. J. Hydrog. Energy* **39** (2014) (1) 505.
[3] S.N. Lee, A. Atkinson, J.A. Kilner, *J. Electrochem. Soc.* **160** (2013) (6) F629.

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0808 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

SOFC Operation on Biogas: Impurity Threshold Levels

Hossein Madi (1), Christian Ludwig (2) and Jan Van herle (1)
(1) FUELMAT Group, Faculty of Engineering Sciences (STI), Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland
(2) Paul Scherrer Institut, General Energy Research Department, Bioenergy and Catalysis Laboratory, CH-5232 Villigen PSI
Tel.: +41-21-693-7322
Fax: +41-21-693-3502
hossein.madi@epfl.ch

Abstract

Biogas-powered solid oxide fuel cells (SOFC) hold great promise for their ability to valorise local waste streams on small scale into electricity. Biogas contains minor constituents, like sulfur compounds, siloxanes, VOCs and halogenated compounds, which can affect the durability of SOFCs. An obvious option in using biogas is gas clean-up. Technologies exist that can remove harmful impurities from biogas that will meet the cleanliness requirements of SOFC stacks, but these add to the system costs, which for small scale application should stay low. This study provides guidelines regarding the maximum impurity concentrations which can be tolerated in biogases after cleaning, for SOFC application. The degradation of anode-supported Ni-YSZ single cells and short stacks have been examined with fuels to which the following trace elements were added: H_2S, HCl, D4-siloxane, C_4H_4S (thiophene) and C_7H_8 (toluene).

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0809 (Will be published elsewhere)

$La_2NiO_{4+\delta}$ as SOEC anode material

Andreas Egger, Nina Schrödl and Werner Sitte
Montanuniversitaet Leoben, Chair of Physical Chemistry
Franz-Josef-Straße 18, 8700 Leoben, Austria
Tel.: +43-3842-402-4814
Fax: +43-3842-402-4802
andreas.egger@unileoben.ac.at

Abstract

High-temperature steam electrolysis (HTSE) offers a way for highly efficient water splitting, especially if thermal coupling to existing heat sources is available. HTSE technology is based on solid oxide electrolyser cells (SOECs) which are operated at temperatures between 600 and 1000°C. Compared to their galvanic counterpart – solid oxide fuel cells (SOFCs) – degradation rates of SOECs are currently roughly one order of magnitude higher than for SOFCs. In this work the promising SOFC cathode material $La_2NiO_{4+\delta}$ is characterised as anode material for high temperature electrolyser cells. Special emphasis is put on the Cr-tolerance of this material, which is an important feature for SOEC and SOFC air electrodes when applied in stacks containing metallic interconnects. The effect of Cr-poisoning on electrode performance is investigated on symmetrical cells with porous $La_2NiO_{4+\delta}$ electrodes at 800°C under both anodic and cathodic polarisation. Degradation processes are continuously monitored by current-voltage analysis and impedance spectroscopy. Post-test analytical investigations are performed by SEM and TEM in order to determine the deposition and distribution of contaminants as well as the composition of secondary phases. The analytical findings are correlated with results from electrochemical measurements and clearly show different degrees of Cr-contamination between oppositely polarised electrode layers.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

A0810 (Will be published elsewhere)

Chromium and silicon poisoning of $La_{0.6}Sr_{0.4}CoO_{3-\delta}$ IT-SOFC cathodes at 800°C

E. Bucher (1), N. Schrödl (1), C. Gspan (2), T. Höschen (3), F. Hofer (2), W. Sitte (1)
(1) Chair of Physical Chemistry, Montanuniversitaet Leoben, Franz-Josef-Straße 18, A-8700 Leoben/Austria
(2) Institute for Electron Microscopy and Nanoanalysis (FELMI), Graz University of Technology & Graz Center for Electron Microscopy (ZFE), Austrian Cooperative Research (ACR), Steyrergasse 17, A-8010 Graz/Austria
(3) Max Planck Institute for Plasma Physics, Boltzmannstraße 2, D-85748 Garching/Germany
Tel.: +43-3842-402-4813
Fax: +43-3842-402-4802
edith.bucher@unileoben.ac.at

Abstract

The oxygen exchange kinetics of the intermediate temperature solid oxide fuel cell (IT-SOFC) cathode material $La_{0.6}Sr_{0.4}CoO_{3-\delta}$ (LSC64) was measured in-situ for 3500 h by the dc-conductivity relaxation method (CR). The chemical surface exchange coefficient (k_{chem}) and the chemical diffusion coefficient (D_{chem}) of oxygen were determined at 800°C in dry and humidified atmospheres in the absence and presence of Cr- and Si-sources. Post-test analyses of degraded samples were performed by scanning electron microscopy (SEM) with energy and wavelength dispersive X-ray spectroscopy (SEM-EDXS/WDXS), X-ray photoelectron spectroscopy (XPS), and analytical scanning transmission electron microscopy (STEM) with EDXS and electron energy loss spectroscopy (EELS).
In dry atmosphere (pO_2=0.10 bar) at 800°C high values of $k_{chem}=1\times10^{-3}$ cm s^{-1} and $D_{chem}=2\times10^{-5}$ $cm^2 s^{-1}$ were found. No degradation was observed during 1300 h without or with the presence of Cr- and Si-sources in the dry test gas. However, a significant decrease in k_{chem} and D_{chem} occurred when the atmosphere was humidified (pO_2=0.10 bar; 30-60 % relative humidity). SEM analyses show that various crystallites are formed on the surface of the sample during the degradation. SEM-EDXS and -WDXS confirm the presence of significant amounts of Cr- and Si-impurities in the near-surface region. XPS elemental depth profiles give evidence of Sr- and Cr-enrichment and Co-depletion of the surface down to depths of approximately 900 nm. STEM shows that Cr- and Si-rich secondary phases are formed on the surface and at the grain boundaries in the near-surface region. Sr-chromate and La-silicate phases were identified in addition to Co-oxide by STEM-EDXS and –EELS cross-sectional analyses. It can be concluded that the decomposition of the oxygen exchange active LSC64 bulk material into inactive secondary phases results in the observed decrease of the oxygen exchange kinetics, and that gas phase humidity is a critical factor for the degradation.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0812

Study of variables for accelerating lifetime testing of SOFCs

Alexandra Ploner, Anke Hagen, Anne Hauch
Technical University of Denmark
Department of Energy Conversion and Storage
Frederiksborgvej 399, DK-4000 Roskilde, Denmark
Tel.: +45-9351-1509
aplo@dtu.dk

Abstract

Solid oxide fuel cell (SOFC) applications require lifetimes of several years on the system level. A big challenge is to proof/confirm/demonstrate such exceptionally long lifetimes. Accelerated or compressed testing are possible methods. Activities in this area have been carried out without arriving at a generally accepted result. First accelerated testing approaches were performed under non-steady operation conditions (current cycling, temperature cycling) by different researchers [1, 2]. However, cycling conditions seemed to have no significant impact on degradation mechanisms. Furthermore, tests done at different current load cycling profiles revealed a strong deviation between predicted and measured lifetime [3].
In this study, we present a detailed analysis of durability results for degradation mechanisms of single SOFC components as function of operating conditions. Electrochemical impedance data is collected and used to de-convolute the individual losses of singe SOFC cell components – electrolyte, cathode and anode. The obtained knowledge is adopted to identify operation profiles and appropriate stresses in order to execute appropriate accelerated testing for lifetime investigation of SOFCs.

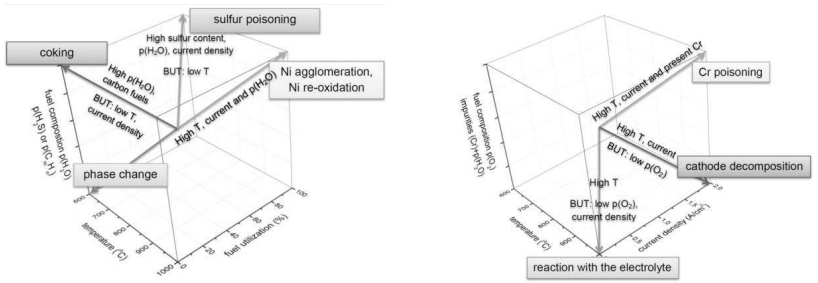


Fig. 1 Dependency of anode and cathode degradation mechanisms (examples) on operating parameters.

A0813 (Will be published elsewhere)

SOFC Anode Protection Using Electrolysis Mode During Thermal Cycling

Young Jin Kim, Seon Young Bae, Hyung-Tae Lim
School of Materials Science and Engineering, Changwon National University
20 Changwondaehak-ro, Changwon, Gyeongnam, South Korea
Tel.: +82-55-213-3716
Fax: +82-55-262-6486
htaelim@changwon.ac.kr

Abstract

The typical operating temperature of a solid oxide fuel cell (SOFC) is above 700 °C, and due to this high temperature, thermal cycling—a start-up and shut-down process— is carried out in a wide temperature range, sometimes with an interruption in fuel supply. The conventional anode material of SOFCs, Ni+YSZ cermet, needs to be protected from Ni re-oxidation during thermal cycling for the prevention of performance degradation. A cover gas such as nitrogen with hydrogen mixture may be supplied for the anode during heating and cooling processes; however, this conventional method is not efficient in regard to fuel cell operation costs and system simplicity. In this study, the electrical method is employed to protect the SOFC anode during thermal cycling in electrolysis cell mode, which allows the cell voltage to be in the safe range (0.7 ~ 1 V) by electrochemically transporting oxygen from the anode to the cathode through the electrolyte. Anode supported cells are thermal-cycled from room temperature to 750°C with (1) cover gas (hydrogen) and (2) in electrolysis cell mode using DC power supply without the cover gas, and then thermal cycling durability is compared. As a result, it was found that there is no change in power density and anode microstructure after the cycling in both cases, and this result indicates that the electrolysis method has an equivalent effect on the anode protection. Therefore, for system efficiency, the electrical method using electrolysis mode is preferred rather than the chemical method using cover gases.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0814

Degradation analysis of SOFC performance

Tohru Yamamoto, Kenji Yasumoto, Hiroshi Morita,
Masahiro Yoshikawa, Yoshihiro Mugikura
Central Research Institute of Electric Power Industry (CRIEPI)
2-6-1 Nagasaka, Yokosuka, Kanagawa 240-0196/Japan
Tel.: +81-46-856-2121
Fax: +81-46-856-3346
tohru-y@criepi.denken.or.jp

Abstract

A national project for SOFC development has been initiated from FY2013 in NEDO's project, "Basic study on rapid evaluation method of SOFC durability". Central Research Institute of Electric power Industry (CRIEPI) has been operated six types of SOFC stacks, which are developed by MITSUBISHI HITACHI POWER SYSTEMS (MHPS), KYOCERA, TOTO, NGK SPARK PLUG, NGK INSULATORS, and MURATA, to reveal their durability and find dominant degradation factor for each SOFC stacks. Target of NEDO durability project is set at 0.1%/1,000hr. In this paper, we report the current status of the performance of segment-in-series tubular stack, flattened tubular stack, micro tubular stack, planar stack, flattened tubular segment–in-series stack and single-step co-fired planar stack which are made by MHPS, Kyocera, TOTO, NTK, NGK, and Murata, respectively.
These works were financially supported by NEDO under the "Basic study on rapid evaluation method of SOFC durability" project. We appreciate advice and support received from NEDO in Japan. We would like to express our gratitude to NEDO, MHPS, Kyocera, TOTO, NTK, NGK, and Murata, as well as to the National Institute of Advanced Industrial Science and Technology (AIST).

A0815

Development of protective coatings on SOFC metallic interconnects fabricated by powder metallurgy

V. Miguel-Pérez (1), M. Torrell (1)*, M. Morales (1), B. Colldeforns (1), A. Morata (1), M.C. Monterde (2), J.A. Calero (2), A. Tarancón (1)
(1) IREC, Catalonia Institute for Energy Research, Dept of Advanced Materials for Energy Applications, Jardins de les Dones de Negre 1, Planta 2, 08930, Sant Adriá del Besós, Barcelona, Spain
(2) AMES Carrer de Laureà Miró, 388, 08980 Sant Feliu de Llobregat, Barcelona
mtorrell@irec.cat

Abstract

One of the main issues that affect the long-term stability of the SOFC stacks is the cathode drop of performance due to its poisoning lead by the chromium poisoning coming from the diffusion of this element from the metallic interconnects. These generated chromium species block the electrochemical active sites of the cathode and generates insulator phases, which cause high cathode polarization resistance those contributions to the final increase of the area specific resistance of the cell (ASR) **[1]**. In order to avoid the undesired chromium diffusion and cathode poisoning, protective layers have been studied and deposited above the metallic interconnects. The deposited layers act as element migration barriers between the cathode and the stainless steels interconnects **[2]**. In the present study, two different materials (Ni-based superalloy and Mn-Co spinel oxide) have been tested as protective coatings. The protective barriers have been deposited on a set of ferritic interconnect plates (Fe-35%Cr based alloy) fabricated by powder metallurgy and used as interconnects of anode supported solid oxide fuel cells (SOFC). Used cells consist in a Ni-YSZ cermet anode support with yttria-stabilized zirconia (YSZ) as an electrolyte and a lanthanum strontium cobalt ferrite oxide (LSCF) as a cathode material. Gadolinium-doped ceria (GDC) was used as a barrier layer between cathode and electrolyte to prevent the formation of insulator secondary phases, such as $SrZrO_3$ or $La_2Zr_2O_7$. The complete stack repetition unit formed by the SOFC and two interconnect plates has been tested at 750 ºC. Effectiveness of protective layers has been microstructurally evaluated by X-ray diffraction (XRD) and scanning electron microscopy (SEM, Zeiss Auriga), and microanalysis compositional maps were carried out by EDX with an Oxford Inca Pentafet X3 energy-dispersive X-ray analyser. The application of Mn-Co spinel oxides and Ni-based superalloys coatings on Fe-Cr metallic interconnects has shown a significant reduction of Cr migration improving the final performance of the whole system.

A0816 (Will be published elsewhere)

Low carbon gases direct feeding to SOFC: operative strategies to reduce anode degradation

Arianna Baldinelli (1), Linda Barelli (1), Gianni Bidini (1)
(1) Università degli Studi di Perugia – Dipartimento di Ingegneria
Via Duranti 93, 06125 Perugia, Italia
Tel.: +39-0755853991
Fax: +39-0755853991
arianna.baldinelli@unipg.it
laboratorio.fuelcell@unipg.it

Abstract

Since methane and biogas are easy-to-handle hydrogen vectors giving rise to low GHG emissions, they are very attractive fuels for the stationary energy generation with Solid Oxide Fuel Cells (SOFCs). Generally, SOFC-equipped systems are provided with an external fuel pre-processing unit, performing methane steam reforming. Because of steam production and compression, system complexity and energy duties grow. However, SOFC high operative temperature enables internal methane decomposition, making direct feeding possible. Nonetheless, considering state-of-the-art Ni-based SOFC anodes, the direct exposure to high-methane fuels produces more relevant and faster degradation mechanisms.

To this concern, as a mitigation measure, the coexistence of an oxygen bearer gas (either air or carbon dioxide) with methane in the SOFC fuel mixture is helpful for the prevention of rapid failure driven by the interaction between solid and gas phases.

Thus, this contribution deals with the evaluation of SOFC performance decay and material degradation when direct feeding with air-diluted natural gas and biogas/upgraded biogas is carried out. The final end is to determine the optimal dilution degree that assures good performances and no material degradation over the time.

The dilution degree of the fuel mixtures of interest is quantified by the oxygen-to-carbon ratio. Varying this parameter in the range of 0.4-1.2, but keeping constant operative temperature and current (namely, 800°C and 500 mA/cm^2), SOFC button cells undergo tests over a time interval of 100 hours and, finally, specimens post-mortem analysis delivers information concerning the material status.

As results, when using air to dilute methane, O/C=0.8 is the best dilution degree (867 mV). On the other hand, while running the cell on biogas, a partial CO_2 separation to get an O/C=0.4 enables good and stable performance (880 mV).

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly. The full paper will be soon available in Applied Energy under the title "SOFC direct fuelling with high-methane gases: optimal strategies for fuel dilution and upgrading to avoid quick degradation" - Baldinelli, Barelli, Bidini, Di Michele, Vivani.

A0817

Degradation of the SOFC anode by contaminants in biogenic gaseous fuels

Michael Geis (1), Stephan Herrmann (1), Sebastian Fendt (1), Hartmut Spliethoff (1)
(1) Institute for Energy Systems, Technische Universität München
Boltzmannstr 15, 85748 Garching/Germany
Tel.: +49-89-289-16355
Fax: +49-89-289-16271
Michael.geis@tum.de

Abstract

Solid oxide fuel cells (SOFCs) have one of the highest efficiencies when converting fuel-gas to electricity. Combining this property with the use of biomass enables a reliable and non-fluctuation form to use renewable energy efficiently even in small operating units. The simplest form of such an integrated system could consist in a gasifier for converting solid biomass to useable fuel-gas, a separation unit for removing particles and the SOFC which uses the fuel gas in an electrochemical reaction to generate electric power. This configuration implies that the SOFC must be resistant to the contaminants (tars, sulphur-, chloride- and alkaline-species) that are leaving the gasifier. Otherwise, the gas must be purified which increases the complexity and therefore the costs of the system. In the current research project, the tolerance of SOFCs regarding contamination in the producer gas of a biomass-gasification is examined. For the experiments, a Fuelcon Evaluator C1000-HT test station together with a mixing station for tars and gaseous contaminants is used. The analyzed anode-supported cells are manufactured by Forschungszentrum Jülich and consist of a NiO/8YSZ anode and an LSFC cathode. First, the degradation when operating the cell with pure syngas is studied, measuring the cell-voltage and the temperature profile along the anode. Subsequently analogous tests with different contaminants will be done.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A0818 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Mechanical properties of $La_{0.6}Sr_{0.4}M_{0.1}Fe_{0.9}O_{3-\delta}$ (M: Co and Ni) perovskites as electrode material for SOFCs

Ali Akbari-Fakhrabadi, Marcelo Orellana, Viviana Meruane
Advanced Materials Laboratory, Department of Mechanical Engineering,
University of Chile
Beauchef 851, Santiago, Chile
Tel.: +56-22-978-4690
Fax: +56-22-689-6057
aliakbarif@ing.uchile.cl

Abstract

$La_{0.6}Sr_{0.4}M_{0.1}Fe_{0.9}O_{3-\delta}$ (M: Co and Ni) perovskite nanostructures were synthesized using low frequency ultrasound assisted synthesis technique. The obtained materials were dried and calcined at 800 ºC for 2 hours. The powder characteristics such as crystal structure, particle size and morphology are analysed by X-ray diffraction (XRD) and High resolution transmission electron microscopy (HRTEM). The TEM and XRD studies revealed the uniform equi-axial shape of the obtained nanostructures with the existence of $La_{0.6}Sr_{0.4}M_{0.1}Fe_{0.9}O_{3-\delta}$ with rhombohedral symmetry (space group: R-3c).
The calcined powders are uni-axially pressed (90 MPa) to fabricate discs sintered at 1250 °C for 2 hours. The elastic behaviour, microhardness and fracture toughness of prepared nanostructires were investigated by impulse excitation (IET) and indentation techniques, respectively. The results of mechanical characterizations show that LSCF and LSNF have similar elastic moduli, however, LSNF shows higher hardness and lower fracture toughness.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1101

Post-Test Analysis of a Solid Oxide Fuel Cell Stack Operated for 35,000h

Norbert H. Menzler (1), Peter Batfalsky (2), Alexander Beez (1), Ludger Blum (1), Sonja-Michaela Groß-Barsnick (2), Leszek Niewolak (1), Willem J. Quadakkers (1), Robert Vaßen (1)
(1) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK)
Wilhelm-Johnen Str., D-52425 Jülich, Germany
(2) Forschungszentrum Jülich GmbH, Central Institute for Engineering, Electronics and Analytics (ZEA)
Wilhelm-Johnen Str., D-52425 Jülich, Germany
Tel.: +49-2461-613059
n.h.menzler@fz-juelich.de

Abstract

Solid oxide fuel cell (SOFC) systems for decentralized, stationary energy conversion are aiming at lifetimes of 40,000 to 80,000 h of operation. During these extraordinary long operation times degradation should be as low as possible to ensure guaranteed power at the end-of-life. Voltage degradation rates of less than 0.25 % per 1,000 h are envisaged. Forschungszentrum Jülich (JÜLICH) is operating SOFC short-stacks routinely with different goals, e.g. effect of new materials for any single component, and of new manufacturing technologies, or the influence of operational conditions, and understanding of degradation effects at the short, middle and large time scale. In the latter, in the past four years a 4 layer short-stack has been operated for ~ 35,000 h under steady galvanostatic conditions (0.5 A/cm²) at 700 °C and with a fuel utilization of 40 %. An overall mean voltage degradation rate of approx. 0.3 % per 1,000 h was observed. Due to enhanced degradation in one layer the stack has been shut down and subsequently post-test analysis was performed to get more insight into materials interactions, materials and microstructural changes and the influence of the long operation time on the overall stack appearance. For this post-test analysis the complete stack was embedded to one third (parallel to gas flow direction) into a polymeric resin and cut into numerous single samples for cross-sectional analyses. The non-embedded part was dismantled and parts of the layers were cut for characterization by various surface analysis techniques. Special emphasis during post-test analysis was e.g. put on the glass-ceramic - interconnect interaction, the microstructure and composition of the atmospheric plasma-sprayed chromium retention layer, cell degradation effects like particle coarsening, as well as chromium interaction with the cathode and other gaseous contaminants.
The presentation will give an overview on the characterized effects and possible conclusions which may be drawn with respect to long-term degradation behavior.

A1102

Understanding lifetime limitations in the Topsoe Stack Platform using modeling and post mortem analysis

Peter Blennow, Jeppe Rass-Hansen, Thomas Heiredal-Clausen, Rainer Küngas, Tobias Holt Nørby, Søren Primdahl
Haldor Topsoe A/S, Haldor Topsøes Allé 1, DK-2800 Kgs. Lyngby / Denmark
Tel.: +45 2552 9424
pebl@topsoe.dk

Abstract

Haldor Topsoe A/S has in recent years developed a stack technology, the Topsoe Stack Platform (TSP), based on solid oxide cells that can run in both electrolysis and fuel cell mode. However, operating the stacks in different modes also gives rise to altered temperature profiles, current density profiles, and local gas concentration variations. Most major lifetime limiting mechanisms are complex functions of temperature, current density, gas composition, gas flow rate and other parameters. None of these parameters are constant throughout the stack during operation. One way to understand the interplay between operating conditions and stack degradation is via multiphysics modeling. We have developed an advanced 3D stack model capable of predicting the performance of a stack, as well as the local temperatures, gas compositions, current densities etc. at given global conditions (see Figure 1). The model has been verified by insertion of various probes in stacks, and it has been shown to capture both cell voltages and temperature distribution well. This work illustrates how modeling can be used to understand the effects of these variations and to improve lifetime and robustness of the stacks by choosing an appropriate operating strategy.

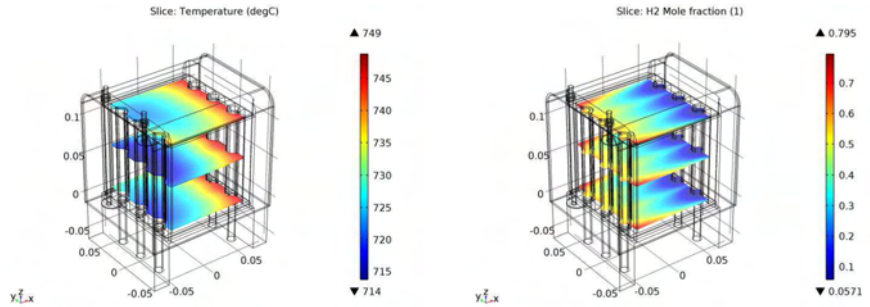


Figure 1. 3D stack model for predicting e.g. the local temperatures and H_2 mole fraction at given global conditions. Example with steam electrolysis @ 750 °C and -70A.

A1103 (Will be published elsewhere)

Understanding of SOEC Degradation Processes by means of a Systematic Parameter Study

Michael P. Hoerlein, Vitaliy Yurkiv, Günter Schiller, K. Andreas Friedrich
German Aerospace Center (DLR)
Institute of Engineering Thermodynamics
Pfaffenwaldring 38-40, 70569 Stuttgart, Germany
Tel.: +49-711-6862-279
Michael.Hoerlein@dlr.de

Abstract

Solid Oxide Electrolysis Cell (SOEC) technology is a promising approach for storing large quantities of electrical energy as hydrogen fuel. One obstacle for wide spread implementation is the cell's limited durability due to a number of degradation phenomena. Therefore, understanding the origin and evolution of degradation processes is essential for developing durable SOEC technology. The present study aims at identifying and characterizing the predominant degradation phenomena of planar Ni/YSZ|YSZ|CGO|LSCF anode supported CeramTec cells operating on H_2/H_2O mixtures, by investigating the influence of operating parameters on cell deterioration.
In order to systematically study the influence of temperature in a range between 750°C and 850°C and fuel gas humidity in a range between 40 mol.-% and 80 mol.-% on SOEC degradation a matrix of experiments over 1000 hours each was devised. Furthermore, the influence of the current density was determined in a range between OCV and 1.5 $A \cdot cm^{-2}$ for each investigated combination of temperature and humidity, thereby gaining insight into coupled correlations between operating parameters and SOEC degradation. In order to shed light on underlying physico-chemical processes and performance limiting factors a detailed physico-chemical modeling approach was employed. A more detailed description of the model and the results is given in a second contribution to this conference (B0811). Periodic in-situ impedance measurements were used to track the development of each individual process over the duration of the experiment. The observed degradation characteristics of each process vary greatly including constant degradation, decreasing degradation and stable behavior, depending on the nature of the processes as well as the operating parameters applied. Finally, the in-situ degradation observations were substantiated by post mortem analyses. In order to identify microstructural changes especially those appeared in electrolyte and fuel electrode SEM measurements were conducted, while EDX measurements were used to monitor elemental enrichment or depletion as well as impurity deposition. Furthermore, changes in surface and bulk crystallography were investigated by XPS and XRD measurements.
Hence, this systematic experimental study on SOEC degradation coupled with the physico-chemical understanding from the modeling approach allows not only the development of strategies for increasing cell's lifetime but could also be used to determine experimental protocols for accelerated degradation.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1104

Durability assessment of SOFC stacks with several types of structures for thermal cycles during their lifetimes on residential use

Koki Sato (1), Takaaki Somekawa (1), Toru Hatae (1), Shinji Amaha (1), Yoshio Matsuzaki (1), Masahiro Yoshikawa (2), Yoshihiro Mugikura (2), Hiroshi Sumi (3), Makoto Ohmori (4), Harumi Yokokawa (5)
(1) Tokyo Gas Co., Ltd.
3-13-1, Minamisenju, Arakawa-ku, TOKYO, JAPAN
(2) Central Research Institute of Electric Power Industry
(3) NGK SPARK PLUG CO., LTD.
(4) NGK INSULATORS, LTD.
(5) The University of Tokyo
Tel.: +81-3-5604-8285
Fax: +81-3-5604-8051
k-sato1218@tokyo-gas.co.jp

Abstract

We have been developing a rapid evaluation method for assessing the durability of SOFC stacks for thermal cycles during their lifetimes based on the assumption of residential use. The durability for thermal cycles is expected to be affected by the degradation in the long-term operation. In order to accelerate the evaluation, some treatments to intentionally cause the degradation were conducted. We determined a degradation factor depending on the different structures of SOFC stacks. This is because each degradation mechanism depends on the stack structure in the long-term. The SOFC stacks were supplied by four SOFC stack manufacturers in Japan. In this work, we conducted a heat oxidation treatment to coated interconnects in planer SOFCs (manufactured by NGK SPARK PLUG) and a S poisoning treatment to flattened tubular segmented-in-series SOFCs (manufactured by NGK INSULATORS). In both cases, we were able to cause 10 years' worth of degradation intentionally in a short period of time.

A1107 (Will be published elsewhere)

Performance Modelling of anode supported cells on a SOFC stack layer level

Helge Geisler (1)*, Jochen Joos (1), André Weber (1) and Ellen Ivers-Tiffée (1)
(1) Institute for Applied Materials (IAM-WET)
Karlsruhe Institute of Technology (KIT), D-76131 Karlsruhe, Germany
Tel.: +49-721-608-41732
Fax: +49-721-608-47492
helge.geisler@kit.edu

Abstract

Planar SOFC stack performance depends on various parameters, but an appropriate choice of cell components and metallic interconnector (MIC) design is a precondition for success. Recent 2D FEM modelling showed [1-3], that matching of a mixed ionic-electronic conducting (MIEC) cathode layer with the metallic interconnector (MIC) design is essential. In this work, we present a further developed 2D FEM model, wherein we use a homogenized surface kinetic (k^{δ}) and oxygen bulk-diffusion (D^{δ}) based modeling approach to model the MIEC cathode polarization kinetics. In this way, we were able to implement electrochemical reaction kinetics of different mixed ionic-electronic conducting (MIEC) cathodes as LSCF, LSC, BSCF from own experiments and from literature in the model.
It will be shown by stationary performance predictions, how material and microstructural parameters as k^{δ}, D^{δ} of MIEC cathode layer and porosity/tortuosity of an applied current collector layer (CCL) determine the performance of anode supported SOFC stacks, and how a well-chosen associated MIC design can further enhance power output.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

A1108 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

An environmental and energetic performance assessment of an integrated power-to-gas concept system

Dimitrios Giannopoulos* (1), Marianna Stamatiadou (1), Manuel Gruber (2), Maria Founti (1), Dimosthenis Trimis (2)
(1) Laboratory of Heterogeneous Mixtures and Combustion Systems, Thermal Engineering Section, School of Mechanical Engineering, National Technical University of Athens, Athens, Greece
(2) Karlsruhe Institute of Technology, Engler-Bunte-Institute, Karlsruhe, Germany
Tel.: +30-210-772-1218
Fax: +30-210-772-3527
*digiann@central.ntua.gr

Abstract

The present paper presents the initial environmental Life Cycle Assessment (LCA) of a highly efficient Power-to-Gas (PtG) concept system, featuring methane as a chemical storage and thermal integration of high temperature electrolysis (SOEC) with methanation. The major objective is to assess the environmental and energetic performance of a “base case” scenario, involving assumptions regarding the CO_2 input feed and the generation mix of the electricity demand. The analysis refers to a “cradle-to-gate” approach, modelling the upstream energy/material flows which lead to the production of 1 m3 of Synthetic Natural Gas (SNG). Assuming a strong trend towards renewable generation and the utilization of CO_2 output from a bioenergy plant, reveals the potential of a fossil CO_2 and primary energy “sink effect”, since more fossil emissions and primary energy are avoided than emitted/consumed.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

Chapter 07 - Session B06

Electrolytes, interconnects, seals

Content **Page B06 - ..**

B0601 ... 4
Usage of Ceria for Solid Oxide Electrochemical Cells **4**
Hirofumi Sumi (1), Eisaku Suda (2), Masashi Mori (3) 4
B0602 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 5
Intermediate temperature proton conducting fuel cells for transportation applications **5**
S. Elango Elangovan (1), Dennis Larsen (1), Cortney Kreller (2), Mahlon Wilson (2), Yu Seung Kim (2), Kwan Soo Lee (2), Rangachari Mukundan (2), Nilesh Dale (3) 5
B0603 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 6
Thin film perovskite coatings and their application for SOFC ferritic steel interconnects **6**
Stefano Frangini (1), Andrea Masi (1,2), Manuel Bianco (3), Jong-Eun Hong (4), Maurizio Carlini (2), Jan Van Herle (3), Robert Steinberger-Wilckens (4) 6
B0604 (Will be published elsewhere) ... 7
Effect of temperature on the oxidation and Cr evaporation behavior of Co and Ce/Co coated steel **7**
Hannes Falk-Windisch, Julien Claquesin, Jan-Erik Svensson, Jan Froitzheim 7
B0605 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 8
Benchmarking Protective Coatings for SOFC ferritic steel interconnects – The SCORED 2:0 Project **8**
Robert Steinberger-Wilckens (1), Shicai Yang (2), Kevin Cooke (2), Johan Tallgren (3), Olli Himanen (3), Stefano Frangini (4), Andrea Masi (4,5), Manuel Bianco (6), Jan Van herle (6), Jong-Eun Hong (1), Melissa Oum (1), Francesco Bozza (7), Alessandro Delai (8) 8
B0606 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 9
Glass ceramic sealants for CFY based SOFC **9**
Jochen Schilm (1), Axel Rost (1), Mihails Kusnezoff (1), Alexander Michaelis (1) 9
B0607 (Abstract only) ... 10
Hee Lak Lee (1), Hyeong Cheol Shin (1), Ji Haeng Yu (2), Su Jeong Lee (2), Kyoung Tae Lim (1)* 10
B0608 (see B0603) ... 11
B0609 (Will be published elsewhere) ... 12
Mechanical stability aspects of SOFC sealants **12**
Jianping Wei, Goran Pećanac, Sonja M. Gross-Barsnick, Dirk Federmann, Jürgen Malzbender 12
B0610 (Will be published elsewhere) ... 13
A combined microstructural and ionic conductivity study of multiple aliovalent doping in ceria electrolytes **13**
Alice V. Coles-Aldridge, Richard T. Baker* 13
B0611 (Will be published elsewhere) ... 14
On the Lifetime of Coated Ferritic Steels used as SOFC interconnects **14**
Rakshith Sachitanand, Maria Nikumaa, Sead Canovic, Jan-Erik Svensson, Jan Froitzheim 14
B0612 ... 15

12th European SOFC & SOE Forum 2016 5 - 8 July 2016, Lucerne Switzerland

Densification of Cerium Pyrophosphate-Polystyrene Composite as Electrolytes of PCFCs **15**
Jae-Woon Hong, Ha-Ni Im, In-Ho Kim, Sun-Ju Song 15
B0613 (Abstract only, published elsewhere) ... 16
Nitriding influence on SOFC ferritic steel interconnects **16**
Manuel Bianco (1), Shicai Yang (2), Johan Tallgren (3), Jong-Eun Hong (4), Olli Himanen (3), Kevin Cooke (2), Robert Steinberger-Wilckens (4), Jan Van herle (1) 16
B0614 (Abstract only) ... 17
Precoated EN 1.4622 and EN 1.4509 For SOFC Interconnect Steel **17**
Mats W Lundberg, Robert Berger, Jörgen Westlinder 17
B0615 ... 18
Charge and Mass Transport Properties of BaCe0.9Y0.1O3-δ **18**
Ha-Ni Im, Dae-Kwang Lim, Jae-Woon Hong, In-Ho Kim, and Sun-Ju Song 18
B0616 ... 19
Characterization of Porous Stainless Steel 430L for Low Temperatures Solid Oxide Fuel Cell Application **19**
Kyung Sil Chung, Lingyi Gu, Sannan Toor, Eric Croiset 19
B0618 ... 20
Electrical interconnect based on AISI 430 stainless steel coated with recycled cobalt from spent Li-ion batteries **20**
Eric Marsalha Garcia (1), Hosane Aparecida Taroco (1), Rubens Moreira de Almeida (2), *Antonio* de Padua Lima *Fernandes* (2), Rosana Zacarias Domingues (2), Tulio Matencio (2) 20
B0619 ... 21
Comparison of different manganese-cobalt-iron spinel protective coatings for SOFC interconnects **21**
Johan Tallgren (1), Manuel Bianco (2), Jyrki Mikkola (1), Olli Himanen (1), Markus Rautanen (1), Jari Kiviaho (1), Jan Van herle (2) 21
B0620 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 22
La-Fe Perovskite Thin Film Coatings of Ferritic Stainless Steels by Surface Chemical Conversion: Dual Atmosphere Oxidation Testing **22**
Andrea Masi (1,2), Davide Pumiglia (1,2), Maurizio Carlini (2), Amedeo Masci (1), Stephen McPhail (1), Stefano Frangini (1) 22
B0621 ... 23
Insight of Reactive Sintering in Manganese Cobalt Spinel Oxide of Protective Layer for Solid Oxide Fuel Cell Metallic Interconnects **23**
Jong-Eun Hong (1), Andrea Masi (1, 2), Manuel Bianco (3), Jan Van herle (3), Robert Steinberger-Wilckens (1) 23
B0623 (Will be published elsewhere) ... 24
High performance ceria-carbonate composite electrolytes for low temperature hybrid fuel cells **24**
Ieeba Khan (1), Muhammad Imran Asghar (2), Peter D. Lund (2), Suddhasatwa Basu (1) 24
B0624 (Abstract only) ... 25
Fabrication of MS-SOFC by Electrophoretic Deposition Technique and its Characterization **25**
Shambhu Nath Maity, Debasish Das, Biswajoy Bagchi, Rejendra N. Basu* 25
B0625 (Abstract only) ... 26
Synthesis and studies of $BaCe_{0.7}Zr_{0.1}Y_{0.1}Pr_{0.1}O_{3-\delta}$ perovskite material for IT-SOFCs **26**
Shahzad Hossain, Juliana Hj Zaini, Abul Kalam Azad 26
B0626 ... 28

Composite $Nd_{0.1}Ce_{0.9}O_{1.9}$ - $BaZr_{0.1}Ce_{0.7}Y_{0.2-x}Yb_xO_3$ electrolytes for intermediate temperature-solid oxide fuel cells 28
Ka-Young Park (1), Jun-Young Park (1) 28
B0627 (Abstract only, published elsewhere) 29
Joint strength of an SOFC glass-ceramic sealant with LSM-coated metallic interconnect 29
Chih-Kuang Lin (1), Fan-Lin Hou (1), Atsushi Sugeta (2), Hiroyuki Akebono (2), Szu-Han Wu (3), Peng Yang (3) 29
B0628 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 30
Nanoindentation of La-Fe Oxide Perovskite Thin Films for Solid Oxide Fuel Cells Steel Interconnects: First Findings 30
Andrea Masi (1,2), Ivan Davoli (3), Massimiliano Lucci (3), Maurizio Carlini (2), Amedeo Masci (1), Stephen McPhail (1), Stefano Frangini (1) 30
B0629 31
Investigation of Advanced Cathode Contacting Solutions in SOFC 31
Patric Szabo (1), Remi Costa (1), Manho Park (2), Bumsoo Kim (2), Insung Lee (3) 31
B0630 (Abstract only) 32
Co-deposition of rare earths along with $(Mn,Co)_3O_4$ spinel as a protective coating for SOFC metallic interconnects 32
Vinothini Venkatachalam (1), Sebastian Molin (1), Wolf-Ragnar Kiebach (1), Ming Chen (1), Peter Vang Hendriksen (1) 32
B0631 34
Cu-Fe substituted Mn-Co spinels by High Energy Ball Milling for interconnect coatings: insight on sintering properties 34
Andrea Masi (1,2,3), Jong-Eun Hong (3), Robert Steinberger-Wilckens (3), Maurizio Carlini (2), Mariangela Bellusci (1), Franco Padella (1), Priscilla Reale (1) 34
B0632 35
Electrolyte supported cells with thin electrolytes 35
Hendrik Pöpke, Franz-Martin Fuchs 35

12th European SOFC & SOE Forum 2016 5 - 8 July 2016, Lucerne Switzerland

B0601

Usage of Ceria for Solid Oxide Electrochemical Cells

Hirofumi Sumi (1), Eisaku Suda (2), Masashi Mori (3)
(1) National Institute of Advanced Industrial Science and Technology (AIST)
2266-98, Anagahora, Simo-shidami, Moriyama-ku, Nagoya 463-8560 / Japan
(2) Anan Kasei Co., Ltd.
210-51, Ogata-cho, Anan, Tokushima 774-0022 / Japan
(3) Central Research Institute of Electric Power Industry (CRIEPI)
2-6-1, Nagasaka, Yokosuka, Kanagawa 240-0196 / Japan
h-sumi@aist.go.jp

Abstract

Doped ceria is one of the most promising materials for an electrolyte of solid oxide fuel cells (SOFCs) and electrolysis cells (SOECs), because it has higher ionic conductivity than stabilized zirconia. However, current leakage through the ceria-based electrolyte occurs in SOFC and SOEC operating conditions, because electron conductivity appears at low oxygen partial pressures. This current leakage decreases energy conversion efficiency for SOFCs and hydrogen evolution rate for SOECs. In order to prevent the current leakage, the blocking layer of perovskite-type strontium or barium cerate was inserted between the ceria electrolyte and Ni-based electrode. Y-doped barium cerate is a proton-O^{2-} mixed conductor. The increase in the open circuit voltage and the demonstration of SOFC and SOEC using the ceria-based electrolyte and the barium cerate blocking layer was succeeded with keeping high performance at a low operating temperature of 500 ^{o}C.

B0602 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Intermediate temperature proton conducting fuel cells for transportation applications

S. Elango Elangovan (1), Dennis Larsen (1), Cortney Kreller (2), Mahlon Wilson (2), Yu Seung Kim (2), Kwan Soo Lee (2), Rangachari Mukundan (2), Nilesh Dale (3)
(1) Ceramatec, Inc., 2425 South 900 West, Salt Lake City, UT 84119-1517, USA
(2) Los Alamos National Laboratory, Los Alamos, NM 87545, USA
(3) Nissan Technical Center, Farmington Hills, MI 48331, USA
Tel.: +1-801-978-2162
Fax: +1-801-972-1925
elango@ceramatec.com

Abstract

Current fuel cells for transportation applications use polymer electrolytes that require platinum catalysts and operate around 80 °C due to water management issues and limiting properties of that polymer electrolyte. At elevated temperature, the electrolyte dries out and rapidly loses conductivity and gradually degrades, and at low temperature, liquid water floods the electrode resulting in performance losses. Low temperature makes stack cooling difficult and favors carbon monoxide poisoning of the catalyst. A paradigm shift in automotive fuel cells can be achieved with an intermediate temperature proton conducting solid-electrolyte that can operate above 150 °C.

A fuel cell using a Tin Pyrophsophate (TPP) based electrolyte holds the promise of anhydrous fuel cell operation capable of quick start-ups from ambient and extended operation up to 250 °C. This intermediate temperature operation can greatly simplify thermal management and enable the use of non-precious or low loading of precious metal catalysts due to the faster kinetics and the absence of phosphate inhibition of the oxygen reduction reaction. The anhydrous electrolyte resolves water management issues and dramatically simplifies the system and lowers the costs. In addition, the less corrosive dry environment improves durability relative to current state-of-the-art PEM fuel cells. Furthermore, the 150 – 250 °C operation overcomes difficulties with carbon monoxide to allow the direct use of liquid alternatives to hydrogen such as methanol or dimethyl ether.

The TPP technology is transformational and has the potential to be disruptive in the future. This project aims to move the technology from small concept demonstration of the electrolyte in fuel cell applications to an actual short stack capable of meeting stringent requirements of automotive transportation.

Acknowledgment: The information, data, or work presented herein was funded in part by the Advanced Research Projects Agency-Energy (ARPA-E), U.S. Department of Energy, under Award Number DE-AR0000314.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0603 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Thin film perovskite coatings and their application for SOFC ferritic steel interconnects

Stefano Frangini (1), Andrea Masi (1,2), Manuel Bianco (3), Jong-Eun Hong (4), Maurizio Carlini (2), Jan Van Herle (3), Robert Steinberger-Wilckens (4)
(1) ENEA CR Casaccia, Via Anguillarese 301 00123 Rome, Italy
(2) DAFNE, University of Tuscia, via San Camillo de Lellis snc 01100 Viterbo, Italy
(3) FUELMAT Group, Inst. Mech. Eng., Ecole Polytechnique Fédérale de Lausanne Valais (EPFL Valais), CH-1950 Sion, Switzerland
(4) Centre for Fuel Cell and Hydrogen Research, School of Chemical Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
Tel.: +39-06-3048-3138
stefano.frangini@enea.it

Abstract

High electrical contact resistance and Cr evaporation are two well recognised technical issues in reliable long-term use of ferritic stainless steel interconnects in solid oxide fuel cells (SOFCs). They have a crucial negative impact on the cell performance and stability, if not adequately addressed. During the last years, many types of conductive ceramic oxides with either a spinel or perovskite lattice structure have been investigated as protective oxide layers for SOFC interconnect applications. For example perovskites show sufficiently high electronic conductivity, good matching of the thermal expansion coefficient (TEC), chemical stability in SOFC-operating environments and low cation mobility. Nevertheless, their performance has been often reported to be below expectations due to poor adherence and higher difficulty in obtaining densely sintered layers in comparison to spinel coatings. As a new attempt to address such aspects, a novel chemical conversion process has been developed for producing dense thin films (below 1 µm) of $LaFeO_3$-based perovskite coatings on ferritic stainless steel surfaces, under relatively low temperature conditions. Commercially available ferritic 22Cr steels (Crofer 22H and Sanergy HT steels) have been used to evaluate electrical contact resistance, corrosion stability and Cr evaporation of the perovskite-modified stainless steel surfaces in medium-term tests at 700°C. X-ray diffraction (XRD) analysis and scanning electron microscopy (SEM) equipped with energy dispersive X-ray analysis (SEM-EDX) have been used to characterise the materials before and after testing. Results show that a stable electrical contact resistance is obtained at 700°C, well below the target value of 0.05 Ωcm^2 at this temperature, for both coated steels. Coated Sanergy HT steel show a somewhat better Cr retention, although not to a fully satisfactory degree. Further efforts are still required for obtaining improved Cr barrier performance on 22Cr steels.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0604 (Will be published elsewhere)

Effect of temperature on the oxidation and Cr evaporation behavior of Co and Ce/Co coated steel

Hannes Falk-Windisch, Julien Claquesin, Jan-Erik Svensson, Jan Froitzheim
Chalmers University of Technology, Energy and Materials
Kemivägen 10, SE-41296 Gothenburg / Sweden
Tel.: +46-31-772-2850
hannes.windisch@chalmers.se

Abstract

In recent years SOFC manufacturers have been able to decrease the operating temperature significantly and today several anode- and metal-supported designs are able to operate at temperatures as low as 600-700 ˚C. One of several advantages of a lower operating temperature is the possibility to use less expensive materials for example for the interconnects. Within the last decade extensive research has been carried out investigating the two main degradation mechanisms related to the use of Cr_2O_3-forming steels as interconnect material; Cr species vaporization and oxide scale growth. Development of specially designed alloys as well as reactive element surface treatments have been shown to improve corrosion resistance and a wide range of spinel based coating systems have been shown to effectively mitigate Cr vaporization. However, the vast majority of studies which investigate the mitigation of Cr vaporization in combination with oxide scale growth, were carried out at significantly higher temperatures in the range 800-900 ˚C, often to accelerate the mentioned degradation mechanisms. Cr vaporization and oxide scale growth are however two separate degradation mechanisms where oxide scale growth shows a much stronger temperature dependence than Cr volatilization. The aim with this work is therefore to investigate commercially available interconnect materials in a typical IT-SOFC temperature regime. This work focuses on oxide scale growth, microstructure, chemical composition, Cr volatilization as well as ASR. The materials investigated were Sanergy HT (manufactured by AB Sandvik Materials Technology) coated with either 640 nm metallic Co or a dual coating of 10 nm Ce + 640 nm Co as well as the uncoated material as a reference. The three materials were exposed for more than 3000 h at 650 and 750 ˚C in air + 3% H_2O using a high flow rate. The obtained results show that the additional thin layer of Ce reduces oxide scale growth even at lower temperatures. Furthermore, the metallic Co coating did effectively suppress Cr vaporization at reduced temperatures even though the chemical composition of the oxidized Co coating differed from that formed at higher temperatures.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0605 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Benchmarking Protective Coatings for SOFC ferritic steel interconnects – The SCORED 2:0 Project

Robert Steinberger-Wilckens (1), Shicai Yang (2), Kevin Cooke (2), Johan Tallgren (3), Olli Himanen (3), Stefano Frangini (4), Andrea Masi (4,5), Manuel Bianco (6), Jan Van herle (6), Jong-Eun Hong (1), Melissa Oum (1), Francesco Bozza (7), Alessandro Delai (8)
(1) Centre for Fuel Cell and Hydrogen Research, School of Chemical Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
(2) Teer Coatings Ltd, Miba Coating, Berry Hill Industrial Estate, Droitwich WR9 9AS, UK
(3) VTT Technical Research Centre, Fuel Cells, P.O. Box 1000, 02044 Espoo, Finland
(4) ENEA CR Casaccia, Via Anguillarese 301, 00123 Rome, Italy
(5) DAFNE, University of Tuscia, via San Camillo de Lellis snc, 01100 Viterbo, Italy
(6) FUELMAT Group, EPFL, Valais (EPFL Valais), 1950 Sion, Switzerland
(7) Turbocoating S.p.a., 43040 Rubbiano di Solignano (PR), Italy
(8) SOLIDpower S.p.a., Via Trento 115/117, 38017 Mezzolombardo, Italy
Tel.: +44-121-415-8169
r.steinbergerwilckens@bham.ac.uk

Abstract

Solid Oxide Fuel Cells are considered as one prime technology for residential CHP and power generation applications. Employment in these sectors requires long operational lifetime beyond 10 years. This corresponds to anything between 20,000 and 100,000 hours of operation. In order to ‘survive’ this extended period of time with the challenging conditions set by SOFC operating parameters (high temperatures, high water content, dual atmospheres across the interconnects etc.) the steel interconnects employed by most current developers require a protective coating to prevent excessive oxidation and release of chromium. A number of different coatings and coating processes have been suggested in the past, ranging from wet powder spraying of MnCo oxides to PVD coating of thin commercial steel sheets with Co and Ce.

The SCORED 2:0 is attempting to benchmark coating materials and the processes they are applied with. The project follows three goals:
1. analyse which is the best process to apply specific materials that have been discussed for SOFC interconnect protective coatings,
2. search for new materials and processes to apply protective coatings, and
3. benchmark the processes and materials against the commercial state of the art.

The expected outcome is a systematic analysis of the interplay between materials, steel substrate, and the physico-chemical processes used to apply the layers.
This contribution offers the overview and summary to the more specialised papers submitted in parallel.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0606 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Glass ceramic sealants for CFY based SOFC

Jochen Schilm (1), Axel Rost (1), Mihails Kusnezoff (1), Alexander Michaelis (1)
(1) Fraunhofer IKTS.
Winterbergstr. 28, 01277 Dresden, Germany
Tel.: +49-351-2553-7824
Fax: +49-351-2553-7600
Jochen.schilm@ikts.fraunhofer.de

Abstract

The integration of single cells in stack requires gastight and long-term stable sealing materials. Within the recent years glass-ceramic materials have been proven as reliable sealants for various planar SOFC stack designs as they can be adapted to the joining conditions such as maximal allowed sealing temperature and satisfy the end-user requirements such as long-term stability. Beside the intrinsic properties of the glass ceramic sealants in terms of their CTE, softening, crystallization and sealing behavior, especially the interactions with metallic interconnector have considerable influence on the longevity of the joints. All known published studies on this topic focus only on chromium containing ferritic steels with composition similar to well-known Crofer 22 APU as metallic interconnectors. In previous studies the earth alkaline oxides SrO and BaO have been identified as critical glass components, which react to $RCrO_4$-scales (R=Sr, Ba) at the interconnect interfaces in presence of atmospheric oxygen.
The present study focuses on the development of glass-ceramic sealants, which have a chemical compatibility to chromium based sinter alloys (i.e. CFY from Plansee SE) which are successfully utilized as SOFC interconnects. As the very high Chromium content promotes the reaction with the sealant resulting in chromate formation it becomes necessary to reduce the reactive components (BaO, SrO) in the glass-ceramics. However, especially these components are responsible for the adjustment of the intrinsic properties of the sealant. A partially crystallizing glass compositions located in the (BaO,CaO)-Al2O3-SiO2-system have been selected as the basis for the development process. The results show how the particular glass components influence both the intrinsic glass-ceramic properties and the reactivity in contact with the CFY-material. Investigations on the latter processes have been conducted with model samples in a self-developed dual-atmosphere test rig under SOFC-typical operating conditions. Selected glasses have been tested in real SOFC stacks. The observed phenomena are discussed in terms of glass properties, gas tightness of the seals, changes in the microstructure and at the interfaces of joints. Sorrow optimization of glass composition allowed to develop glass-ceramic sealants with adjusted coefficient of thermal expansion (CTE), appropriate sealing temperature range and no chromate formation at the interface with uncoated CFY interconnect. The results presented in this paper have been also submitted to the Journal of the European Ceramic society for publication.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0607 (Abstract only)

Improved Durability of ScSZ Electrolyteby Addition of RE_2O_3 (RE=Gd, Yb, Sm)

Hee Lak Lee (1), Hyeong Cheol Shin (1), Ji Haeng Yu (2), Su Jeong Lee (2), Kyoung Tae Lim (1)*
(1) KCeraCell Co., Ltd.
Dabok-ro 465-9, Geumsan-gun, Chungcheongnam-do 312923, Republic of Korea
(2) Korea Institute of Energy Research (KIER)
Gajeong-ro 152, Daejeon 34129, Republic of Korea
Tel.: +82-41-753-8611
Fax: +82-41-753-8612
kceracell@gmail.com

Abstract

Scandia stabilized zirconia (ScSZ) has been widely used as an electrolyte of solid oxide cells since the oxide ion conductivity is the highest among the zirconia systems. CeO2 is added (typically 1 mol%) to prevent degradation of ionic conductivity caused by it partial transformation into tetragonal phase. However, even with the addition of CeO2, minor phase transformation at the grain boundary in reducing atmosphere and thus increase of resistance is inevitable.[1] In this study, we prepared new composition of ScSZ electrolytes by substitution of Ce partly or fully with rare-earth elements such as Gd, Yb, and Sm. The structural degradation is investigated. It is found that the substitution of Ce with RE_2O_3 (RE=Gd, Yb, Sm) improves the durability of electrolyte in H_2. Based on the degradation results, Yb and Sc co-doped zirconia was used as an electrolyte of Ni-YSZ anode supported cells. Anode and electrolyte casting tapes were laminated and sintered into disk. The anode supported cell with the cathode (LSCF) area ~0.5 cm^2 showed a maximum power density of ~3 W/cm^2 at 750 ^oC. A large area anode supported cell (electrode area=81 cm^2) was also successfully manufactured from the casting tapes. The effects of RE_2O_3 (RE=Gd, Sm, Yb) addition on the structural stability and electrical degradation rate of ScSZ are discussed.

(1) Z. Wang et al., Materials Letters 59 (2005) 2579 – 2582

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0608 (see B0603)

B0609 (Will be published elsewhere)

Mechanical stability aspects of SOFC sealants

Jianping Wei, Goran Pećanac, Sonja M. Gross-Barsnick, Dirk Federmann, Jürgen Malzbender
Forschungszentrum Jülich GmbH,
Wilhelm-Johnen-Straße
52428 Jülich, Germany
Tel.: +49-2461-61-9399
Fax: +49-2461-61-3699
j.wei@fz-juelich.de

Abstract

The structural integrity of the sealant is crucial for a reliable operation of solid oxide fuel cell stacks and systems since the leakage of the sealant might lead to a malfunction of the whole system. Hence, fracture properties and elevated temperature deformation need to be assessed, particularly for partially crystallized glass-ceramic sealants that might suffer from instability issues at operation relevant temperatures due to viscoelastic deformation of the residual glass phase. In this work, a modified sealant was characterized, which is a glass matrix on basis of the BaO-CaO-SiO_2 ternary system with a reinforcement by Ag particles. Bending tests were carried out at room temperature and at typical stack operation temperatures on a head-to-head specimen geometry in as-sintered and annealed state, yielding average fracture stresses and creep data. Furthermore, torsion tests were used to investigate the shear strength. The results of the mechanical analyses' are supported by advanced microstructural characterization to gain insight into the annealing and reinforcement filler effects.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0610 (Will be published elsewhere)

A combined microstructural and ionic conductivity study of multiple aliovalent doping in ceria electrolytes

Alice V. Coles-Aldridge, Richard T. Baker*
School of Chemistry, University of St. Andrews
North Haugh, St Andrews, Fife, KY16 9ST, United Kingdom
aca4@st-andrews.ac.uk

*Corresponding author. T: +44 1334 463899; F: +44 1334 463808; E: rtb5@st-andrews.ac.uk

Abstract

Owing to their high oxygen ion conductivity, aliovalently doped ceria electrolyte materials are of great interest for use in solid oxide fuel cells (SOFCs) and oxygen sensors. The accepted strategy for improving ionic conductivity involves doping these materials with trivalent lanthanide elements such as Gd^{3+} and Sm^{3+}. These substitutions, as well as the processing conditions of the final electrolyte materials, influence total conductivity via both microstructure-dependent grain boundary and intrinsic bulk effects. In this study, the effects of aliovalent doping with one, two and more lanthanide elements on these microstructural and intrinsic factors are investigated by preparing and evaluating a series of singly, doubly and triply-substituted ceria electrolytes.
A citrate-nitrate complexation method was used to produce these singly, doubly and triply-doped cerias containing varying amounts of Gd, Sm and Nd. This method results in very pure and fine oxide powders.[1] XRD and TEM were used to determine the crystallography of these materials. The powders were sintered under a standard set of conditions to produce dense ceramic electrolytes for comparison. Impedance spectroscopy was employed to obtain oxygen ion conductivity data at a wide range of temperatures. Both intrinsic and grain boundary conductivity were followed. The effect of grain structure– determined by SEM– on conductivity was determined. A number of other supporting measurements were also performed to confirm the crystal structure and chemical compositions.
The results will be discussed in terms of the advantage or otherwise over the singly-doped materials of combining two and three dopants.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0611 (Will be published elsewhere)

On the Lifetime of Coated Ferritic Steels used as SOFC interconnects

Rakshith Sachitanand, Maria Nikumaa, Sead Canovic, Jan-Erik Svensson, Jan Froitzheim
Department of Chemistry and Chemical Engineering
Chalmers University of
Technology
41279 Gothenburg, Sweden
Tel.: +46-31-772-2748
maria.nikumaa@chalmers.se

Abstract

Cr evaporation from and the rapid oxidation of interconnect materials on the air side of an SOFC are key factors influencing the durability of the fuel cell stack. The issue of Cr evaporation can be effectively mitigated using a 640 nm PVD applied Co coating, while a 10 nm Ce coating is known to improve oxidation resistance. A combination Co/Ce coating has been shown to inherit both positive effects [1]. To study the long term (>3000 h) durability of these coatings and the impact they might have on the lifetime of the steel 0.2 mm thick foils of the 22%Cr ferritic steel Sanergy HT has been exposed discontinuously for >4000 h at 850°C in air+3% H2O @ 6000 sml/min (27 cm/s) in a tubular reactor. Additionally, time resolved, isothermal Cr evaporation measurements for the coated and uncoated steel were carried out over 1000 h. The samples were analyzed using Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) coupled with Energy-dispersive X-ray Spectroscopy (EDX). Mass balances based on oxidation and evaporation data were in good agreement with SEM/EDX Cr concentration measurements in the steel when accounting for sample edge effects, see Figure 1 [2]. A simple lifetime model based on the measured Cr depletion rates was developed and showed that the time to a critical concentration of 15 wt% Cr in the steel bulk increased significantly when the duplex Co 640nm/Ce 10nm coating was used.

References

[1] S. Canovic, J. Froitzheim, R. Sachitanand, M. Nikumaa, M. Halvarsson, L. G. Johansson and J. E. Svensson, *Surface and Coatings Technology*, **215**, 62 (2013).
[2] R. Sachitanand, J. E. Svensson and J. Froitzheim, *Oxidation of Metals*, 1 (2015).

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0612

Densification of Cerium Pyrophosphate-Polystyrene Composite as Electrolytes of PCFCs

Jae-Woon Hong, Ha-Ni Im, In-Ho Kim, Sun-Ju Song
Ionics Laboratory, School of Materials Science and Engineering
Chonnam National University, Gwang-Ju 61186, Republic of Korea
Tel.: +82-62-530-1706
Fax: +82-62-530-1699
song@chonnam.ac.kr

Abstract

Considering the fact that tetravalent metal pyrophosphates (TMPs) have poor sintering-ability and the substrates sintered at high temperatures have poor proton-conductivity, several strategies to utilize TMPs as dense electrolytes in proton-conducting ceramic electrolyte fuel cells(PCFCs) have been reported. Among them, an inorganic-organic composite materials is composed by using polystyrene as a pore-filler in partially sintered cerium pyrophosphate substrates. Gd^{3+}-doped cerium pyrophosphate($Ce_{0.9}Gd_{0.1}P_2O_7$, CGP) and highly cross-linked polystyrene is prepared by polymerization of divinylbenzene monomers in partially sintered CGP substrates. To understand their proton conductivity and long-term stability, the microstructure and electrochemical behavior of the CGP-polystyrene (CGP-PS) composites are investigated.

B0613 (Abstract only, published elsewhere)

Nitriding influence on SOFC ferritic steel interconnects

Manuel Bianco (1), Shicai Yang (2), Johan Tallgren (3), Jong-Eun Hong (4), Olli Himanen (3), Kevin Cooke (2), Robert Steinberger-Wilckens (4), Jan Van herle (1)
(1) FUELMAT group, École Polytechnique Fédérale de Lausanne
17 Rue de l'industrie, CH-1950 Sion
(2) Teer Coatings Ltd, Miba Coating Group
Berry Hill Industrial Estate, Droitwich WR9 9AS, UK
(3) VTT Technical Research Centre of Finland Ltd, Fuel Cells,
P.O. Box 1000, FI-02044, Finland
(4) School of Chemical Engineering, College of Engineering and Physical Sciences
University of Birmingham, Edgbaston B15 2TT, UK
Tel.: +41216936768
manuel.bianco@epfl.ch

Abstract

Nitriding is a process used in industry to improve steel surface properties including hardness and corrosion resistance. The latter property is particularly interesting for SOFC interconnects. To our knowledge, this treatment has not yet been applied to evaluate its performance for the interconnect substrates studied. Besides, nitridation in ferritic steel is rarely encountered in the literature.
This study will introduce the first results on nitrided ferritic steel substrates (Crofer 22 H, K41, Sandvik Sanergy HT) coated with an $(MnCo)_3O_4$ ceramic protective layer and tested under SOFC operating conditions (700 °C, 0.4 Acm^{-2}, 3% humidified air). Different deposition techniques of protective coating, applied after nitriding, have been used and evaluated.
The nitriding effect on the interconnects' electrical conductivity and Cr retention properties has been investigated through ASR measurement and SEM-EDS analysis. It is compared with a series of samples consisting of similar coated steel substrates without prior nitriding.

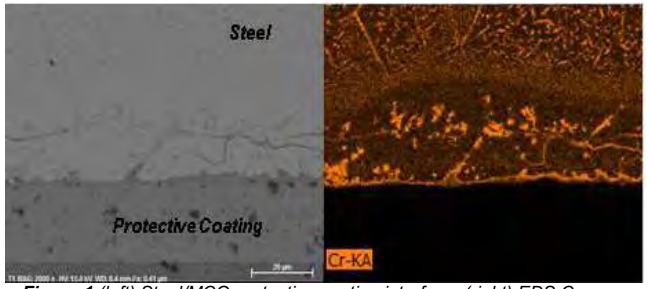


Figure 1 *(left) Steel/MCO protective coating interface, (right) EDS Cr map*

Acknowledgments:
This work was supported by the FCH JU under contract no. 325331.

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

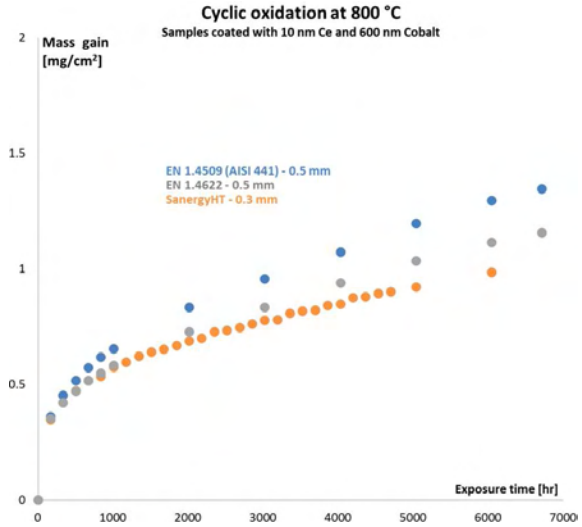
B0614 (Abstract only)

Precoated EN 1.4622 and EN 1.4509 For SOFC Interconnect Steel

Mats W Lundberg, Robert Berger, Jörgen Westlinder
AB Sandvik Materials Technology
SFFY (4371)
SE-811 81 Sandviken / Sweden
Tel.: +46-26-266364
mats.w.lundberg@sandvik.com

Abstract

Sandvik Materials Technology develops thin PVD coatings for SOFC stainless steel interconnects. In this study Outokumpu 4622 (EN 1.4622) and AISI441 (EN 1.4509), both precoated with Sandvik's the state of the art CeCo coating, have been exposed at 800°C in air. The EN 1.4622 is a newly developed steel (October 2013) and is not commonly used in SOFC applications. EN 1.4622 is similar to AISI441 but with higher chromium content as used in more expensive steel grades. A higher chromium content could be beneficial from the interconnect lifetime perspective. Measured mass gain from cyclic oxidation, SEM and EDS analysis, and Cr-volatilization studies were performed. The results suggest that precoated Outokumpu 4622 could be a viable alternative to AISI 441 for SOFC interconnects.



Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0615

Charge and Mass Transport Properties of BaCe0.9Y0.1O3-δ

Ha-Ni Im, Dae-Kwang Lim, Jae-Woon Hong, In-Ho Kim, and Sun-Ju Song
Ionics Laboratory, School of Materials Science and Engineering
Chonnam National University, Gwang-Ju 61186, Republic of Korea
*Tel: +82-62-530-1706, Fax: +82-62-530-1699
song@chonnam.ac.kr

Abstract

Cerium- and zirconium-based perovskites have been the most studied materials among the perovskites proton-conductor. Among these materials, doped barium cerates have shown high protonic conductivity. Study of mass and charge transport properties of $BaCe_{0.9}Y_{0.1}O_{3-\delta}$(BCY10) important to get better insight into the performance of this material in electrochemical devices. The mass and charge transport properties are governed by the nature and concentration of various ionic defects and it is well known that the acceptor doped cerate have multiple defects, such as protons, oxygen ions, positive holes, and excess electrons. In order to better to understand mass and charge transport properties, it is necessary to quantify the contribution to individual defect species toward the overall charge transfer with respect to the changes in thermodynamic parameters. In this work, we monitored the electrical conductivity variations in BCY10 in different thermodynamic conditions. The defect chemical analysis of BCY10 was presented to obtain the contributions of individual defects using solutions to the defect equations, which in term was used to calculate the partial conductivities by fitting to experimental conductivity data. Also, the electrical conductivity relaxation (ECR) during oxidation/reduction processes at a fixed pH_2O and during hydration / dehydration at fixed pO_2 were used for the calculation of surface exchange coefficients and chemical diffusivities of oxygen and hydrogen from the Fick's second law by the nonlinear least squares fitting of the conductivity data.

B0616

Characterization of Porous Stainless Steel 430L for Low Temperatures Solid Oxide Fuel Cell Application

Kyung Sil Chung, Lingyi Gu, Sannan Toor, Eric Croiset
Chemical Engineering
University of Waterloo
200 University Ave West Waterloo
Ontario N2J 3G1/Canada
Tel.: +1-519-888-4567
Fax.: +1-519-888-4347
ecroiset@uwaterloo.ca

Abstract

High operating temperatures in SOFC (e.g. ~900-1000°C) can cause serious physical and chemical degradation problems and are responsible for high cost of SOFC materials and operation. To address these issues, researches have aimed at reducing the operating temperature of SOFC. One option is to use alternative ceramic materials, by replacing conventional Yttria Stabilized Zirconia (YSZ) with materials possessing higher ionic conductivities at lower temperatures (e.g. 600-800°C), such as Samarium Doped Ceria (SDC). Operating temperatures below 700°C allows the use of metal-supported cells. Use of porous stainless steel layer can provide increased durability, reduced cost, higher oxidation resistance, and tolerance to thermal resistance. The porous metal support must satisfy several requirements: it must be porous enough (~20-40% porosity) to provide gas diffusion pathways, able to operate at high operating temperatures without oxidation, and match the coefficient of thermal expansion (CTE) with that of ceramic materials (YSZ and SDC have CTE of 10-12 ppm K^{-1}). The stainless steel 400 series satisfies the above requirement and in the present work, SS430L (d_{50} = 44 μm) was chosen as support materials. The porous metal support is fabricated using various precursor formulations; such formulations comprise metal support powder (SS430L), plasticizer (DOP), pore former (PMMA), binder (PVB) and solvent (ethanol). Beside the precursor formulation, the sintering process is also critical. The sintering temperature profile was determined through thermogravimetric analysis (TGA) of individual components. The sintered porous metal support was characterized by Archimedes porosity measurements, dilatometry and SEM imaging. Correlation between precursor formulation, sintering profile and the resulting metal support was established. These measurements can provide guidelines to fabricate compatible metal support for MSOFC.

B0618

Electrical interconnect based on AISI 430 stainless steel coated with recycled cobalt from spent Li-ion batteries

Eric Marsalha Garcia (1), Hosane Aparecida Taroco (1), Rubens Moreira de Almeida (2), *Antonio* **de Padua Lima** *Fernandes* **(2),**
Rosana Zacarias Domingues (2), Tulio Matencio (2)
(1) Federal University of São João del Rei
188 ***Sétimo*** Moreira Martins, Sete Lagoas/Minas Gerais - Brazil
(2) Federal University of Minas Gerais-Departamento de Química
AV. Antonio Carlos, 6627 - Pampulha - Belo Horizonte
Cep: 31270-901 Minas Gerais- Brazil
Tel.: +31-55-31- 34095742
tmatencio@ufmg.br

Abstract

The electrical interconnectors are the cell component with higher production cost. Interconnects are usually metallic, however, the requisites such as good resistance to corrosion and good conductivity at high temperatures (~ 750°C) must be achieved. In this sense, the Ni and Cr alloys are preferred due its high corrosion resistance and the formation of outside low electrical resistance oxide. However, these alloys are relatively expensive. Thus, in this work one layer of Co_3O_4 was successfully obtained onto 430 stainless steel from cobalt electrodeposition. The cobalt electrodeposition was performed in potential equal to -1.50 V using the cobalt solution from dissolution of spent cathode from Li-ion batteries. After the oxidation at 850 ° C by 1000 hours, the electrodeposited cobalt was converted in Co_3O_4. The cobalt electrodeposition improves the morphological characteristics of 430 stainless steel making it a promising candidate for electrical interconnect of SOFCs.

Key words: *Li-ion batteries, Cobalt, Recycling, Solid oxide fuel cell*

B0619

Comparison of different manganese-cobalt-iron spinel protective coatings for SOFC interconnects

Johan Tallgren (1), Manuel Bianco (2), Jyrki Mikkola (1), Olli Himanen (1), Markus Rautanen (1), Jari Kiviaho (1), Jan Van herle (2)
(1) VTT Technical Research Centre of Finland Ltd, Fuel Cells
P.O. Box 1000, Espoo, FI-02044, Finland
(2) FUELMAT group, École Polytechnique Fédérale de Lausanne (EPFL),
17 Rue de l'industrie, CH-1950 Sion, Switzerland
Tel.: +358-40-6840646
johan.tallgren@vtt.fi

Abstract

Chromium poisoning is a well-known degradation mechanism in solid oxide fuel cell (SOFC) stacks. Stainless steel interconnects (IC) have been identified as a major source of chromium. Additionally, depletion of chromium in very thin IC plates can lead to destructive break-away oxidation. This calls for protective coatings to inhibit the evaporation of chromium from the IC plates and to improve the SOFC stack durability. Such coatings should have a low electric resistivity and high physical and chemical stability in high temperatures. Much literature has been published on the performance of coatings. However, comparison between them is difficult due to the wide range of testing conditions. This work contributes to the field by comparing coating solutions from different companies and research centres, manufactured by different methods. The evaluated coatings include manganese-cobalt-iron and cerium-cobalt protective layers. The developed coatings build on previous work within the SCoReD2.0 project. Thin steel samples of AISI441, Sandvik Sanergy HT and Crofer 22 H were used as substrates. These steels were chosen since they are commercially available and widely used in SOFC applications. Area specific resistance (ASR) and overall stability were investigated with a measurement setup that mimics the conditions found in SOFC stacks. The steel samples were placed on top of thin palladium foils with a screen-printed lanthanum-strontium-cobalt (LSC) layer. The measurement setup replicates the interactions at an SOFC cathode since the LSC layer is manufactured the same way as real cathodes. In addition, the use of palladium spacers instead of steel enables electron microscopy analysis of chromium migration into the LSC layer as well as of oxide scale growth. ASR measurements were carried out in a humid air atmosphere at 700 °C for 1000 hours. The paper compares the protective coatings in terms of ASR, chromium retention and overall stability and discusses their usability in SOFC stacks.

This work has been conducted within the SCoReD2.0 project, which has received funding from the European Union's Fuel Cells and Hydrogen Joint Technology Initiative under contract no. 325331. Additionally, the NELLHI (grant agreement no. 621227) and INNO-Sofc (grant agreement no. 671403) projects are acknowledged.

B0620 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

La-Fe Perovskite Thin Film Coatings of Ferritic Stainless Steels by Surface Chemical Conversion: Dual Atmosphere Oxidation Testing

Andrea Masi (1,2), Davide Pumiglia (1,2), Maurizio Carlini (2), Amedeo Masci (1), Stephen McPhail (1), Stefano Frangini (1)
(1) ENEA CR Casaccia, Via Anguillarese 301 00123 Rome, (Italy)
(2) DAFNE, University of Tuscia, via San Camillo de Lellis snc 01100 Viterbo, (Italy)
Tel.: +39-06-3048-3138
andrea.masi@enea.it

Abstract

One of the challenges to be addressed in order to increase Solid Oxide Fuel Cells (SOFC) stack durability is represented by the corrosion occurring at the interconnect/cathode interface, giving rise to the growth of insulating layers and to Chromium diffusion in the cathode layer. To avoid these issues, protective coatings must be deposited on the interconnect surface. In the last years, Mn-Co spinel layers have been widely studied due to their excellent electrical conductivity and good thermal expansion match with the substrate. The coatings can be obtained by several deposition techniques and each one has different characteristics in terms of costs, scalability and effectiveness.
As different approach, a novel passivation technique is currently being developed and studied to produce dense La-Fe perovskite layers to reduce the steel interconnect degradation. The method consists in a chemical conversion of the steel surface occurring in a molten carbonate salt, exploiting spontaneous reactions promoted in the synthesis medium. Perovskite oxides can be considered suitable coating materials due to their sufficiently high electronic conductivity, good thermal matching and low cation mobility. Deposition of perovskite coatings suffers, however, from technological issues related to low sintering capability and relatively high porosity. The proposed conversion technique provides the possibility of obtaining dense perovskite structures for more effective coatings.
In this work, a La-Fe perovskite modified commercial 22Cr ferritic stainless steel is studied under dual-atmosphere oxidation test conditions. Morpho-structural evolution during the exposure to typical IT-SOFC conditions (700°C, humid hydrogen at the anode side, humid air at the cathode side) is followed by means of X-ray diffraction (XRD) analysis and scanning electron microscopy (SEM) equipped with energy dispersive X-ray analysis (EDX).

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0621

Insight of Reactive Sintering in Manganese Cobalt Spinel Oxide of Protective Layer for Solid Oxide Fuel Cell Metallic Interconnects

Jong-Eun Hong (1), Andrea Masi (1, 2), Manuel Bianco (3), Jan Van herle (3), Robert Steinberger-Wilckens (1)
(1) Centre for Hydrogen and Fuel Cell Research, School of Chemical Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
(2) DAFNE, University of Tuscia, Via San Camillo de Lellis snc, 01100 Viterbo, Italy
(3) FUELMAT Group, Inst. Mech. Eng., Ecole Polytechnique Fédérale de Lausanne Valais (EPFL Valais), CH-1950 Sion, Switzerland
Tel.: +44-121-418-5081
j.hong@bham.ac.uk

Abstract

A dense protective layer has to be applied onto ferritic stainless steel metallic interconnects for solid oxide fuel cell (SOFC) stacks to prevent a rapid performance degradation caused by chromia scale growth and chromium poisoning of the cathode. Manganese and cobalt spinel oxide (MCO) is known as an effective protective layer material owing to the high electrical conductivity and the thermal expansion coefficient matching that of the ceramic cell components. However, it appears difficult to prepare a dense MCO layer with wet chemical coating processes rather than dry coating methods such as physical vapour deposition and atmospheric thermal plasma spraying; a porous coating limits durability of the stack; on the other hand, a wet coating process could reduce production cost. We introduced a reactive sintering process consisting of a reduction and subsequent oxidation step for MCO layers that are prepared by wet coating methods. As a result, the durability was enhanced by the improved coating density which suppressed the increase of area specific resistance and the chromium volatilisation.

In this study, we have analysed detailed properties of the MCO coatings under reactive sintering conditions in order to understand how the sintering property is enhanced. Finally, we discuss a modified sintering process to prepare a dense MCO layer using a simple wet chemical coating method and report on its performance as a protective coating for SOFC metallic interconnects.

Acknowledgments:
This work was supported by the European FCH JU under contract no. 325331.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0623 (Will be published elsewhere)

High performance ceria-carbonate composite electrolytes for low temperature hybrid fuel cells

Ieeba Khan (1), Muhammad Imran Asghar (2), Peter D. Lund (2), Suddhasatwa Basu (1)
(1) Department of Chemical Engineering, Indian Institute of Technology, New Delhi-110016, India
(2) Department of Applied Physics, Aalto University, P. O. Box 15100, 00076, Finland
ieebakhan@gmail.com, sbasu@iitd.ac.in

Abstract

Low-temperature solid oxide fuel cells (LT-SOFC) are developing as a potential fuel cell technology. The performance of these fuel cells is limited due to poor conductivities of the ceria based electrolytes at low operating temperature (400-600^{o}C) [1]. The conductivity of the electrolyte can be improved by using nanocomposite mixture of doped ceria (GDC or SDC) and eutectic mixture of alkali metals (Li, K, Na) carbonates [2,3].

We performed various studies on ceria carbonate nanocomposites for obtaining high conductivity. Electrolytes with single, binary and ternary carbonates mixtures were prepared and their impedance was measured using electrochemical impedance spectroscopy for a temperature range of 250^{o}C-700^{o}C. Previously, reported by our group (Chockalingum et al.) [4], power density of 92 mW cm-2 at 550 °C for cell with GDC-25 wt% Li-Na CO3 electrolyte, NiO-GDC/ Li-Na CO3 anode and lithiated NiO-GDC/Li-Na CO3 cathode, the performance was further improved using eutectic combinations of different carbonates. The electrolytes have been physically and electrochemically characterized with respect to their thermal behaviour, phase, microstructure, elemental analysis and electrochemical performance using thermogravimetric analysis (TGA), X-ray diffraction (XRD), scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Energy-dispersive X-ray spectroscopy (EDX) and electrochemical impedance spectroscopy (EIS) respectively. It was found that Li-Na carbonate mixtures resulted in the highest conductivity.

[1] M. I. Asghar and P. D. Lund, Catal. Today 259, 259 (2016).
[2] R.Raza, H. Qin, L. Fan, K. Takerda, M. Mizuhata, B. Zhu, J. of Power Sources, 201, 121 (2012).
[3] J. Patakangas, Y. Jing, M. I. Asghar and P. D. Lund, Int. J. Hydrogen Energy, 41, 7609 (2015).
[4] R. Chockalingam and S. Basu, J. Hydrogen Energ., 36,14977 (2011).

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0624 (Abstract only)

Fabrication of MS-SOFC by Electrophoretic Deposition Technique and its Characterization

Shambhu Nath Maity, Debasish Das, Biswajoy Bagchi, Rejendra N. Basu*
Fuel Cell & Battery Division
CSIR-Central Glass and Ceramic Research Institute, Kolkata 700032, India
Tel.: +91-33-2429-2951
Fax: +91-33-2473-0957
rajenbasu54@gmail.com, rnbasu@cgcri.res.in

Abstract

Conventionally, most of the SOFCs are based on electrode supported design ceramic or cermet provides the mechanical support. Additionally, such ceramic supports have developed cracks due to excessive thermal stress during redox cycling. To address that, metal-supported SOFC (MS-SOFC) design can be a suitable alternative where thin electrode and electrolyte layers are supported on a comparatively inexpensive and robust, porous metallic support. These metallic substrates not only eliminate the redox cycling, but also helps during stacking of single cell thus reducing the overall cost and increasing the mechanical strength of SOFCs.

Electrophoretic deposition (EPD), a cost effective wet-ceramic process used to deposit thin films on conducting substrate may prove to be a promising alternative for the fabrication of MS-SOFC due to having several advantages such as high deposition rate, excellent control on film thickness and ability to form both dense and porous films on any complex shape.

In the present work, we explore the synthesis of Ni-Fe bimetallic alloy using NiO and iron salt as precursors. Pellets prepared from the synthesized powder are sintered at elevated temperature to obtain porous metal support with good mechanical strength. These porous substrates are then used to fabricate MS-SOFC single cell by EPD technique. As a prerequisite of EPD, stable suspension of NiO-YSZ and YSZ are prepared in isopropanol (IPA) medium using I_2-acetylacetone as dispersants and PVB as binder. To optimize the process parameters, the deposition kinetics of YSZ and NiO-YSZ composite material have been studied in depth using conducting plate as the depositing electrode. Once the deposition parameters are optimized, first a thin NiO-YSZ anode film has been deposited on the prepared metal support using a conducting steel plate at the reverse side of the substrate. Thereafter, YSZ electrolyte film is fabricated on the top of the deposited NiO-YSZ layer using EPD. These electrophoretically deposited half-cells (anode + electrolyte) along with the metal substrate are then co-fired at 1400°C/6h to obtain a dense electrolyte film on the top of the porous NiO-YSZ anode layer. Finally, MS-SOFC single cells are obtained by screen printing of nanostructured LSM cathode layer on the top of the dense electrolyte film followed by a successive firing step. Electrochemical characterizations were carried out to evaluate the performance of such developed MS-SOFC single cells.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0625 (Abstract only)

Synthesis and studies of $BaCe_{0.7}Zr_{0.1}Y_{0.1}Pr_{0.1}O_{3-\delta}$ perovskite material for IT-SOFCs

Shahzad Hossain, Juliana Hj Zaini, Abul Kalam Azad
Faculty of Integrated Technologies
Universiti Brunei Darussalam, Jalan Tungku Link, Gadong BE 1410, Brunei Darussalam
Tel.: +673-8974076
14h8854@ubd.edu.bn or, shahzad_baec@yahoo.com

Abstract

The perovskite-type specimen of $BaCe_{0.7}Zr_{0.1}Y_{0.1}Pr_{0.1}O_{3-\delta}$ has been synthesized for application in an anode-supported electrolyte protonic solid oxide fuel cell by the conventional solid state reaction in air at 1350°C for 8 hours. Room temperature X-ray diffraction (XRD) and Scanning Electron Microscopy (SEM) were done for structural analysis and thermal characterization has been performed using Thermogravimetric Analysis (TGA) and Differential Thermal Analysis (DTA). Rietveld refinement of the XRD data has been performed by FullProf program and confirmed the single phase with an orthorhombic crystal structure in the Pbnm space group. To understand the temperature dependent behavior of the precursor the TG/DTA scan was recorded and was done under constant flow of Argon which exhibits weight loss at 800°C. The SEM image of the pellet surface of the sample shows that the sample sintered at 1350°C was densed and suitable to use as electrolyte in solid oxide fuel cells (SOFCs). The conductivity, power density and other measurements of the sample are in progress and will be reported in the conference.

Pictures:

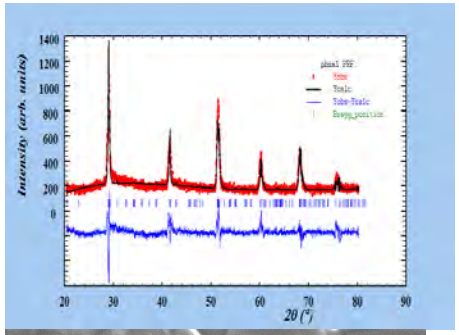


Fig. 1: Rietveld analysis profile of X- ray diffraction pattern of as-prepared $BaCe_{0.7}Zr_{0.1}Y_{0.1}Pr_{0.1}O_{3-\delta}$ at room temperature.

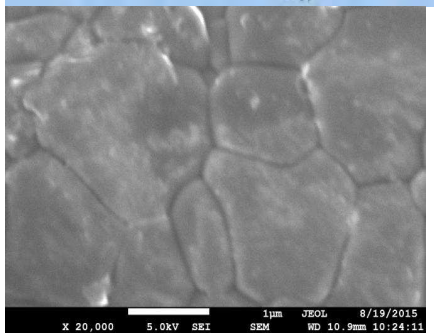


Fig. 2: SEM micrograph of as prepared sample

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0626

Composite $Nd_{0.1}Ce_{0.9}O_{1.9}$ - $BaZr_{0.1}Ce_{0.7}Y_{0.2-x}Yb_xO_3$ electrolytes for intermediate temperature-solid oxide fuel cells

Ka-Young Park (1), Jun-Young Park (1)
(1) Department of Nanotechnology and Advanced Materials Engineering, Sejong University
209 Neungdong-ro, Gwangjin-gu, Seoul, 143-747
Tel.: +82-2-3408-3848
Fax: +82-2-3408-4342
jyoung@sejong.ac.kr

Abstract

Composite electrolytes based on both proton and oxygen-ion conductors are designed for the operation of solid oxide fuel cells (SOFCs) at the intermediate temperature (IT, 500-700°C). Ceria-based oxygen-ion conductors such as $Nd_{0.1}Ce_{0.9}O_{2-\delta}$ (NDC) have attracted attention as alternatives of yttria-stabilized zirconia (YSZ) electrolytes due to their high ionic conductivity at the IT. However, NDC materials are reduced at low oxygen partial pressure. Proton conductors such as $BaZr_{0.85}Y_{0.15}O_{3-\delta}$ (BZY) have also received considerable attention as electrolytes of protonic ceramic fuel cells (PCFCs), because protons have lower activation energy for ion diffusion than that of oxygen ions. However, a high sintering temperature is required to densify BZY pellets. In this work, co-ionic (H^+/O^{2-}) composite electrolytes are designed by compositing both oxygen-ion and proton conductors. Hybridization of NDC and BZY materials may help to improve poor sinterability of BZY and prevent the electronic conductivity of NDC in reducing atmospheres. The performance of composite electrolytes is measured under real SOFC operating conduction.

B0627 (Abstract only, published elsewhere)

Joint strength of an SOFC glass-ceramic sealant with LSM-coated metallic interconnect

Chih-Kuang Lin (1), Fan-Lin Hou (1), Atsushi Sugeta (2), Hiroyuki Akebono (2), Szu-Han Wu (3), Peng Yang (3)
(1) Department of Mechanical Engineering, National Central University, Jhong-Li 32001, Taiwan
(2) Department of Mechanical Science and Engineering, Hiroshima University, Hiroshima 739-8527, Japan
(3) Nuclear Fuels and Materials Division, Institute of Nuclear Energy Research, Lung-Tan 32546, Taiwan
Tel.: +886-3-426-7340
Fax: +886-3-425-4501
t330014@cc.ncu.edu.tw

Abstract

Although lanthanum strontium manganite (LSM) coatings have been practically applied on metallic interconnects to prevent Cr poisoning in cathode side of planar solid oxide fuel cell (pSOFC), the bonding characteristics and joint strength between LSM-coated metallic interconnects and glass-ceramic sealants have not been well studied yet. The objective of this study is thus to investigate the joint strength between a BaO-B_2O_3-Al_2O_3-SiO_2 glass-ceramic sealant (GC-9) and an LSM-coated interconnect steel (Crofer 22 APU), when subjected to tensile and shear loadings at room temperature (RT) and 800 °C in air. The joint strength is reduced as the testing temperature is increased from RT to 800 °C, regardless of specimen and loading conditions. The joint strength between the given glass-ceramic sealant and interconnect steel is degraded by 36%-80% in applying an LSM coating on the interconnect steel. Such a degradation of joint strength is attributed to existence of pores around the interface of GC-9/LSM in the LSM-coated specimens. The shear strength of LSM-coated joint specimen is enhanced by 52% at RT and 200% at 800 °C after 1000-h thermal aging in air. The given thermal aging treatment also improves the tensile strength of LSM-coated joint specimen by 50% at 800 °C, but has no improvement at RT. This is attributed to a self-healing effect of the glass-ceramic sealant during thermal aging, which reduces the size of pores around the GC-9/LSM interface. An overall comparison of the joint strength and fracture mode for all given specimen and testing conditions indicates fracture involving the LSM layer and its adjoining interfaces accompanies a lower joint strength.

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0628 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Nanoindentation of La-Fe Oxide Perovskite Thin Films for Solid Oxide Fuel Cells Steel Interconnects: First Findings

Andrea Masi (1,2), Ivan Davoli (3), Massimiliano Lucci (3), Maurizio Carlini (2), Amedeo Masci (1), Stephen McPhail (1), Stefano Frangini (1)
(1) ENEA CR Casaccia, Via Anguillarese 301, 00123 Roma, (Italy)
(2) DAFNE, University of Tuscia, via San Camillo de Lellis snc, 01100 Viterbo, (Italy)
(3) Department of Physics, University of Rome Tor Vergata, Via della Ricerca Scientifica, 00133, Roma (Italy)
Tel.: +39-06-3048-3138
andrea.masi@enea.it

Abstract

Coating of ferritic Stainless Steels (SS) interconnect is mandatory to alleviate issues related to growth of insulating layers and evaporation and diffusion in the cathode of Cr-rich species. As the deposition of coatings introduces new interfaces (SS/coating/cathode), this points out the importance of the mechanical properties compatibility, particularly between steel and coating, to guarantee stability on long term tests. Studies of coating deformation behavior under concentrated loading and accurate measurement of the mechanical properties can be therefore of great importance.
In this work, a commercial 22Cr ferritic stainless steel has been passivated through a novel chemical conversion process, consisting in the immersion of the steel in a properly tailored molten carbonate salt. The molten carbonate bath promotes the conversion of the steel surface in a La-Fe perovskite crystalline layer. Uncoated and coated steel have been subjected to nanoindentation analysis with the purpose of measuring elasto-plastic properties of the materials. Main results are here reported and compared.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0629

Investigation of Advanced Cathode Contacting Solutions in SOFC

Patric Szabo (1), Remi Costa (1), Manho Park (2), Bumsoo Kim (2), Insung Lee (3)
(1) DLR e.V.
Pfaffenwaldring 38-40, D-70569 Stuttgart/Germany
(2) Alantum
8F StarWood B/D, 5439-1, Sangdaewon, Seongnam/Korea
(3) RIST
67 Cheongamro, Namgu, Pohang 790-330, Gyeongbuk/Korea
Tel.: +49-711-6862494
Patric.szabo@dlr.de

Abstract

Contacting solutions for air electrode in Solid Oxide Cells stacks often implement a ceramic paste made of electronic conducting perovskite, comparable or same as the electro-active material. This contact layer is applied in a green state by wet-powder-spray or screen-printing, and in situ fired during stack commissioning. The low level of necking between ceramic particles causes increased ohmic losses. Moreover the shrinkage usually observed during long term operation in temperature of this layer, due to sintering effect, lead to cracks and contact losses which hinder the cell performance. Increasing cell's footprint, performance and lifetime at the stack level requires appropriate contacting solution.
In this paper we report the investigation of a new advanced monolithic contacting solution, easy to handle, soft and flexible, highly porous and highly conductive. Two different compositions have been investigated, with respect of their compatibility with Crofer (SEM, XRD). In addition, solid oxide cells contacted with this solution as well as with a ceramic paste have also been electrochemically tested up to 1000 hours in order to compare and assess the impact of this contacting solution on cell's performance. Results will be presented and discussed.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0630 (Abstract only)

Co-deposition of rare earths along with $(Mn,Co)_3O_4$ spinel as a protective coating for SOFC metallic interconnects

Vinothini Venkatachalam (1), Sebastian Molin (1), Wolf-Ragnar Kiebach (1), Ming Chen (1), Peter Vang Hendriksen (1)
(1) Department of Energy Conversion and Storage, Technical University of Denmark, Risø Campus, Frederiksborgvej 399, 4000 Roskilde, Denmark
Tel.: +41-24895673
Fax: +41-56-987-1235
viven@dtu.dk

Abstract

Solid oxide fuel cells (SOFCs) are solid state energy conversion devices that produce electricity directly from various fuels e.g. hydrogen or hydrocarbons. The reduction in SOFC/SOEC operating temperature enables use of metallic interconnects. Chromia forming ferritic steels matches the thermal expansion coefficient of other SOFC electrodes and also forms conductive and protective oxide scale but on the downfall the Cr volatilized from these steels poison the electrode and degrades the electro catalytic reaction. Hence many efforts have been taken on developing protective coating such as $LaCrO_3$, Co, Ce/Co, $(Mn,Co)_3O_4$ and other rate earths etc. Among these MnCo spinel is proven to be one of the promising materials to prevent Cr volatilization. Addition of rare earths has proven to further reduce the corrosion behavior of interconnects along with better coatings adhesion. Although multilayers can be produced in multistep as the trend is towards lean manufacturing, in the present study we have attempted to develop protective coatings by co depositing rare earth oxide along with $(Mn,Co)_3O_4$ spinel using electrophoretic deposition (EPD) technique and the coatings were evaluated based on their oxidation behavior at 800°C in air.

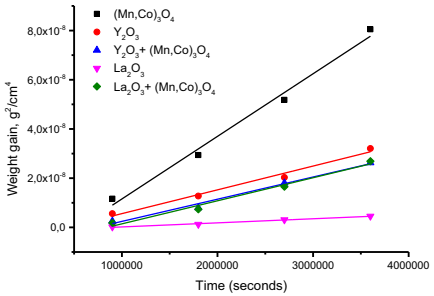
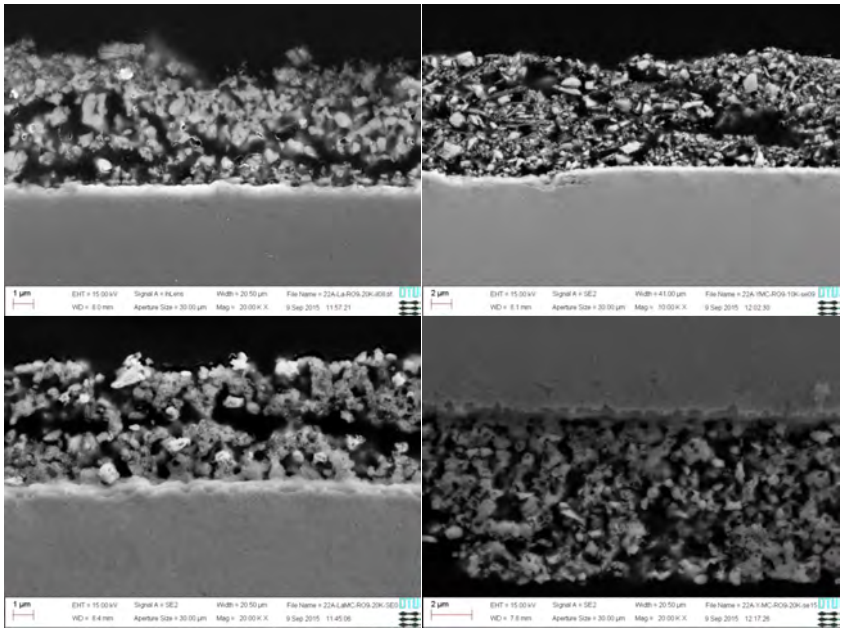


Figure 1 : Weight gain plots of different coatings oxidised at 800 °C in air



Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0631

Cu-Fe substituted Mn-Co spinels by High Energy Ball Milling for interconnect coatings: insight on sintering properties

Andrea Masi (1,2,3), Jong-Eun Hong (3), Robert Steinberger-Wilckens (3), Maurizio Carlini (2), Mariangela Bellusci (1), Franco Padella (1), Priscilla Reale (1)
(1) ENEA C.R. Casaccia, Via Anguillarese 301 00123 Rome, Italy
(2) DAFNE, University of Tuscia, via San Camillo de Lellis snc 01100 Viterbo, Italy
(3) Centre for Fuel Cell and Hydrogen Research, School of Chemical Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
Tel.: +39-06-3048-3248
andrea.masi@enea.it

Abstract

Corrosion effects on metallic interconnects of Solid Oxide Fuel Cells (SOFC), including the growth of insulating scales and chromium evaporation, can be reduced through the deposition of protective coatings. Mn-Co oxide coatings obtained by wet chemical coating techniques are competitive on large-scale manufacture due to low costs and high producing volumes. These methods however require the formulation of powders and inks as well as high temperature sintering treatments for reducing residual porosity being one of the main drawbacks. Metal doping of the traditional Co-Mn composition has been suggested as an option to improve the sintering behaviour and the final coating properties.

In this work, a simple High Energy Ball Milling (HEBM) process of metal oxides is exploited to produce Cu and Fe substituted Mn-Co spinel nanostructured precursors. Among the powder production techniques, HEBM is an environmentally friendly and low cost mechano-chemical processing methodology, which exploits hitting balls as energy transfer media. The HEBM treatment produces a very fine grinding and intimate mixing of particles, which leads to particle activation, nucleation of stable or metastable phases, amorphisation processes, or chemical reactions.

The high temperature behaviour of the produced powders has been studied by means of thermogravimetric and dilatometric analyses, while investigating morphological and structural properties of the processed powders and pellets, in order to evaluate the role of the additives in the sintering behaviour.

B0632

Electrolyte supported cells with thin electrolytes

Hendrik Pöpke, Franz-Martin Fuchs
Kerafol GmbH
Koppe-Platz 1
D-92676 Eschenbach i. d. Opf.
Tel.: +49-9645-88-429
Fax: +49-9645-88-492
hendrik-poepke@kerafol.com

Abstract

Electrolyte supported cells have intrinsically high cell resistances due to high electrolyte thicknesses. Especially when choosing mechanically stable materials with high strength, for example the partly stabilized zirconia 3YSZ, the cell resistances can reach high values. The largest lever to lower cell resistances is the use of thinner electrolyte substrates.
When lowering the electrolyte thickness, three things must be considered: production of thin electrolytes is challenging, the electrolyte substrate must stand the mechanical stress during cell production (screen printing and sintering) and the cells must be stable enough for the integration into stacks. In case the production of very thin electrolyte substrates is possible, the optimum between the cell resistance and the mechanical stability must be found.
Kerafol is able to produce thin electrolyte substrates made of 3YSZ (70 µm) and 6Sc1CeSZ (100 µm) and is additionally testing 3YSZ with a thickness of 45 µm. Cell tests with these three electrolyte thicknesses are presented. Especially cells with thin 3YSZ substrates show a good performance both for SOFC and SOEC operation and a very low degradation rate.

Next EFCF Events

6th European
PEFC & ELECTROLYSER
Forum 4 - 7 July 2017

13th European
SOFC & SOE
Forum 3 - 6 July 2018

Lucerne Switzerland

Chapter 08 - Sessions B08, B11

B08: Modelling, validation & optimisation: Cell & stack
B11: Modelling, validation & optimisation: System

Content **Page B08, B11 - ..**

B0801 (Will be published elsewhere)....4
Simulation of the electrochemical impedance response of SOFC anodes: from the microstructural reconstruction to the physically-based modelling 4
Antonio Bertei, Enrique Ruiz-Trejo, Farid Tariq, Vladimir Yufit, Kristina Kareh, Nigel Brandon 4
B0802 (Will be published elsewhere)....5
Relaxation of stresses during reduction of anode supported SOFCs 5
Henrik Lund Frandsen*, Christodoulos Chatzichristodoulou, Peter Stanley Jørgensen, Kawai Kwok, Peter Vang Hendriksen 5
B0803 (Will be published elsewhere)....6
Designing Porous Cathode Structures for SOFCs 6
Jochen Joos (1)*, Helge Geisler (1), André Weber (1), Ellen Ivers-Tiffée (1) 6
B0804 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....7
Dealing with fuel contaminants degradation in Ni-anode SOFCs 7
Andrea Lanzini, Davide Papurello, Domenico Ferrero, Massimo Santarelli 7
B0807 (Will be published elsewhere)....8
A steady state and dynamic 1-D model study of reversible solid oxide cells for energy storage 8
Srikanth Santhanam (1), Marc P. Heddrich (1), K.A. Friedrich (1) 8
B0808....9
Analysis of temperature profiles in SOECs during startup and shutdown periods 9
Filip Karas, Roman Kodým, Martin Paidar, Karel Bouzek 9
B0809 (Will be published elsewhere)....10
A Physical Model to Interpret Electrochemical Impedance Spectra for LSM-YSZ Composite Cathodes 10
Aayan Banerjee (1), Olaf Deutschmann (1) 10
B0810 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....11
Modelling of gas diffusion limitations in Ni/YSZ electrode material in CO_2 and co-electrolysis 11
Jakob Dragsbæk Duhn (1), Anker Degn Jensen (1), Stig Wedel (1), Christian Wix (2) 11
B0811 (Will be published elsewhere)....12
Evaluation of Solid Oxide Cell (SOC) performance and degradation: Combined experimental and modeling study 12
Vitaliy Yurkiv, Michael P. Hoerlein, Günter Schiller, K. Andreas Friedrich 12
B0813 (Will be published elsewhere)....13
Nonlinear Model Predictive Control (NMPC) for SOFC 13
Yousif Al-sagheer, Vikrant Venkataraman, Robert Steinberger-Wilckens 13
B0815 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....14
FEA analysis and modelling of thermal stress in SOFCs 14
Dr Harald Schlegl (1), Dr Richard Dawson (1) 14
B0816 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....15
Numerical investigation of fuel starvation effect at high current in novel planar SOFC design 15
Tomasz Zinko, Paulina Pianko-Oprych, Zdzisław Jaworski 15
B0818 (Will be published elsewhere)....16
Numerical surface coverage condition analysis of a porous Ni/YSZ anode during internal reforming 16
Christoph Schluckner, Vanja Subotić, Christoph Hochenauer 16
B0819 (Abstract only, published elsewhere)....18
Geometric modeling of infiltrated solid oxide fuel cell electrodes with directional backbones 18
Mehdi Tafazoli(1) ,Majid Baniassadi(2),Alireza Babaei(3) ,Mohsen Shakeri(1) 18
B0820....19
Accuracy of the Numerically Computed Spatial Current and Temperature Variations in SOFCs 19
Özgür Aydın (1), Hironori Nakajima (2), Tatsumi Kitahara (2) 19
B0821....20
Evaluation of SOFC anode polarization characteristics with pillar-based YSZ structure 20
Takaaki Shimura (1), Keisuke Nagato (2,3), Naoki Shikazono (1,4) 20
B0822 (Will be published elsewhere)....21
Local reacting environment within SOFC stacks examined by three-dimensional numerical simulations 21
Sanghyeok Lee (1,2), Hyoungchul Kim (1), Kyung Joong Yoon (1), Ji-Won Son (1), 21
Jong-Ho Lee (1), Byung-Kook Kim (1), Wonjoon Choi (2), Jongsup Hong (1),* 21
B0823 (Abstract only)....22
Geometric characterisation and performance improvement of IT-SOFCs in highly efficient CHP systems 22
Luca Mastropasqua (1), Stefano Campanari (1), Paolo Iora (2) 22
B0824 (Will be published elsewhere)....24
3D simulation of a patterned LSM cathode considering reaction on LSM/pore double-phase boundary 24
Takuma Miyamae, Hiroshi Iwai, Motohiro Saito, 24
Masashi Kishimoto, Hideo Yoshida 24
B0826 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....25
Numerical Evaluation of Direct Internal Reforming SOFC Operated with Biogas 25
Tran Dang Long (1), Tran Quang Tuyen (2), Yusuke Shiratori (1,2) 25
B0827 (Abstract only)....26
Harvesting Big Data in SOFC Short Stacks – A Step Beyond Contemporary Characterization Techniques 26
Carlos Boigues Muñoz (1,2), Davide Pumiglia (1,3), Francesca Santoni (1,4), Stephen J. McPhail (1), Gabriele Comodi (2) 26
B0828 (Will be published elsewhere)....27
Numerical study on the SOFC characteristics variation with various internal reforming ratio 27
Sanggyu Kang (1, 2), Youngduk Lee (1), Kook-Young Ahn (1,2), Jacob Brouwer (3) 27
B1101 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....28
Efficient integration of SOFC and gasification system 28
Stephan Herrmann (1), Manuel Jimenez Arreola (2), Michael Geis (1), Sebastian Fendt (1), Hartmut Spliethoff (1) 28
B1102 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)....29
Development of the FlexPCFC: a Low-Cost Intermediate-Temperature Fuel-Flexible Protonic Ceramic Fuel Cell 29
Alexis Dubois (1), Kevin J. Albrecht (1), Chuancheng Duan (2), Jianhua Tong (3), Ryan O'Hayre (2), Robert J. Braun (1) 29

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

Modelling, validation & optimisation: Cell & stack
Modelling, validation & optimisation: System

B1103 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....30
A Thermodynamic Analysis of Integrated SOFC Cycles for Ships **30**
Lindert van Biert, Klaas Visser, Purushothaman V. Aravind 30
B1104 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....31
Power to Power efficiencies based on a SOFC/SOEC reversible system **31**
A. Chatroux (1), S. Di Iorio (1), G. Roux (1), C. Bernard (1), J. Mougin (1), M. Petitjean (1), M. Reytier (1) 31
B1107 (Abstract only).....32
Sensitivity analysis and optimization of solid oxide fuel cells: a review **32**
Seyedehmina Tonekabonimoghadam (1), Yashar S. Hajimolana (1,2), Mohammed Harun Chakrabarti (2), Jelle Nicolas Stam (3), Mohd Azlan Hussain (1), Nigel Brandon (3), Mohd Ali Hashim (1), P.V. Aravind (2) 32
B1108 (Will be published elsewhere).....33
Dynamic behavior of the solid oxide fuel cell-engine hybrid system **33**
Sanggyu Kang (1, 2), Kanghun Lee (1), Keunwon Choi (1), Youngduk Lee (1), Kook-Young Ahn (1,2) 33
B1109.....34
Gasifier, solid oxide fuel cell integrated systems for energy production from human waste **34**
Mayra Recalde, Theo Wousdtra, P.V. Aravind 34
B1111 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....35
Thermochemical and Kinetic Modelling of Chromium- Rich Alloys **35**
Mélissa Oum, Jong-Eun Hong, Robert Steinberger-Wilckens 35
B1112 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....36
Multi-stage highly-efficient SOFC system using proton and oxide-ion conducting electrolyte **36**
Yuya Tachikawa (1), Yoshio Matsuzaki (2,3), Takaaki Somekawa (2,4), 36
Shunsuke Taniguchi (1,3,6), Kazunari Sasaki (1,3,4,5,6) 36
B1114 (Abstract only).....37
Solid Oxide Fuel Cells Operating on Methane with Anode Off-Gas Recirculation **37**
Tsang-I Tsai*, Robert Steinberger-Wilckens 37
B1115 (Will be published elsewhere).....38
Model development of integrated CPO$_x$ reformer and SOFC stack system **38**
Paulina Pianko-Oprych, Mehdi Hosseini, Zdzislaw Jaworski 38
B1116 (Abstract only, published elsewhere) 39
Stationary, Polygenerative Electrochemical Systems **39**
Whitney G. Colella (1, 2) 39
B1117 (Abstract only).....40
Development of BoP model of the SOFC sub-system with CPOx reforming **40**
Barbara Zakrzewska, Paulina Pianko-Oprych 40
B1118 (Abstract only).....41
Electrochemical Impedance Spectroscopy model for a symmetric cell as an SOFC application **41**
Assist. Prof. Dr. Oktay Demircan, Gulsun Demirezen, Aysenur Eslem Kisa 41
B1119 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....42
SOFC simplified performance prediction model **42**
Irad Brandys (1,2), Yedidia Haim (2), Yaniv Gelbstein (3) 42

B0801 (Will be published elsewhere)

Simulation of the electrochemical impedance response of SOFC anodes: from the microstructural reconstruction to the physically-based modelling

Antonio Bertei, Enrique Ruiz-Trejo, Farid Tariq, Vladimir Yufit, Kristina Kareh, Nigel Brandon
Department of Earth Science and Engineering, Imperial College London
Prince Consort Road, SW7 2AZ London/United Kingdom
Tel.: +44-(0)20-7594-7333
Fax: +44-(0)20-7594-7444
a.bertei@imperial.ac.uk

Abstract

In this contribution, a combination of experimental and modelling techniques are integrated and applied to link the electrode microstructure to the performance and degradation of SOFC anodes. Symmetric anodes made of scandia-stabilized zirconia and nickel were fabricated with 30, 40 and 50% vol. of Ni. The impedance response of the samples was measured at 600-800°C in 50-100% wet H_2. The microstructure of the electrodes was reconstructed from FIB-SEM tomography for the evaluation of the effective properties. This information was fed to a physically-based model that takes into account the main transport and reaction phenomena occurring within the electrode. Impedance spectra were simulated and fitted with a reduced number of material-specific electrochemical parameters, which showed a clear dependence on temperature and did not vary in different samples (Fig. 1). The same approach was used to decouple the microstructural contribution to performance of infiltrated electrodes [1].
The study reveals that the coupling among microstructural characteristics, impedance and degradation can be methodically addressed to gain a fundamental understanding and to provide design indications to improve the performance and the lifetime of electrodes.

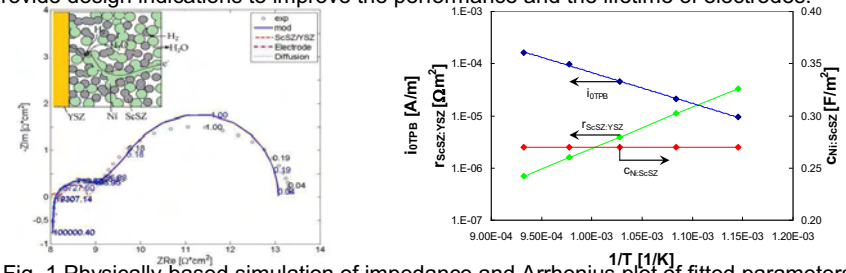


Fig. 1 Physically-based simulation of impedance and Arrhenius plot of fitted parameters.

[1] A. Bertei, E. Ruiz-Trejo, F. Tariq, V. Yufit, A. Atkinson and N. P. Brandon, Physically-based modelling of solid oxide fuel cell composite anodes: validation using impedance spectroscopy in different electrode microstructures, in preparation.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0802 (Will be published elsewhere)

Relaxation of stresses during reduction of anode supported SOFCs

Henrik Lund Frandsen*, Christodoulos Chatzichristodoulou, Peter Stanley Jørgensen, Kawai Kwok, Peter Vang Hendriksen
Technical University of Denmark
Frederiksborgvej 399
4000 Roskilde / Denmark
Tel.: +45-4677-5668
Fax: +45-4677-5858
hlfr@dtu.dk

Abstract

To assess the reliability of solid oxide fuel cell (SOFC) stacks during operation, the stress field in the stack must be known. During operation the stress field will depend on time as creep processes relax stresses. This work reports further details on a newly discovered creep phenomenon, *accelerated creep*, taking place during the reduction of a Ni-YSZ anode. This relaxes stresses at a much higher rate (~×10^4) than creep during operation. Thus, the phenomenon of *accelerated creep* during reduction has to be considered both in the production of stacks and in the analysis of the stress field in a stack based on anode supported SOFCs.
Accelerated creep has previously been studied in experiments with simultaneous loading and reduction. The hypothesis for the phenomenon centers around a significant softening of the Ni phase, which amongst other should lead to a significant relaxation of internal stresses in the Ni(O)-YSZ microstructure. The internal residual stresses can be anticipated due the different thermal contractions of the two phases from the sintering temperature to the reduction temperature. It was thus concluded that with the recorded high creep rates, the stresses in a cell at the time of reduction *should* decrease significantly over minutes.
In this work these internal stresses are measured *in-situ* before and after the reduction by use of X-ray diffraction. This is done by determining the elastic micro-strains (correlating to the stresses), which are assessed from the widening of the Bragg peaks. This enables us to determine the stresses in the different phases locally inside the microstructure of the composite Ni(O)-YSZ anode.
Furthermore, the residual stresses have been modeled during cool-down from the reduction temperature. The stresses have been assessed by use of a combination of a 3D microstructural reconstruction by FIB-SEM, a microstructural finite element model and analytical homogenization considerations.
A significant decrease of stresses is observed through the reduction as predicted, which partly confirms the hypothesis for the accelerated creep. Also, a significant relaxation of stresses to lower temperatures (~300°C) was also found. This was confirmed by the models, but is however not consistent with previous recorded coefficients of thermal expansion.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0803 (Will be published elsewhere)

Designing Porous Cathode Structures for SOFCs

Jochen Joos (1)*, Helge Geisler (1), André Weber (1), Ellen Ivers-Tiffée (1)
(1) Institute for Applied Materials (IAM-WET)
Karlsruhe Institute of Technology (KIT), D-76131 Karlsruhe, Germany
Tel.: +49-721-608-47494
Fax: +49-721-608-47492
jochen.joos@kit.edu

Abstract

Chemical composition and microstructure determine the electrochemical performance characteristics of mixed ionic-electronic conducting (MIEC) cathodes. This work focuses on the performance simulation and evaluation of porous LSCF cathodes with the same nominal chemical composition, but with microstructures differing in porosity, tortuosity, surface area density and particle- and pore sizes. A numerical tool is presented, which mimics the sintering process, thus generating realistic (synthetic) 3D microstructures. This tool was validated by comparing microstructure parameters of the generated structures with those derived from “real” cathodes, reconstructed via FIB-tomography.
Together with adequate performance models [1-3], this approach allows to decouple the influence of material composition and microstructure on performance. It enables us to analyse microstructure development at different sintering parameters (temperature or time). Thus, this tool provides guidelines for designing high-performance cathodes (e.g., ideal material fractions, cathode thickness, etc.).

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

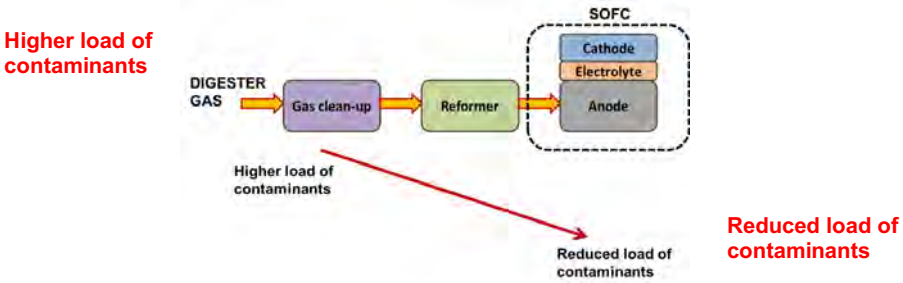
B0804 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Dealing with fuel contaminants degradation in Ni-anode SOFCs

Andrea Lanzini, Davide Papurello, Domenico Ferrero, Massimo Santarelli
Energy Department, Politecnico di Torino
Corso Duca degli Abruzzi 24, 10129 Torino, ITALY
Tel.: +39-011-090-4424
andrea.lanzini@polito.it

Abstract

The real-life operation of solid oxide fuel cell (SOFC) system has to deal with fuel contaminants that might reduce even significantly the lifetime of reformer and stack depending on the type and amount of contaminant present in the feed stream.
From a system-perspective, detecting and correlating observed stack and reformer performance degradation with fuel contamination is fundamental to implement correctional procedures (e.g., change of clean-up vessels catalysts) and/or trigger alarms to prevent a further contamination of the fuel cell.
In this work, based on own experiments with several fuel contaminants (H_2S, HCl, tars, siloxanes), we have developed empirical degradation models that are able to quantitatively correlate the range of degradation rate resulting from known amounts of a certain contaminant type in the fuel stream.
The techno-economic trade-off of having ultra-stringent purification requirements on the fuel clean-up unit due to additional operating costs (e.g., for frequent catalysts change) or capital costs (e.g., for vessel over-sizing to accommodate for larger amount of catalysts and possibly of different types) versus the lifetime of the fuel cell stacks is eventually analysed.
Practical guidelines for the operation of large fuel cell systems operated on biogas and bio-syngas fuels are finally provided for the early detection of model-aided degradation from fuel contamination.



Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0807 (Will be published elsewhere)

A steady state and dynamic 1-D model study of reversible solid oxide cells for energy storage

Srikanth Santhanam (1), Marc P. Heddrich (1), K.A. Friedrich (1)
(1) German Aerospace Centre (DLR),
Institute of Engineering Thermodynamics
Pfaffenwaldring 38-40, 70569, Stuttgart, Germany
Tel.: +49-711-6862-755
Fax: +49-711-6862-747
santhanam.srikanth@dlr.de

Abstract

Solid oxide cell reactors are attractive for hydrogen and hydrocarbon generation due to their superior electrical efficiency and fuel flexibility. In reversible mode SOC are also discussed as an interesting option for electric energy storage.

A transient and steady state 1-D model of a Reversible Solid Oxide Cell (RSOC) has been developed using the Equation based Object Oriented (EOO) Modelica language. The model is implemented using the Dymola editor. With the model SOC reactor behavior is to be studied.

A detailed steady state analysis is performed for electrolysis operation mode under pressure to identify the regimes for methanation to occur within the cell during co-electrolysis. Parametric analysis was carried out to observe the impact of operating pressure, current density, sweep gas airflow rate on temperature distribution, methane evolution and gas concentrations along the length of the cell. Impact of counter flow and co flow on cell behavior is analyzed.

Based on results obtained from electrolysis operation, the cell model is operated in mode under steady state conditions for two cases: a) with internal methanation during electrolysis b) without internal methanation during electrolysis to highlight advantages and drawbacks of internal methanation in SOC. All results obtained from the above analysis will further be used for selecting operating parameters for a 0-D electrochemical reactor model in a follow-up work of a detailed process system analysis of RSOC systems.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0808

Analysis of temperature profiles in SOECs during startup and shutdown periods

Filip Karas, Roman Kodým, Martin Paidar, Karel Bouzek
University of Chemistry and Technology Prague
Department of Inorganic Technology
Technická 5, Praha 6 - Dejvice
166 28, Czech Republic
Tel.: +420-22-044-4009
Fax: +420-22-044-4410
karasf@vscht.cz

Abstract

Hydrogen is considered as an auspicious candidate for temporary electric energy storage. The importance of this application of hydrogen increases rapidly within the current decade in parallel to the growing production capacity of the renewable energy sources characterized by power output highly fluctuating in time integrated to the distribution grid. Hydrogen production via water electrolysis offers an effective way how to level the output of these sources and to stabilize the distribution grid.
Except of the well-known and established technologies, like alkaline or proton exchange membrane water electrolysis, the high temperature steam electrolysis realized in the solid oxide electrolysis cell is nowadays investigated with increasing intensity. This is due to its advantages when compared to the low temperature alternatives, the main of them being (i) lower reversible cell voltage, (ii) rapid electrode reaction kinetics and (iii) possibility to operate cell in a reversible regime, i.e. both as an electrolyser (SOEC) and fuel cell (SOFC). Although significant progress has been achieved in the research of SOEC during the last decade, there are still issues to be overcome. They are mainly connected with the long term durability and flexibility of the system.
The present study is focused on the analysis of SOEC system on a local scale with a special attention being paid to the identification of a possible thermal degradation risks. The two dimensional mathematical model of a single SOEC was developed for this purpose. The model is macrohomogeneous and describes local mass, charge and heat transport under both stationary and transient regime. Parametric study of several operating parameters was carried out to understand more into the detail mass and heat transport, their coupling with electrochemical reactions and their effect on the SOEC performance.
An attempt was undertaken to validate the model results experimentally during startup and shutdown periods. Planar electrolyte supported cells (Ni/YSZ – YSZ – LSM/YSZ – LSM) was used for this purpose.

Acknowledgement: Financial support of this research by FCH JU within framework of the project SElySOs, grant agreement No. 671481 is gratefully acknowledged.

B0809 (Will be published elsewhere)

A Physical Model to Interpret Electrochemical Impedance Spectra for LSM-YSZ Composite Cathodes

Aayan Banerjee (1), Olaf Deutschmann (1)
(1) Karlsruhe Institute of Technology (KIT)
Engesserstr. 20, 76131 Karlsruhe, Germany
Tel.: +49-721-608-43064
Fax: +49-721-608-44805
aayan.banerjee@kit.edu

Abstract

To help unambiguously interpret electroimpedance spectra and better understand the mechanism of oxygen reduction in LSM-YSZ composite cathodes, a fully transient, continuum multi-physics model of a LSM-YSZ composite cathode sintered to a YSZ electrolyte is developed from first principle conservation equations of mass, charge and species transport. The model studies the coupled interactions of porous media transport and chemistry. Gas-phase species diffusion and convection are evaluated using the Dusty Gas model while the distributed charge transfer model calculates charge transport throughout the cathode. All effective transport parameters and volume-specific reactive lengths and areas required by the model are obtained using percolation theory. The oxygen reduction reaction is modeled using two detailed elementary kinetic mechanisms. The thermodynamically consistent mechanisms formulate the kinetics of each elementary step using mass action law. The mechanisms include both surface and bulk reaction pathways in parallel and are driven by three separate electric phase potentials. The simulated results using both mechanisms are compared against Tafel plots and impedance spectra measured by Barbucci et al. [*J. Appl. Electrochem,* **39**, 513–521 (2009)] over a wide range of operating temperatures (973 K – 1123 K), inlet O_2 concentrations (8% - 100%) and overpotentials (-1V to +1V) for model validation. After the most appropriate mechanism is selected, a sensitivity analysis is performed to reveal the rate-limiting steps. Results indicate that ionic transport, oxygen dissociation and charge transfer at the three phase boundary are the rate-limiting processes. Moreover, the bulk pathway was found to be insignificant even at high cathodic overpotentials.

This extended abstract is part of a paper which will be submitted to the Journal of the Electrochemical Society.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0810 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Modelling of gas diffusion limitations in Ni/YSZ electrode material in CO_2 and co-electrolysis

Jakob Dragsbæk Duhn (1), Anker Degn Jensen (1), Stig Wedel (1), Christian Wix (2)
(1) DTU Chemical Engineering
Søltofts Plads 229, 2800 Kgs. Lyngby/Denmark
(2) Haldor Topsoe A/S; Haldor Topsøes Allé 1, 2800 Kgs. Lyngby/Denmark
Tel.: +45-22476700
Fax: +45-45272999
jadu@kt.dtu.dk

Abstract

Carbon formation during CO_2 and co-electrolysis (combined electrolysis of H_2O and CO_2) has been observed in recent studies, under operating conditions where carbon formation, based on the bulk gas composition, should be thermodynamically unfavorable. The carbon can principally be formed by the Boudouard reaction ($2CO \rightarrow CO_2 + C(s)$) or the CO reduction reaction ($CO+H_2 \rightarrow H_2O + C(s)$), and will disintegrate the cell structure as it grows. It is therefore of great importance to be able to predict when the carbon is formed, and subsequently take actions to prevent formation.
The literature offers suggestions that the carbon formation is caused by diffusion limitations within the Ni/YSZ electrode, but this has not been verified. To do so, the diffusion has been modelled with the dusty gas model and the effect of the electrode tortuosity τ, porosity ϵ, temperature T, electrode thickness d_c, and current density i, has been investigated. It is shown that diffusion limitations on reactant transport may lead to very significant increases in equilibrium temperatures for the two carbon forming reactions. For given electrode properties (ε, τ and d_c) increasing current density leads to increasing equilibrium temperatures. The model can be used to calculate limitations on operating conditions (T, i) that ensure no carbon formation.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0811 (Will be published elsewhere)

Evaluation of Solid Oxide Cell (SOC) performance and degradation: Combined experimental and modeling study

Vitaliy Yurkiv, Michael P. Hoerlein, Günter Schiller, K. Andreas Friedrich
German Aerospace Center (DLR)
Institute of Engineering Thermodynamics
Pfaffenwaldring 38-40, 70569 Stuttgart, Germany
Tel.: +49-711-6862-8044
Vitaliy.Yurkiv@dlr.de

Abstract

High temperature water electrolysis using Solid Oxide Cell (SOC) offers a favorable way for hydrogen production. It is expected that SOC stationary power systems should be able to operate over 40000 hours, with quasi-negligible loss in performance, to be commercially competitive. Nowadays, this goal is far from being achievable due to different degradation phenomena occurring during the SOC operation. Thus, in the present contribution we combine our own experimental measurements with elementary kinetics numerical modeling to shed more light on key factors which limit SOC long term performance.
Planar fuel electrode supported cells (Ni/YSZ|YSZ|CGO|LSCF) produced by CeramTec, Germany, were electrochemically characterized (impedances, I-V curves and voltage stability tests) in a broad variety of conditions. More detailed description of experimental procedure used to analyze cells' physical properties is given in our second contribution to this conference.
In order to identify rate limiting/determining steps and factors governing performance decrease, an elementary kinetic model is established to represent the coupled behavior of (electro)-chemistry, transport and degradation processes in the SOC. The simulation of cells, operated on H_2/H_2O mixture, shows that both performance and degradation are significantly influenced by the operating temperature and the applied potential. Specifically, the electrochemical impedance spectra consist of four features which are: (i) gas conversion impedance appearing in the frequency at ~5 Hz; (ii) oxygen reduction at the LSCF cathode with the average frequency of approx. 10^2 Hz; (iii) anode charge-transfer resistance (~10^3 Hz); (iv) oxygen ion transfer throughout YSZ layers of anode support coupled to hydrogen charge-transfer (high frequency processes ~10^4 Hz). Based upon those findings, voltage stability tests, performed over 1000 h in different current densities, were modeled and analyzed. It was identified that degradation of the cathode layer, due to strontium segregation on the surface along with increasing ohmic resistances, causes significant voltage drop at applied current densities.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0813 (Will be published elsewhere)

Nonlinear Model Predictive Control (NMPC) for SOFC

Yousif Al-sagheer, Vikrant Venkataraman, Robert Steinberger-Wilckens
Centre for Fuel Cell and Hydrogen Research
School of Chemical Engineering
The University of Birmingham, B15 2TT, UK
YIW213@bham.ac.uk

Abstract

Model predictive control (MPC) is an advanced and sophisticated control tool in comparison to classical control tools, such as P, PI or PID methods. MPC utilizes a finite number of optimized control actions along a finite prediction horizon. Although at a specific time the MPC predicts a sequence of optimal control actions, only the first control action is applied to the system. After which a repetition of the optimization process starts at the new time step.
Determining the optimal control actions depends on the predesigned performance indices that form the cost function of the system. The performance indices, for example, could be the sum of weighted second norms of the system output deviation from a set point, the input deviation and/or the rate change of input to avoid fatigue. Simply speaking, the cost function calculates the impact of control variables along a control horizon on the system performance along a prediction horizon.
The optimal control actions along the control horizon will be the values of the input that minimize the underlying cost function, where the optimization process is subjected to system constraints to protect the system from undesired input values. It is necessary to include some important operational constraints in the optimization calculation. For the case of SOFC operation, for instance it is important to maintain the current of the fuel cell between physically feasible limits.
A fundamental model of an SOFC has been developed that forms the basis for future predictions of SOFC output power. However, the SOFC model is highly nonlinear and the power amplitude of SOFC undergoes a gain sign change at maximum power point, which makes the implementation of classical control tools difficult especially when forcing the controller output to obey amplitude saturation of rate change saturation.
In this work, a nonlinear MPC controller shows very good tracking to the input signal of power demand with keeping the output power of the SOFC within operational constraints. Furthermore, the controller succeeded in noise and error rejection, which arise from measurement noise and model imperfection, by updating the SOFC model regarding the operating temperature and pressure changes and by updating SOFC power prediction by taking into account the error between the voltage prediction and filtered measurement of SOFC voltage.
The controller could help in operation of SOFC in distributed power generation units where there is the need to run SOFC units at precise demand levels and within safety or operational constraints.
The Matlab Symbolic Math and Optimization toolboxes are used to construct and solve the cost function, while the LabVIEW is used to simulate controller performance and to investigate the on-line tuning of controller parameters.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0815 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

FEA analysis and modelling of thermal stress in SOFCs

Dr Harald Schlegl (1), Dr Richard Dawson (1)
(1) Lancaster University Engineering Dept.
Gillow Avenue, Lancaster LA1 4YW / United Kingdom
Tel.: +44 (0)1524 593685
h.schlegl@lancaster.ac.uk, r.dawson@lancaster.ac.uk

Abstract

Durability and reliability of anode supported SOFC stacks have proven unsatisfactory in large scale trials, showing rapid failure, thermal cycling intolerance and step change in electrochemical performance most likely related to mechanical issues. Monitoring and understanding the mechanical conditions in the stack especially during temperature changes can lead to improvements of the design and of the operating regime targeting maximum durability. Within this project modelling and simulation of thermal stresses within the different parts of the cells and the stack and the validation of this models play a key role and were performed in this work.

The modelling and simulation of stress and strain have been carried out using the FEA software Abaqus™. Model variations documented the importance of exact knowledge of material properties like Young's modulus, Poisson's ratio, thermal expansion coefficient, thermal conductivity and creep viscosity. The benefit of literature data for these properties is limited by the fact that all these properties are highly dependent on the composition of materials but also on details of the fabrication process like mixing, fabrication technique and sintering temperature and duration. The work presented here is an investigation into the modelling techniques which can be most efficiently applied to represent anode supported solid oxide fuel cells and demonstrates the temperature gradient and constraint on the stresses experienced in a typical design.

The work described in this paper is part of a project with the title "Novel diagnostic tools and techniques for monitoring and control of SOFC stacks – understanding mechanical and structural change" and is a collaboration with Loughborough University and Imperial College in the UK and the POSTECH institute of new and renewable energy, the Korea Institute of Energy Research (KIER) and Hankook Oil in Korea.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0816 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Numerical investigation of fuel starvation effect at high current in novel planar SOFC design

Tomasz Zinko, Paulina Pianko-Oprych, Zdzisław Jaworski
Faculty of Chemical Technology and Engineering
Institute of Chemical Engineering and Environmental Protection Processes
West Pomeranian University of Technology, Szczecin
al. Piastów 42, 71-065 Szczecin, Poland
tomasz.zinko@zut.edu.pl

Abstract

Computational Fluid Dynamics (CFD) calculations were carried out to investigate the fuel starvation effect at high current in a single planar anode-supported Solid Oxide Fuel Cell (SOFC) of a novel design of flow channels.
Understanding of voltage loss mechanism is crucial in optimization and improvement of fuel cell performance. Current-voltage curves can be divided into three main areas, where different mechanisms predominate. In the first area at a low current value, activation losses (slow reaction kinetics) are the most important, while Ohmic losses and mass transport losses have meaningful impact at higher current.
In this work, the focus was laid on the last type of losses related to the fuel flow. During the numerical investigations, it was noticed that too low inlet mass fuel flow affects the produced current. The impact on the current values at operating voltage of 0.7- 0.8 V was not significant, however it was noticeable at lower voltage or higher current values. It contributed to an unexpected power drop there. This phenomenon was referred to as a fuel shortage. The cause of the fuel starvation was assigned to a too low value of the inlet mass fuel flow as well as inappropriate flow channels geometry.
The accuracy of the CFD predictions was estimated based on experimental I-V curves.
In addition, the obtained CFD results were compared with previous results for the same SOFC design at different fuel flow rates to estimate the effect of the fuel starvation. The numerical simulations allowed to predict gas flow, current density and temperature distributions inside the gas channels and Membrane Electrode Assembly (MEA) structure, which can be helpful in further SOFC geometry optimization.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0818 (Will be published elsewhere)

Numerical surface coverage condition analysis of a porous Ni/YSZ anode during internal reforming

Christoph Schluckner, Vanja Subotić, Christoph Hochenauer
Institute of Thermal Engineering, Graz University of Technology
Inffeldgasse 25/B, 8010 Graz, Austria
Tel.: +43-316-873-7811
Fax: +43-316-873-7305
christoph.schluckner@tugraz.at

Abstract

Internal reforming of light hydrocarbons is a major advantage of solid oxide fuel cells (SOFCs). This reforming process includes the risk of carbon formation on the active nickel sites of the porous fuel electrode. This heterogeneous process was numerically investigated by means of a detailed computational fluid dynamics (CFD) model for a broad range of carbon containing fuel feeds and steam-to-carbon (S/C) ratios. The model enables to scrutinize the surface coverage condition of the catalytically active nickel sites. 13 surface adsorbed species including elementary carbon, its precursors and hydrogenated species can spatially and temporally be simulated by means of this model. In a first step, most prominent carbon precursors were identified. Feeds of methane, carbon monoxide and equi-molar blends of methane and carbon monoxide were used at different S/C-ratios. It was shown that highest carbon surface coverages occur when using pure methane/steam feeds. Carbon monoxide/steam feeds led to considerably lower coverages. Besides the spatial distribution of carbon, distinctly differing surface conditions are prevalent when running the SOFC at varied temperatures and fuel feeds. This knowledge of the amount and position of surface adsorbed species helps to understand the occurring processes and can be used to identify prevalent cell degradation mechanisms induced by internal reforming.

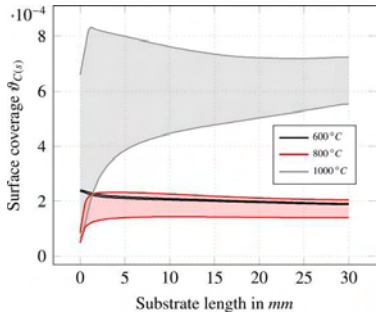


Fig. 1 Minimum and maximum surface coverages of elementary carbon at 600, 800 and 1000°C for CH_4/H_2O feeds at S/C 0.5

Fig. 1 shows minimum and maximum surface coverages of elementary carbon at the catalytically active nickel sites for methane/steam feeds at a S/C of 0.5. Highest surface coverages were calculated for 1000°C. With increasing temperature, absolute coverages and coverage variations increase. The upper and lower limits correspond to the anode surface and the anode/electrolyte-interface, respectively. Scrutiny of these surface coverage conditions reveals distinctly different amounts of species adsorbed to the surface for the different fuels and temperature ranges scrutinized in this study.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

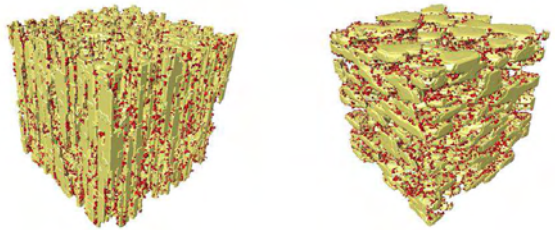
B0819 (Abstract only, published elsewhere)

Geometric modeling of infiltrated solid oxide fuel cell electrodes with directional backbones

Mehdi Tafazoli(1) ,Majid Baniassadi(2),Alireza Babaei(3) ,Mohsen Shakeri(1)
(1) Department of Mechanical Engineering, Babol University of Technology, Babol, Iran
(2) School of Mechanical Engineering, College of Engineering, University of Tehran, Tehran, Iran
(3) School of Metallurgy and Materials Eng. College of Engineering, University of Tehran, Tehran, Iran
Tel.: +0098-21-88084413
fax: +0098-21-88578806
tafazoli@stu.nit.ac.ir

Abstract

Solid oxide fuel cell electrodes with directional properties have shown their potential to get the maximum electrochemical reaction sites with highest gas diffusion property and ionic conductivity. New manufacturing methods like freeze type casting and thermal spray have used to make this kind on electrodes. The effect of backbone directional behavior in infiltrated solid oxide fuel cell (SOFC) has been investigated in this work. A series of directional backbones were generated by a statistical method and analyzed in regard of available active surface and pore tortuosity. Different amount of electrocatalyst particles virtually infiltrated on the surface of those scaffolds. Some geometric parameters like triple phase boundary (TPB) density, active electrocatalyst surface density and tortuosity have been extracted from those realized models. The simulations have shown that the optimum amount of infiltration to get the maximum TPB density or active surface density of impregnated particles can be varied depends on the anisotropy and porosity in scaffolds. In the backbones, being directional normal to the electrolyte has a positive effect on active electrochemical sites especially in active surface density of deposited particles. Also adding infiltrate particles considerably increased the pore tortuosity only in low porosity macrostructures. Accordingly, directional backbones can enhance the physical and electrochemical performance of the electrodes simultaneously.



Realized macrostructure geometry of two different infiltrated directional backbone

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0820

Accuracy of the Numerically Computed Spatial Current and Temperature Variations in SOFCs

Özgür Aydın (1), Hironori Nakajima (2), Tatsumi Kitahara (2)
(1) Department of Hydrogen Energy Systems, Graduate School of Engineering, Kyushu University, ITO Campus, 744 Motooka, Nishi-ku, Fukuoka, 819-0395, Japan
(2) Department of Mechanical Engineering, Kyushu University, ITO Campus, 744 Motooka, Nishi-ku, Fukuoka, 819-0395, Japan
Tel.: +81-92-802-3234
Fax: +81-92-802-3234
ozgur.aydin@mech.kyushu-u.ac.jp

Abstract

As of other technologies, numerical models contribute to the research and development of SOFCs (solid oxide fuel cells) effectively, via predicting the regarding properties spatially. Essentially, the reliability of the models requires them to be validated with the experimental data under benchmark conditions. Because it is impractical to execute experiments for SOFCs, due mainly to the high operation temperatures, the SOFC models are hardly validated with the experimental data. The models present in the literature are either not-validated at all, or validated utmost with the conventional I-V (current-voltage) curves. This means that almost all of the models are not verified for the temperature variations at all, despite the fact that they are extensively employed to estimate the spatial temperature variations giving rise to the thermal stresses. Thereby, in this study, we evaluate the accuracy of the SOFC models in terms of the current and temperature variations. For this evaluation, we lean upon the spatial current and temperature variations in-situ measured via the electrode-segmentation method in microtubular-SOFCs operating on hydrogen and air. The analysis of the correlation between the spatial I-V curves acquired with the model validated by the conventional I-V curve and by the electrode-segmentation method reveals that the numerical calculations predict smaller current variations. Secondly, we evaluate the correlation between the spatial temperature variations obtained by the model validated by the conventional I-V curve and by the electrode-segmentation method. This evaluation discloses a substantial deviation among the numerical and experimental results, which is mainly attributed to whether radiant heat transfer is included in the model. Finally, we explore the impact of the model validation with both the conventional I-V curve and the spatial temperature measurements on the spatial current variations. Although this double validation approach improves the model accuracy, numerical computations yield smaller current variations.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0821

Evaluation of SOFC anode polarization characteristics with pillar-based YSZ structure

Takaaki Shimura (1), Keisuke Nagato (2,3), Naoki Shikazono (1,4)
(1) Institute of Industrial Science, The University of Tokyo;
4-6-1 Komaba, Meguro-ku, Tokyo / Japan
(2) Department of Mechanical Engineering, Graduate School of Engineering, The University of Tokyo;
7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan
(3) JST PRESTO; 7 Gobancho, Chiyoda-ku, Tokyo, Japan
(4) JST CREST; 7 Gobancho, Chiyoda-ku, Tokyo, Japan
Tel.: +81-3-5452-6777
Fax: +81-3-5452-6777
tshimura@iis.u-tokyo.ac.jp

Abstract

To reduce the overpotential of solid oxide fuel cell (SOFC) electrodes, microstructure modification has been investigated by many researchers. Among the diffusion processes of gas, ion and electron in the electrodes, it is known that ionic conduction generally has the greatest impact on the overall electrode performance. In order to enhance effective ionic conductivity of SOFC anode, insertion of Yttria-stabilized Zirconia (YSZ) pillars can be an effective solution. In this study, the effect of YSZ pillar in an anode was evaluated by a three dimensional numerical simulation using a Lattice Boltzmann method. A microstructure obtained by focused ion beam scanning electron microscopy (FIB-SEM) was used as the reference structure. Then, YSZ pillar was virtually inserted into the reference microstructure. For the anode with YSZ pillars, predicted area specific resistance was smaller than the reference anode, while active TPB density showed slight decrease. The enhancement of anode performance can be attributed to the increase of the effective ionic conductivity. Relationships between overpotential and pillar geometries were schematically discussed.

B0822 (Will be published elsewhere)

Local reacting environment within SOFC stacks examined by three-dimensional numerical simulations

Sanghyeok Lee (1,2), Hyoungchul Kim (1), Kyung Joong Yoon (1), Ji-Won Son (1), Jong-Ho Lee (1), Byung-Kook Kim (1), Wonjoon Choi (2), Jongsup Hong (1),*
(1) High-temperature Energy Materials Research Center
Korea Institute of Science and Technology (KIST)
Hwarangno 14-gil 5, Seongbuk-gu, Seoul 02792, South Korea
(2) Department of Mechanical Engineering, Korea University
Anamno 145, Seongbuk-gu, Seoul 02841, South Korea
Tel.: +82-2-958-5431
Fax: +82-2-958-5529
*corresponding author: jhong@kist.re.kr

Abstract

Recent development of SOFC stacks emphasizes that it is highly important to elucidate the thermochemical reacting environment and local thermodynamic state in the vicinity of cells and their impact on performance and materials degradation. This may provide insights to engineer the cell and stack design achieving high performance and durability. However, stack configuration and high-temperature sealing conditions make it extremely difficult to characterize experimentally the phenomena taking place inside the SOFC stack. To tackle this issue, numerical simulations using a high-fidelity 3D model that incorporates a thermo-fluid sub-model, electrochemistry and materials characteristics were performed in this study. The physical model considers planar, anode-supported cells comprised of Ni-YSZ/YSZ/GDC/LSCF-GDC/LSCF. The model was validated against in-house experimental measurements obtained at a number of temperature and fuel compositions which correspond to actual SOFC stack operating conditions. Then, a parametric study with respect to fuel utilization, materials parameters such as thermal conductivity, thickness, porosity and CrO_3 scale (growing on the interface between the cathode and metallic interconnect) thickness was conducted. Results show that they influence substantially the local thermodynamic state and the internal reacting environment, resulting in non-uniform thermal, mechanical and chemical field variables along the cell. Their effect on heat, momentum and mass transfer was examined, which is correlated with thermal, mechanical and chemical stresses imposed on cell and metallic interconnect materials. Local variations including electrical current distribution, electrochemical reaction zones, hot spots and contact resistances were analysed.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0823 (Abstract only)

Geometric characterisation and performance improvement of IT-SOFCs in highly efficient CHP systems

Luca Mastropasqua (1), Stefano Campanari (1), Paolo Iora (2)
(1) Department of Energy, Politecnico di Milano
Via Lambruschini 4, 20156 Milano (IT)
(2) Department of Mechanical and Industrial Engineering
Università di Brescia
Via Branze 38, 25123 Brescia (IT)
Tel.: +39-02-2399-3842
luca.mastropasqua@polimi.it

Abstract

SOFC-based micro-CHP systems are under thorough study by our research group due to their outstanding potentialities for highly efficient distributed generation. The present work aims at further developing the performance characterisation of the cells which are employed in such systems. Specifically, natural gas-fed cells are characterised from a geometrical point of view in order to reproduce the expected performance available from the manufacturer. Moreover, an existing 2D SOFC model has been employed to calibrate and simulate them, especially highlighting how the most used mass and charge transfer literature models should be updated to entirely reproduce their operating conditions. In order to support these choices, a sensitivity analysis on the most important model parameters has been carried out.

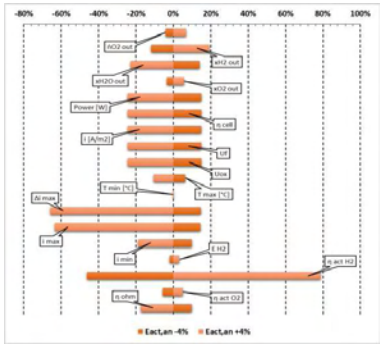


Figure 1 – Sensitivity analysis on anodic charge transfer activation energy

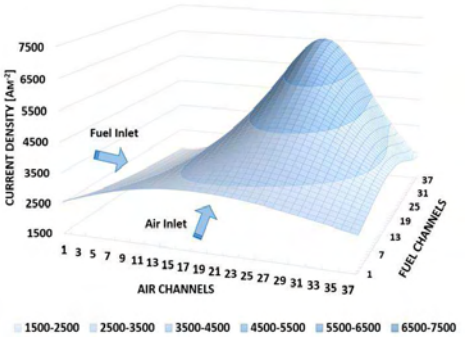


Figure 2 – Current density profile of natural gas-fed case

The combination of a complex flow-field design and the extremely high once-through utilisation factors has suggested the possibility of an internal multi-passage fuel flow arrangement, which is proposed herein. By means of an additional design variable, the internal temperature and current density profiles are modified with an expected overall beneficial effect on the cell performance.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0824 (Will be published elsewhere)

3D simulation of a patterned LSM cathode considering reaction on LSM/pore double-phase boundary

Takuma Miyamae, Hiroshi Iwai, Motohiro Saito, Masashi Kishimoto, Hideo Yoshida
Department of Aeronautics and Astronautics, Kyoto University
Nishikyo-ku, Kyoto 615-8540 JAPAN
Tel.: +81-75-383-3652
Fax: +81-75-383-3652
miyamae.takuma.22a@st.kyoto-u.ac.jp

Abstract

Electrochemical activity of solid oxide fuel cell (SOFC) electrodes has been of great interest in electrode designing, such as choice of materials and optimization of porous microstructure. Numerical modeling of SOFC electrodes also requires an empirical formula of the electrochemical activity. Patterned electrodes have been commonly used to evaluate the electrode electrochemical activity because they have well-defined reaction site density. However, in the LSM cathodes, the oxygen reduction reaction can occur also at the LSM/pore double-phase boundaries (DPBs), in addition to the conventional LSM/YSZ/pore triple-phase boundaries (TPBs). Therefore, if an empirical formula of the electrochemical activity (exchange current density per unit TPB length, $i_{0,\mathrm{TPB_PTN}}$) is obtained from a thin and dense patterned electrode, it can include the effect of DPBs. In our group, the electrochemical activity of the TPBs was evaluated from a porous LSM cathode ($i_{0,\mathrm{TPB_PRS}}$); however, the activity of the DPBs still remains unclear.

In this study, we evaluated the exchange current density per unit DPB area in LSM cathodes using 3D numerical simulation. Cathode overpotentials were numerically obtained in a patterned electrode geometry (Fig.1 (a)) using two different empirical formulas of the electrochemical activity, i.e., $i_{0,\mathrm{TPB_PTN}}$ and $i_{0,\mathrm{TPB_PRS}}$, and the electrochemical activity of the DPBs was estimated from the difference between the two simulation results. The numerical results also revealed a steep gradient in the oxygen potential in the vicinity of the TPB (Fig.1 (b)), and this is considered to be the driving force of the reported morphological change in the LSM phase during operation.

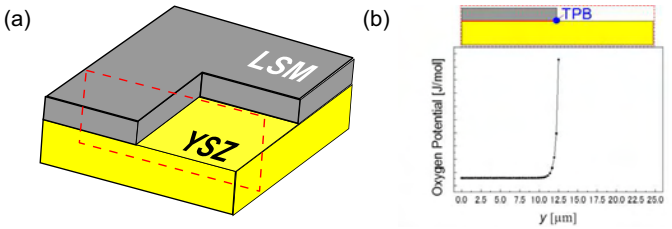


Fig. 1. (a) Schematic picture of the patterned LSM cathode for numerical simulation. (b) an example of the distribution of oxygen potential.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0826 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Numerical Evaluation of Direct Internal Reforming SOFC Operated with Biogas

Tran Dang Long (1), Tran Quang Tuyen (2), Yusuke Shiratori (1,2)
(1) Department of Hydrogen Energy Systems, Faculty of Engineering,
(2) International Research Center for Hydrogen Energy,
Kyushu University
Motooka 744, Nishiku, Fukuoka, 819-0395, Japan
Tel.: +81-92-802-3095
Fax: +81-92-802-3094
3TE14098G@s.kyushu-u.ac.jp

Abstract

Among energy conversion systems including fuel cell systems and heat engines, solid oxide fuel cell (SOFC) systems operated in the temperature range between 600 and 900 ^{o}C may exhibit the highest electrical efficiency in the feed of biogas due to fast electrochemical reaction process and simplified fuel processing (direct internal reforming (DIR) capability). During electricity generation, dry reforming of CH_4 (endothermic) and electrochemical oxidations of H_2 and CO (exothermic) simultaneously occur in the porous cermet anode causing non-homogeneous temperature distribution over the dense electrolyte. The resulting mechanical stress can cause electrolyte (cell) fracture. Here, DIR-operation of planar anode-supported SOFC with the feed of biogas mixture was evaluated by means of 3D-CFD model coupling mass- and heat transfers and chemical and electrochemical reaction processes. A black-box-based chemical model of concurrent dry and steam reforming of CH_4 in the anode induced from button cell testing was incorporated into the simulation to obtain distributions of temperature, chemical species and current density. The established SOFC model is capable of reproducing operational status of SOFC fuelled by all types of biogas fuels, including humidifed- and pre-reformed biogases. Using this model, risk of electrolyte fracture and output performance focusing on the influences of air inlet temperature and gas flow configuration were discussed. It was found that co-flow in conjunction with high air inlet temperature may be better choice for the stable operation of DIR-SOFC fuelled by biogas.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0827 (Abstract only)

Harvesting Big Data in SOFC Short Stacks – A Step Beyond Contemporary Characterization Techniques

Carlos Boigues Muñoz (1,2), Davide Pumiglia (1,3), Francesca Santoni (1,4), Stephen J. McPhail (1), Gabriele Comodi (2)
(1) DTE-PCU-SPCT, ENEA C.R. Casaccia, Via Anguillarese 301, Rome 00123, Italy
(2) Dipartimento di Ingegneria Industriale e Scienze Matematiche, Università Politecnica delle Marche, Via Brecce Bianche, Polo Montedago, Ancona 60131, Italy
(3) DAFNE, Università degli Studi della Tuscia, Via S. Camilo de Lellis snc, Viterbo
(4) Department of Science and Technology, Parthenope University, Naples 80143, Italy
Tel.: +39-392-313-7650
carlos.boigues@enea.it

Abstract

Solid Oxide Fuel Cell (SOFC) is regarded as a powerful applied science that can radically improve nowadays energy scenario, especially when used collectively with other power generation systems relying on sustainable and renewable energy sources. As of today, fuel cell technology is already a reality, several prototypal power and cogeneration systems have been installed worldwide, yet SOFCs are still far from being a mature technology, a series of flaws compromising robustness and reliability of the power units (i.e. stacks) have been delaying their market penetration for over a decade now.

In order to completely override the current drawbacks and glitches affecting the performance of SOFCs, it is essential to discern the origin and nature of these, and this can only be done by radically improving the characterization tools and techniques existing nowadays. *Big Data* analysis by means of innovative processing applications is seen as a costless technique capable of complementing the more traditional and specific analysis tools and techniques.

A statistically rational processing of vast amounts of time-dependent data obtained from an SOFC short stack operated in an apposite test station has demonstrated to be an effective non-invasive analysis technique capable of characterizing the healthiness of SOFC-based power units (i.e. stacks). Notwithstanding this fact, the coupling of *Big Data* analysis with more traditional analysis tools and techniques such as polarization curves, electrochemical impedance spectroscopy (EIS), gas chromatography and the more innovative distribution relaxation times (DRT) method has demonstrated to go one step beyond contemporary characterization techniques.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0828 (Will be published elsewhere)

Numerical study on the SOFC characteristics variation with various internal reforming ratio

Sanggyu Kang (1, 2), Youngduk Lee (1), Kook-Young Ahn (1,2), Jacob Brouwer (3)
(1) Korea Institute of Machinery and Materials (KIMM)
(2) University of Science and Technology (UST)
(3) National Fuel Cell Research Center (NFCRC), UCI
Tel.: +82-42-868-7267
Fax: +82-42-868-7284
kyu2613@kimm.re.kr

Abstract

Solid oxide fuel cell (SOFC) system has been received an attention as one of the alternative power sources for stationary application. Since SOFC is operated at high temperature, many researchers have been studied to improve the system efficiency by using its high thermal energy. When the SOFC is operated with high internal reforming ratio, the system thermal efficiency can be increased. However, high internal reforming ratio may cause high temperature gradient through SOFC stack, which result in decrease of the SOFC stack performance. Finding an optimal internal reforming ratio is crucial to achieve the high performance and stable operation for the SOFC system.

The objectives of the work are to develop the three-dimensional dynamic modeling of SOFC and investigate the effect of the internal reforming ratio on the performance of the SOFC stack. The energy and mass balance is resolved with discretization into several control volumes in the fuel flow perpendicular direction to capture the temperature and species concentration through the SOFC, respectively. To investigate the distribution of the SOFC characteristics, SOFC is also discretized into several control volumes in the fuel flow parallel direction. The SOFC stack model has been validated by comparison with the experimental data of current-voltage polarization curve. The SOFC characteristics distribution of current density, temperature, and species concentration are captured with various flow configurations and various internal reforming ratios. This work can provide the basic insight to establish the optimal internal reforming ratio and flow configuration.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1101 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Efficient integration of SOFC and gasification system

Stephan Herrmann (1), Manuel Jimenez Arreola (2), Michael Geis (1), Sebastian Fendt (1), Hartmut Spliethoff (1)
(1) Lehrstuhl für Energiesysteme, Technische Universität München
15 Boltzmannstrasse, DE-85748 Garching/Germany
(2) Nanyang Technological University
50 Nanyang Ave, 639798 Singapore/Republic of Singapore
Tel.: +49-89-289-16279
Fax: +49-89-289-16271
stephan.herrmann@tum.de

Abstract

In the presented work a medium sized integrated system based on the Güssing gasification plant concept and Solid Oxide Fuel Cells (SOFC) is introduced, simulated and validated in Aspen Plus. Suitable feedstocks for such fluidized bed gasification systems are for example waste and biomass, especially wood.

During an allothermal fluidized bed gasification process high temperature heat at around 800°C (1073K) is necessary to drive the endothermic gasification reactions. In the Güssing gasifier this heat is produced in an additional combustion chamber by burning a share of about 20-25% of the generated product gas and transported into the gasifier via circulating bed material. At the same time SOFC produce excess high temperature heat. Thus, the scope of the presented system integration approach is to use the heat generated in the SOFC for the gasification process to reduce the amount of valuable fuel for the combustion process and increase the efficiency. For this purpose the normal steam and air streams to the gasifier are replaced with the anode and cathode outlets of the SOFC, respectively. Like this the exhaust streams carry SOFC waste heat into the gasifier. Furthermore, since the steam is replaced by the anode exhaust residual fuel is recycled into the gasifier.

The gasifier model used in this work has been validated against data from the Güssing plant. The SOFC model applied is a thermodynamic model, which has been developed in the frame of SOFCOM and already described in detail in other works.

A case study is conducted, from which an optimal exergy efficiency of 71.89% is found for the case where the SOFC power output as small as possible, so that the heat transported into the gasifier via the SOFC exhausts and the combustion process is just high enough to eliminate the necessity for additional fuel.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1102 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Development of the FlexPCFC: a Low-Cost Intermediate-Temperature Fuel-Flexible Protonic Ceramic Fuel Cell

Alexis Dubois (1), Kevin J. Albrecht (1), Chuancheng Duan (2), Jianhua Tong (3), Ryan O'Hayre (2), Robert J. Braun (1)
(1) Department of Mechanical Engineering
(2) Department of Materials & Metallurgical Engineering
Colorado School of Mines
1610 Illinois Street Golden CO USA 80401
(3) Department of Materials Science and Engineering, Clemson University
Tel.: +1-303-273-3055
Fax: +1-303-273-3602
adubois@mines.edu, rbraun@mines.edu

Abstract

Protonic ceramic fuel cells (PCFCs) are emerging as a promising low-cost, high-performance technology for power generation. Protonic ceramic fuel cells with triple conducting cathodes [1] have demonstrated record high power densities at operating temperatures as low as 500°C. This technology is being developed for lower temperature operation to enable reduced system startup time, increased cell durability and lower material costs compared to solid oxide fuel cells (SOFCs). These high-performance PCFCs leverage a solid-state reactive sintering (SSRS [1]) process that reduces the number of high temperature fabrication steps, thereby achieving a dramatic reduction in cell manufacturing costs. While the performance and cost reduction potential of PCFCs is promising, the next steps for the technology development lie in cell scale-up, stack development, and system design. In this work, PCFC-based system designs for micro-combined heat and power (CHP) applications on the order of 10 kW are studied in terms of their technical and economic performance potential based on current experimentally validated performance characteristics. A model is developed and exercised to identify attractive system configurations that can achieve net electric efficiencies exceeding 50% (LHV). Performance sensitivity to system configuration and stack operating parameters is presented.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1103 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

A Thermodynamic Analysis of Integrated SOFC Cycles for Ships

Lindert van Biert, Klaas Visser, Purushothaman V. Aravind
3mE, Delft University of Technology,
Leeghwaterstraat 39, 2628 CB, Delft, The Netherlands
Tel.: +31-15-278-8249
l.vanbiert@tudelft.nl

Abstract

The recently commenced Dutch national project GasDrive aims to reduce emissions in shipping, by maximising the profitable effects of liquefied natural gas as a maritime bunker fuel. Solid Oxide Fuel Cell (SOFC) systems are of interest, since they provide an efficient way to generate electricity natural gas, while emitting few hazardous compounds. Even higher electrical efficiencies are projected for SOFC systems equipped with a bottoming cycle, since exhaust gases from the SOFC stack still contain thermochemical energy due to the high operating temperature and practical fuel utilisation limitations.

In particular the integration with a recuperated gas turbine received much attention. Despite several efforts, no such system has demonstrated satisfactory performance to this date. Therefore, several design aspects of integrated cycles are analysed in this study. More specifically, two SOFC-gas turbine integrated cycles, one with a pressurised SOFC and another with an SOFC at atmospheric pressure, and a novel SOFC-reciprocating engine combined cycle are compared to a stand-alone SOFC system. The fixed operational conditions in the SOFC stack allow direct comparison of different bottoming cycle integration schemes. Contours of overall system electrical efficiency are generated for changes in fuel utilisation, stack temperature and power density.

The efficiency contours reveal how the optimal operating conditions of the SOFC stack depend on the system integration flowsheet. As expected, it is beneficial for stand-alone SOFC systems to operate at high fuel utilisation, while an optimum may exist for combined cycles. In SOFC-gas turbine schemes with a high fuel utilisation, for example, the rejected heat after expansion might be of insufficient quality for pre-reforming and pre-heating. In that case, additional fuel needs to be burned and the overall system efficiency drops as a result.

It is shown that the inherently different SOFC-reciprocating engine system can provide a viable alternative for SOFC-gas turbine integrated systems, and can achieve high electrical efficiencies for a range of operating conditions. In addition, the system is less sensitive to changes in fuel utilisation, which is a result of the limited degree of coupling, allowing individual optimisation rather than close matching of mass and heat flows. Design and operation of this combined system is expected to be significantly less complicated than pressurised gas turbine integration scheme. Therefore, SOFC integration with reciprocating engines may prove to be an efficient, simple, robust and cost effective way to generate electricity on-board ships.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1104 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Power to Power efficiencies based on a SOFC/SOEC reversible system

A. Chatroux (1), S. Di Iorio (1), G. Roux (1), C. Bernard (1), J. Mougin (1), M. Petitjean (1), M. Reytier (1)
(1) CEA-Grenoble, LITEN
17 rue des Martyrs, F-38054 Grenoble Cedex 9, FRANCE
Tel.: +33-(0)4-38-78-25-64
Fax: +33-(0)4-38-78-54-79
andre.chatroux@cea.fr

Abstract

High temperature solid oxide electrolysis cells are able to work at high temperature in fuel cell mode (SOFC) or in electrolysis mode (SOEC). This specificity is a promising way to build efficient systems to balance electricity supply and demand with the same core of technology through the hydrogen vector. Such a system has been designed and tested at CEA to operate both in electrolysis mode and in fuel cell mode, including an operation in methane direct internal reforming, thus providing an interesting link between the electrical and natural gas grids. This system has been validated in terms of performance [1,2] and reversibility.

It is shown that a single system can reach high efficiency levels in optimized conditions (>100% / HHV in SOEC mode at the stack level and 55-60% / LHV in SOFC mode at the stack level).

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1107 (Abstract only)

Sensitivity analysis and optimization of solid oxide fuel cells: a review

Seyedehmina Tonekabonimoghadam (1), Yashar S. Hajimolana (1,2), Mohammed Harun Chakrabarti (2), Jelle Nicolas Stam (3), Mohd Azlan Hussain (1), Nigel Brandon (3), Mohd Ali Hashim (1), P.V. Aravind (2)
(1) Chemical Engineering Department
Faculty of Engineering, University of Malaya
50603, Kuala Lumpur, Malaysia
(2) Process and Energy Department
Delft University of Technology
Leeghwaterstraat 44, CA Delft 2628, The Netherlands
(3) Department of Earth Science and Engineering
Imperial College London, South Kensington, London SW7 2AZ, UK
Tel.: +60-172826199
Yashar_molana1@yahoo.com

Abstract

Solid oxide fuel cells (SOFCs) are considered as one of the most promising fuel cell types for application as high efficiency power generators. This work reviews the use of computational fluid dynamics (CFD) to maximise SOFC performance and life, and minimise cost, by considering numerous configurations and designs. A critical analysis of available literature proves that a detailed research on the simulation of thermal stress and its damaging impact on the SOFC are still in its early stage of development. Numerical simulation is expected to help optimize the design, operating parameters and fuel cell materials. Therefore, sensitivity analysis of fuel cell parameters using simulation models is analyzed to address the issue. Finally, the present status of the SOFC optimization efforts is summarized so that unresolved problems can be identified and solved.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1108 (Will be published elsewhere)

Dynamic behavior of the solid oxide fuel cell-engine hybrid system

Sanggyu Kang (1, 2), Kanghun Lee (1), Keunwon Choi (1), Youngduk Lee (1), Kook-Young Ahn (1,2)
(1) Korea Institute of Machinery and Materials (KIMM); Gajeongbukro 156; Daejeon/Republic of Korea
(2) University of Science and Technology (UST), Gajeongro 217; Daejeon/Republic of Korea
Tel.: +82-42-868-7267
Fax: +82-42-868-7284
kyu2613@kimm.re.kr

Abstract

Our previous study has introduced the novel hybrid system composed of solid oxide fuel cell (SOFC) and engine. In order to enhance the electrical system efficiency, anode off gas from the SOFC is reused in the engine. Hybrid system could have higher efficiency than the stand-alone system. However, since anode-off gas is fuel lean condition, optimal system operation should be necessary.
The dynamic modeling of the SOFC-engine hybrid system has been developed. Quasi-three dimensional dynamic modeling of SOFC, two-dimensional dynamic modeling of methane steam reformer (MSR), two-dimensional dynamic modeling of heat exchangers and lumped dynamic modeling of air blower and engine have been developed by Matlab-Simulink®. In order to improve the computational performance of the system model, the engine model has been converted into Simulink model from the Cantera model, which is based on the empirical correlation to determine the auto ignition timing. The system dynamic behavior and correlation among each component model during transients is investigated. This model can be useful to develop the optimal control strategy of SOFC-engine hybrid system during transients.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1109

Gasifier, solid oxide fuel cell integrated systems for energy production from human waste

Mayra Recalde, Theo Wousdtra, P.V. Aravind
Process and Energy, Delft University of Technology
Leeghwaterstraat 39, 2628 CA Delft, The Netherlands
Tel.: +31-15-278-6987
mayra.recalde@tudelft.nl

Abstract

Biomass is the most possible renewable organic substitute for fossil fuels. Nowadays, there is worldwide interest in diversifying the energy supply [1]. Human waste, when dried and charred, have similar energy content to coal [2]. Therefore, with the appropriate treatment, human waste is a potential clean fuel for power generation. In addition to power generation, this technology would represent a sanitary intervention to improve the quality of the environment.
Hydrothermal gasification is an energy-efficient technology for waste treatment, due to the advantageous physical properties of water at supercritical conditions.
This work presents the thermodynamic performance of a plant for processing human waste. Human waste is treated in supercritical water gasification (SCWG) at experimental operating conditions without a catalyst (600 °C, 25 MPa). A gasifier design with present day engineering limitations is considered. The produced gas is fed with a solid oxide fuel cell (SOFC) to convert the chemical energy of the fuel into electricity in an efficient way. The integrated system reaches an electric efficiency of around 22%. The main reason for this low value is the low carbon (CG) gasification efficiency as well as the low heating value of the syngas produced in SCWG. This is caused by present day technical limitations.
The performance of the SCWG-SOFC system is compared with the performance of two other similar systems, i.e. 1) an SCWG-SOFC-GT system where the gasification process is reaching equilibrium, and 2) a microwave plasma assisted two-stage gasifier-SOFC-MST system. Both of these systems have shown efficiencies close to 50%. Those systems have been presented by our group Toonssen et al. [3] and Recalde et al. [4].
SCWG and the plasma assisted two-stage gasifier are promising technologies for producing syngas from human waste. SOFC fed with syngas can then be used to produce electric power efficiently. However, there are barriers to overcome. In the case of the plasma gasifier combined system, the complexity of the plant will represent the main limitation. The combined SCWG-based system, on the other hand, has technical limitations towards reaching complete gasification. This includes the difficulties in the development of efficient and stable catalysts at competitive costs for SCWG of real biomass.
Intensive research in different areas to overcome these barriers might give these technologies great potential for commercialisation in large scale in the future. That will provide economic, environmental and health benefits.

B1111 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Thermochemical and Kinetic Modelling of Chromium-Rich Alloys

Mélissa Oum, Jong-Eun Hong, Robert Steinberger-Wilckens
Centre for Fuel Cell & Hydrogen Research, School of Chemical Engineering
Edgbaston, University of Birmingham, B15 2TT, Birmingham, United Kingdom
Tel.:+44 (0) 121 414 5283
MXO469@student.bham.ac.uk

Abstract

Ferritic stainless steel interconnects are critical components in Solid Oxide Fuel Cells (SOFCs), which electrically connect the cells and prevent gases from mixing. At high temperatures and in the presence of air, oxidation of the metallic interconnects leads to the formation of a passivation scale of chromium oxide. The growing thickness of the scale increases the electrical contact resistance of the interconnects and the formation of volatile chromium species lead to chromium poisoning in the cathode. It is therefore critically important for the estimation of the lifetime of SOFCs to investigate these degradation mechanisms which affect the long-term output cell voltage.

This study examines the high temperature oxidation behavior in conventional ferritic stainless steel (FeCr) interconnects, using thermodynamic and kinetic modelling approaches. The first stage of the study involves designing a coupled one-dimensional thermodynamic-kinetic oxidation and diffusion model. This model is based on the simultaneous thermodynamic assessment of oxidation reactions and calculation of scale growth kinetics, using a finite difference numerical method.

The expected results allow to predict the composition profile in the alloy, as well as the thickness of the oxide layer formed as a function of oxidation time. This model will serve as a basis for life-time prediction of a manganese and cobalt spinel protective layer coated FeCr interconnect in the second stage of the study.

Acknowledgements:
This work was supported by the European FCH JU under contract no. 325331.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1112 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Multi-stage highly-efficient SOFC system using proton and oxide-ion conducting electrolyte

Yuya Tachikawa (1), Yoshio Matsuzaki (2,3), Takaaki Somekawa (2,4), Shunsuke Taniguchi (1,3,6), Kazunari Sasaki (1,3,4,5,6)
(1) Center for Co-Evolutional Social Systems (CESS), Kyushu University
744 Motooka, Nishi-ku, Fukuoka City, Fukuoka 819-0395, Japan
(2) Fundamental Technology Department, Tokyo Gas Co., Ltd.,.
1-7-7 Suehiro-cho, Tsurumi-ku, Yokohama City, Kanagawa 230-0045, Japan
(3) Next-Generation Fuel Cell Research Center (NEXT-FC), Kyushu University
744 Motooka, Nishi-ku, Fukuoka City, Fukuoka 819-0395, Japan
(4) Faculty of Engineering, Kyushu University
744 Motooka, Nishi-ku, Fukuoka City, Fukuoka 819-0395, Japan
(5) International Institute for Carbon-Neutral Energy Research (WPI-I2CNER)
744 Motooka, Nishi-ku, Fukuoka City, Fukuoka 819-0395, Japan
(6) International Research Center for Hydrogen Energy, Kyushu University
744 Motooka, Nishi-ku, Fukuoka City, Fukuoka 819-0395, Japan
Tel.: +81-92-802-3094
Fax: +81-92-802-3094
tachikawa.yuya.657@m.kyushu-u.ac.jp

Abstract

Multi-stage SOFC concept is known that electrical efficiency becomes higher due to gross fuel utilization increase. With increasing the number of stages, the maximum gross fuel utilization will become higher. However, an electrochemical reaction generates water vapor at conventional SOFC anodes, so that an SOFC stack near the outlet operates using highly humidified fuel. Anode nickel becomes oxidized in such a condition and the nickel oxidation leads to SOFC performance degradation. Therefore, it is difficult to completely use the fuel in conventional systems.

One of the solutions to this important issue is the application of proton conducting electrolyte. Protons transport across the electrolyte to the cathode side and the electrochemical reaction occurs at the cathode. Hence, no water vapor is generated on the anode side in the proton-conducting-electrolyte SOFC. In this study, multi-stage SOFC systems are compared using the proton-conducting electrolyte and the oxide-ion-conducting electrolyte are compared. The number of stages is varied for the simulation. Effect of fuel utilization in each stage on electrical efficiency is also evaluated to consider the optimal system design.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1114 (Abstract only)

Solid Oxide Fuel Cells Operating on Methane with Anode Off-Gas Recirculation

Tsang-I Tsai*, Robert Steinberger-Wilckens
School of Chemical Engineering, University of Birmingham, Edgbaston, B15 2TT, UK
Tel.: +44-121-414-5283
tsait@bham.ac.uk

Abstract

Carbon formation inside Solid Oxide Fuel Cells (SOFCs) from hydrocarbon internal reforming leads to severe degradation, as the porous anode structure is blocked and the metallic nickel loses its catalytic activity for reforming. One of the common solutions is Anode-Off Gas Recirculation (AOGR). The steam and other gases produced from the SOFCs anode are recycled to the fuel inlet in order to supply the oxygen necessary for improving the reforming process and overcome the carbon deposition issue. Moreover, as carrying a similar temperature, the AOGR can reduce the thermal stress, lower the system complexity and increase the overall efficiency.

When AOGR is applied, methane can react with steam and carbon dioxide through steam and dry reforming respectively. This leads to different fuel partial pressures and thus varying cell performance. A higher recycling rate will improve the reforming, and lower carbon formation, but also lower the cell performance simultaneously, and vice versa.

A detailed study of methane reforming, carbon formation and cell performance is required for building a long-term operation SOFC with AOGR. In this study, a 0-D model is presented for investigating the system with respect to different performance indicators. Both steam and dry reforming of methane is considered simultaneously, and, the reforming results will be used as the fuel composition for the SOFC model to predict the cell performance. Additionally, carbon formation is discussed in both reforming and SOFC sections to examine how the cell operation affects the formation of carbon and the next reforming section.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1115 (Will be published elsewhere)

Model development of integrated CPO_x reformer and SOFC stack system

Paulina Pianko-Oprych, Mehdi Hosseini, Zdzislaw Jaworski
Faculty of Chemical Technology and Engineering
Institute of Chemical Engineering and Environmental Protection Processes
West Pomeranian University of Technology, Szczecin
al. Piastów 42, 71-065 Szczecin, Poland
Tel.: +48 91 449 47 31
Fax: +48 91 449 46 42
paulina.pianko@zut.edu.pl

Abstract

Operating conditions of Catalytic Partial Oxidation (CPO_x) reformers influence fuel conversion and product (H_2, CO) selectivity. Therefore, it is important to understand the unique demands of a CPO_x reformer – Solid Oxide Fuel Cell (SOFC) stack system. The main purpose of this study was to develop a mathematical model, in a steady state and dynamic mode, of the integrated system in order to evaluate mass and energy fluxes in the system as well as to assess the system performance. Mass balance equations were written for each component in the system together with energy equation and implemented into the MATLAB Simulink simulation tool. The system was operating with methane that was converted via CPO_x to a hydrogen rich gas. Temperature, gas concentrations, pressure and current density were computed in the steady-state mode and validated against experimental data. The calculated I-V curve matched well the experimental one. In the dynamic modelling, several different conditions including step changes in fuel flow rates, stack voltage as well as temperature values were applied to investigate the dynamic performance of the system and to estimate the system response against the load variations. These results provide valuable insight into the operating conditions that have to be achieved to ensure efficient CPO_x performance for fuel processing for the SOFC stack applications.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1116 (Abstract only, published elsewhere)

Stationary, Polygenerative Electrochemical Systems

Whitney G. Colella (1, 2)
(1) Gaia Energy Research Institute, Arlington, VA, USA
(2) The Johns Hopkins University, Whiting School of Engineering, Baltimore, MD, USA
Tel.: +1 (650) 283-2701
Fax: +1 (215) 893-5171
wgc@gaia-energy-research-institute.com, wcolell1@jhu.edu

Abstract

This research focuses on resolving bottlenecks in our stationary energy supply chains with next generation, polygenerative, electrochemical systems. Insights are shared into the engineering design, economics, and environmental impacts of advanced fuel cell system (FCS) concepts, including:

1. combined heat and power (CHP) FCSs;
2. combined cooling, heating and electric power (CCHP) FCSs; and
3. fast-ramping stationary FCSs.

An energy supply chain spans all of the processes from primary feedstock energy extraction to ultimate end-use. A conventional electricity supply chain often includes the following sequential processes: exploration, primary fuel extraction, fuel transport, fuel storage, consumption of fuel in a power plant for electricity generation, transmission of electricity at high voltage, distribution of electricity at low voltage, and end use of electricity in devices. This research uniquely defines a bottleneck within an energy supply chain as the main process within an energy supply chain that has the highest energy losses, greenhouse gas emissions, air pollution emissions, energy costs, lack of security of supply, or other negative impacts or costs. Within electricity supply chains, the process that is typically least energy efficient and dissipates the greatest amount of energy to the environment as heat is the generation of electricity at power plants. The U.S. loses about 1/5th of its total annual primary feedstock fuel energy (~21 exajoules (EJ)) as heat at power plants. Importantly, the U.S. then re-generates about the same amount of heat downstream to heat residential, commercial, and industrial buildings and processes.
With respect to this energy efficiency bottleneck, stationary CHP FCSs have the potential to collectively displace both the heat losses at power plants and the heat re-generated within buildings (~21 EJ), at high electrical efficiencies (~60%) and overall efficiencies (~95%). This research work shares insights into the thermodynamics, chemical engineering process plant design, economics, and environmental impacts of CHP FCSs and combined cooling, heating and electric power (CCHP) FCSs.
Within the electricity supply chain, some of the highest air pollution emissions are seen at fossil fuel power plants under fast ramping conditions. Certain types of stationary FCSs in certain design configurations hold the promise of being able to ramp quickly while maintaining high efficiency and low air pollution emissions. This work discusses some of these design options.

Key results are discussed from both detailed thermodynamics modeling work and techno-economic-environmental impact models. Important findings are also highlighted from independent analyses of measured data from deployed systems.

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1117 (Abstract only)

Development of BoP model of the SOFC sub-system with CPOx reforming

Barbara Zakrzewska, Paulina Pianko-Oprych
West Pomeranian University of Technology, Szczecin
Institute of Chemical Engineering and Environmental Protection Processes
al. Piastow 42, 71-065 Szczecin / Poland
Tel.: +48-91-449-4159
Fax: ++48-91-449-4642
zakrzewska@zut.edu.pl

Abstract

The balance of plant (BoP) model of the SOFC sub-system with catalytic partial oxidation (CPOX) reforming reactor fueled by methane was developed. The commercially available Aspen Plus process simulator was used. The pre-defined models for individual units, already available in the software, were employed to model the working conditions of the system elements, including the SOFC stack. The effect of O_2/C ratio in fuel-air mixture at the inlet to the CPOx reactor was investigated, because carbon deposition strongly depends on temperature, gas phase composition, presence of catalysts and a type of catalyst. According to thermodynamic literature data [1] for methane–air composition O_2/C = 0.6 was assumed to avoid carbon formation. The air stream value affects CPOx temperature as well as stack temperature, therefore O_2/C ratios of 0.4; 0.50 and 0.55 were also investigated. The results of BoP simulations were presented in this study. Decrease in oxygen in the fuel-air composition resulted in temperature decrease of each stream, and at the same time electrical power decrease was also observed. However, the lower value of CPOx temperature with the O_2/C = 0.4 and 0.5 resulted in soot formation [1] and finally fuel cell destruction. The study was also focused on equilibrium conditions of carbon deposition from reformed fuels. The calculations were based on minimization of the Gibbs energy using HSC Chemistry v.7.1 software. The model predicted that a lot of carbon (41% of total fuel moles) will be deposited at the anode surface for ratio O_2/C = 0.4.
The study results should be very useful in optimising system parameters.

[1] van Herle J., Maréchal F., Leuenberger S., Membrez Y., Bucheli O., Favrat D., 2004. J. Power Sources, 131, 127-141.

Acknowledgments:
The research programme leading to these results received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) under grant agreement no [325323]. Information contained in the paper reflects only view of the authors. The FCH JU and the Union are not liable for any use that may be made of the information contained therein. The work was also financed from the Polish research funds awarded for the project No. 3043/7.PR/2014/2 of international cooperation within SAFARI in years 2014-2016.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1118 (Abstract only)

Electrochemical Impedance Spectroscopy model for a symmetric cell as an SOFC application

Assist. Prof. Dr. Oktay Demircan, Gulsun Demirezen, Aysenur Eslem Kisa
Alternative Energy Lab.
Boğaziçi University Department of Chemistry
34342 Etiler/İstanbul/Turkey
gulsun.demirezen@boun.edu.tr

Abstract

Electrochemical impedance spectroscopy (EIS) is known as one of the best tools so far in the field of electrochemistry because via EIS, the behavior of a Solid Oxide Fuel Cell system can be pre-investigated. In this study a model of electrochemical impedance spectroscopy (EIS) has been developed for a symmetric cell as an SOFC application. The model is able to work with different operating parameters. The results shown here are based on a different temperature values from 673 K to 1073 K, a pressure of 1 atm and the materials for the cathode and electrolyte, LSM and YSZ respectively. After the simulation process, the driven Bode and Nyquist plots showed a good agreement with the experimental data. The concept of EIS model following the finite elements method is explained in this study.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1119 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

SOFC simplified performance prediction model

Irad Brandys (1,2), Yedidia Haim (2), Yaniv Gelbstein (3)
(1) NRCN
P.O.Box 9001, Beer Sheva, Israel
(2) Faculty of Engineering, Ben Gurion University of the Negev
(3) Dept. of Energy, Ben Gurion University of the Negev
P.O.Box 653, Beer Sheva 8410501, Israel
Tel.: 972+50+6244207
Fax: 972+8+6569129
iradbr@gmail.com

Abstract

In this work, a simplified model for predicting a SOFC-based system performance is introduced. The model regards a SOFC-based system in the low range of net output power. General configuration of the system and its different components is described in Fig 1. The model is based on parameterization of common variables, which characterize such a system. The parameterization refers to the fuel mass flow rate, the fuel utilization factor, the stack's efficiency and the balance of plant (BOP). The parameterized model enables to evaluate the net output power of the system and its efficiency, regardless complicated theories, which consider materials, thicknesses etc. According to the model, which refers to three common SOFC fuels, an optimal work point can be determined, depending on defined limitations.

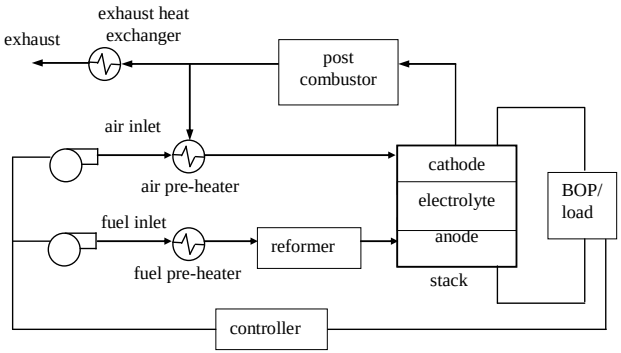


Fig. 1 - General SOFC-based system scheme

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

Chapter 09 - Session B09

Metal supported SOFCs

Content **Page B09 - ..**

B0901 2
Recent Results of the Christian Doppler Laboratory for Interfaces in Metal-Supported Electrochemical Energy Converters **2**
Martin Bram (1,2), Marco Brandner (3), Jürgen Rechberger (4), Alexander Opitz (1,5) 2
B0902 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 3
Validation methodology and results from a Ceres Power Steel Cell technology platform **3**
Adam Bone, Oliver Postlethwaite, Robert Leah, Subhasish Mukerjee, Mark Selby 3
B0903 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 4
Development of robust metal supported SOFCs and stack components in EU-METSAPP consortium **4**
B.R. Sudireddy (1), J. Nielsen (1), Å. H. Persson (1), K. Thydén (1), K. Brodersen (1), S. Ramousse (1), D. Neagu (2) E. Stefan (2), J.T.S. Irvine (2), H. Geisler (3), A. Weber (3), G. Reiss (4), R. Schauperl (5), J. Rechberger (5), J. Froitzheim (6), R. Sachitanand (6), H. F. Windisch (6), J. E. Svensson (6), M. W. Lundberg (7), R. Berger (7), J. Westlinder (7), S. Hornauer (8), T. Kiefer (8) 4
B0904 (Will be published elsewhere) 5
Development of advanced high temperature metal supported cell with perovskite based anode: a step toward the next generation of SOFC **5**
Feng Han (1), Robert Semerad (2), Patric Szabo (1), Vitaliy Yurkiv (1), Laurent Dessemond (2,3), Rémi Costa (1) 5
B0905 (Will be published elsewhere) 6
Development of metal supported proton ceramic electrolyser cells (PCEC) for renewable hydrogen production **6**
M. Stange (1), E. Stefan (2), C. Denonville (1), Y. Larring (1), R. Haugsrud (b) 6
B0906 (Will be published elsewhere) 7
Adapted Sintering of LSCF-Electrodes for Metal-Supported Solid Oxide Fuel Cells **7**
D. Udomsilp (1,2), D. Roehrens (1,2), N.H. Menzler (2), W. Schafbauer (3), O. Guillon (2,4) and M. Bram (1,2) 7

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B0901

Recent Results of the Christian Doppler Laboratory for Interfaces in Metal-Supported Electrochemical Energy Converters

Martin Bram (1,2), Marco Brandner (3), Jürgen Rechberger (4), Alexander Opitz (1,5)
(1) Christian Doppler Laboratory for Interfaces in Metal-Supported Electrochemical Energy Converters
(2) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK-1), D-52425 Jülich, Germany
(3) Plansee SE, Innovation Services, A-6600 Reutte, Austria
(4) AVL List GmbH, A-8020 Graz, Austria
(5) Institute of Chemical Technologies and Analytics, Technical University Vienna, A-1060 Vienna, Austria
Tel.: +49-2461-61-6858
Fax: +49-2461-61-2455
m.bram@fz-juelich.de

Abstract

In the recent past, Metal-Supported Solid Oxide Fuel Cells (MSCs) have been proposed as a promising next generation SOFC technology. Especially, the possible entry of ceramic fuel cell technology to mobile applications for uses like auxiliary power units (APU) was considered. After years of research, MSCs have been shown to be a valid cell concept with the potential of a cost effective mass manufacturing. However, the long term stability of the cell remains a critical issue. Recently a Christian-Doppler Laboratory has been established at Forschungszentrum Jülich GmbH in close cooperation with Technical University Vienna, Plansee SE and AVL List GmbH. The main topics comprise the understanding of sulfur related poisoning of the fuel side electrode and the development of optimized materials and microstructures that exhibit higher tolerance to sulfur contamination, allow for a simplified manufacturing route and show increased performance. For the air side electrode an understanding of the mechanisms that lead to chromium related degradation is established via theoretical modeling and experiments. Additionally, optimized processing and sintering conditions allow for the application of cathodes which show better performance and lifetime. The dependence of the electrode performance to layer thickness and composition was identified and quantified with numerical calculations and electrochemical experiments. Furthermore, the protection of the metal substrate requires tailored oxidation- and interdiffusion-barrier layers for maximum lifetime of the cell.

B0902 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Validation methodology and results from a Ceres Power Steel Cell technology platform

Adam Bone, Oliver Postlethwaite, Robert Leah, Subhasish Mukerjee, Mark Selby
Ceres Power Ltd.
Viking House
Foundry Lane
Horsham RH13 5PX/ UK
Tel.: +44-1403-273463
Fax: +44-1403-327860
adam.bone@cerespower.com

Abstract

Ceres Power has developed a robust, low cost metal supported SOFC cell (also called the “Steel Cell”) operating at lower operating temperatures (~600ºC) [1-4]. In order to verify performance against requirements, a significant number of stacks were tested so that performance, degradation through operation and the variation therein could be better understood. In this paper, we will present the methodology employed by Ceres Power in the verification testing of their 2015 cell and stack technology as well as the results.

Twelve stacks were tested and operated at >900W. The tests were split over two testing platforms: a stack only test and a prototype system test stand. Steady state degradation rates were analysed in a standard operating condition on all tests. Cell manufacturing parameters were incorporated into the stack builds as a means of validating process specifications. In a second phase of testing, change in ASR degradation rate relative to operation in the standard condition was studied as a function of selected operating conditions.

The mean stack degradation rate after ~1500h operation was 0.34%/kh with evidence of further reduction in degradation rate with prolonged operating times. The degradation rates of the stacks were found to be sensitive to fuel utilisation and operating temperature.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0903 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Development of robust metal supported SOFCs and stack components in EU-METSAPP consortium

B.R. Sudireddy (1), J. Nielsen (1), Å. H. Persson (1), K. Thydén (1), K. Brodersen (1), S. Ramousse (1), D. Neagu (2) E. Stefan (2), J.T.S. Irvine (2), H. Geisler (3), A. Weber (3), G. Reiss (4), R. Schauperl (5), J. Rechberger (5), J. Froitzheim (6), R. Sachitanand (6), H. F. Windisch (6), J. E. Svensson (6), M. W. Lundberg (7), R. Berger (7), J. Westlinder (7), S. Hornauer (8), T. Kiefer (8)
(1) Department of Energy Conversion and Storage, Technical University of Denmark Frederiksborgvej 399, DK-4000, Roskilde, Denmark
(2) School of Chemistry, University of St Andrews, St Andrews, Fife KY16 9ST, Scotland, UK
(3) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), D-76131 Karlsruhe, Germany
(4) ICE Strömungsforschung GmbH, Hauptplatz 13, 8700 Leoben, Austria
(5) AVL List GmbH, Hans-List-Platz 1, A-8020 Graz, Austria
(6) Department of Chemistry and Chemical Engineering, Chalmers University of Technology, 41296 Gothenburg, Sweden
(7) AB Sandvik Materials Technology, SFFY (4371), SE-811 81 Sandviken, Sweden
(8)ElringKlinger AG, Max-Eyth-Stasse 2, 72581 Dettingen, Germany
Tel.: +45-4677-5640
Fax: +45-4677-5858
bhsu@dtu.dk

Abstract

Metal supported SOFCs (MS-SOFCs) is an attractive alternative to conventional SOFCs due to their cheaper material cost, mechanical robustness, redox stability and thermal cycling capabilities. The potential of MS-SOFCs was demonstrated through the previous EU METSOFC project, which concluded that the development of corrosion resistant novel MS-SOFC design and stack is the requirement to advance this technology to the next level. The following EU METSAPP project has been executed with an overall aim of developing advanced metal supported cells and stacks based on a robust, reliable and up-scalable technology. In this presentation, the advancements achieved in cell and stack development, cell manufacturing, modelling, mechanical, electrochemical and corrosion testing will be presented. In summary, corrosion resistant nanostructured anodes based on modified $SrTiO_3$ were developed and integrated into MS-SOFCs to enhance their robustness. In addition, the manufacturing of metal supported cells with different geometries, scalability of the manufacturing process was demonstrated and more than 200 cells with an area of ≈150 cm^2 were produced. The electrochemical performance of different cell generation was evaluated and satisfying performance and stability was observed with doped-$SrTiO_3$ based anode designs. Furthermore, numerical models to understand the corrosion behavior of the metal support were developed and validated with experiments. Finally, the cost effective concept of coated metal interconnects was developed, which resulted in 90% reduction in Cr evaporation, three times lower Cr_2O_3 scale thickness and increased lifetime. The possibility of assembling these cells into two radically different stack designs was demonstrated.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0904 (Will be published elsewhere)

Development of advanced high temperature metal supported cell with perovskite based anode: a step toward the next generation of SOFC

Feng Han (1), Robert Semerad (2), Patric Szabo (1), Vitaliy Yurkiv (1), Laurent Dessemond (2,3), Rémi Costa (1)
(1) German Aerospace Center (DLR), Pfaffenwaldring 38-40, DE-70569 Stuttgart
(2) Université Grenoble Alpes, Laboratoire d'Electrochimie et de Physico-Chimie des Matériaux et des Interfaces, FR-38000 Grenoble
(3) CNRS, Laboratoire d'Electrochimie et de Physico-Chimie des Matériaux et des Interfaces, FR-38000 Grenoble
(4) Ceraco Ceramic Coating GmbH, Rote-Kreuz-Str. 8, DE-85737 Ismaning
Tel.: +49-711-6862-733
Fax: +49-711-6862-747
remi.costa @dlr.de

Abstract

Nickel-zirconia based fuel electrode of Solid Oxide Cell (SOC) shows poor reliability in redox cycles, which might happen during on/off sequences, and a high sensitivity towards sulfur poisoning and carbon deposition. In order to overcome these deficiencies, perovskite materials based on $La_xSr_{1-x}TiO_{3-\alpha}$ (LST) solid solution have received increasing attention in recent years. In addition to having good chemical stability in redox cycling and tolerance to different chemical poisoning, LST possesses sufficient doping flexibility, good dimensional stability and good catalytic properties.
In this contribution, we report the progress in the development of an advanced metal supported cell using LST based anode materials and thin film electrolyte. The prepared cells are supported by NiCrAl metal foam, which has been impregnated with LST or Ni-LST cermet as electrical conductive material. An LST-$Gd_{0.1}Ce_{0.9}O_{2-\alpha}$ (GDC) composite anode functional layer with average pore size in the micrometer range was deposited onto the metal foam support. $Zr_{0,84}Y_{0,16}O_{2-\alpha}$ (YSZ) layers were dip-coated as supporting layer. Successively, a gas-tight GDC electrolyte was deposited by Electron Beam Physical Vapor Deposition (EB-PVD) method. The thickness of the gas-tight thin-film YSZ-GDC bi-layer electrolyte was less than 3 µm. Full button cells were successfully produced showing an air leakage rate less than 0.5 $Pa \cdot m \cdot s^{-1}$ satisfying the gas-tightness quality control threshold of the state of the art metal supported SOC at DLR. During electrochemical characterization single cells with 4x4 cm² active $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$ (LSCF) cathode at 750°C showed an OCV of 1.02 V, power density above 320 $mW \cdot cm^{-2}$ at 0.7 V, and good tolerance towards redox cycling. The progress and results relevant to the size up-scaling (up to 90 cm^2 footprints) of cell architecture will also be presented and discussed.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0905 (Will be published elsewhere)

Development of metal supported proton ceramic electrolyser cells (PCEC) for renewable hydrogen production

M. Stange (1), E. Stefan (2), C. Denonville (1), Y. Larring (1), R. Haugsrud (b)
(1) SINTEF Materials and Chemistry, P.O. Box 124, Blindern, N-0314 Oslo, Norway,
(2) Dept. of Chemistry, University of Oslo, FERMIO, Gaustadalleen 21, 0349 Oslo, Norway
Tel.: +47-99-024-433
Fax: +47-220-67-350
marit.stange@sintef.no

Abstract

Metal supported protonic electrolysis cells (MS-PCEC) offer several major advantages over solid oxide electrolysis cells (SOEC) with oxygen conducting electrolytes; e.g. lower operating temperature and production of dry hydrogen. Metal supports (MS) for planar MS-PCEC were manufactured using scalable and flexible techniques, such as tape-casting of low cost ferritic stainless steel. A protective coating was applied by vacuum infiltration, and cathode and buffer layers, such as $La_{0.5}Sr_{0.5}Ti_{0.75}Ni_{0.25}O_{3-\delta}$ (LSTN) or CeO_2 were applied on the MS by spray-coating. $BaZr_{0.85}Y_{0.15}O_{3-\delta}$–NiO (BZY15-NiO) cathode and $BaZr_{0.85}Y_{0.15}O_{3-\delta}$ (BZY15) electrolyte were applied by pulsed laser deposition (PLD). The main challenges are related to the restrictions in sintering temperature and atmosphere induced by the metal support, as well as strict demands on the roughness of the substrate used for pulsed laser deposition (PLD). BZY15–NiO electrode and BZY15 electrolyte films sequentially deposited at elevated substrate temperatures on metal/ceramic substrates by PLD, resulted in metal supported layered architectures e.g., MS/CeO_2/(BZY15-NiO)/BZY15 and MS/LSTN/(BZY15-NiO)/BZY15. Different microstructures for electrode and electrolyte were achieved in one PLD process with depositions at different substrate temperatures (800, 600 °C) and a gradual decrease of pressure. Important advances in employing metal supports in cell assemblies, utilizing the planar approach will be presented.

Keywords: Protonic conducting electolysis cell (PCEC), tape casting, thin film deposition, metal supports

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B0906 (Will be published elsewhere)

Adapted Sintering of LSCF-Electrodes for Metal-Supported Solid Oxide Fuel Cells

D. Udomsilp (1,2), D. Roehrens (1,2), N.H. Menzler (2), W. Schafbauer (3), O. Guillon (2,4) and M. Bram (1,2)
(1) Christian Doppler Laboratory for Interfaces in Metal-Supported Electrochemical Energy Converters
(2) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research – Materials Synthesis and Processing (IEK-1), 52425 Jülich, Germany
(3) PLANSEE SE, Innovation Services, Metallwerk-Plansee-Strasse 71, Reutte, Austria
(4) Jülich Aachen Research Alliance: JARA-Energy
Tel.: +49-2461-6196650
Fax: +49-2461-619120
d.roehrens@fz-juelich.de

Paper submitted to Materials Letters

Abstract

Metal-supported solid oxide fuel cells (MSCs) have shown good mechanical robustness and manufacturability, but also imply a major challenge for ceramic processing. Because of the reactive metallic substrate, sintering in ambient air at temperatures above 1000 °C, which will lead to extensive oxidation of the substrate, is not applicable to MSCs. Recently a MSC was developed in close cooperation between Plansee SE and Forschungszentrum Jülich GmbH, which relies on sintering of the ceramic layers under hydrogen atmosphere. However, traditional cathode materials like (La,Sr)(Co,Fe)O_3 (LSCF) are not stable in hydrogen atmosphere at high temperatures necessary to realize a good microstructure. Therefore, modified sintering routes, cathode materials and properties are examined in order to tailor the air side electrode microstructure of the MSC to the boundary conditions introduced by the metallic substrate. It was shown, that by careful control of the pO2 during sintering and adjusting of the powder properties a significant lowering of the sintering temperature for the air side electrode is possible.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

Next **EFCF** Events

6th European
PEFC & ELECTROLYSER
Forum 4 - 7 July 2017

13th European
SOFC & SOE
Forum 3 - 6 July 2018

Lucerne Switzerland

Chapter 10 - Session B12

Advanced characterisation tools and techniques

Content **Page B12 - ..**

B1201 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....3
High spatial resolution monitoring of the temperature distribution from an operating SOFC **3**
Manoj Ranaweera, Vijay Venkatesan, Erdogan Guk, Jung-Sik Kim 3
B1202 (Will be published elsewhere).....4
Oxide ion blocking effect at $SrZrO_3$/YSZ and Y-doped $SrZrO_3$/YSZ interfaces **4**
Katherine Develos-Bagarinao (1), Harumi Yokokawa (1, 2), Haruo Kishimoto (1) Teruhisa Horita (1), Katsuhiko Yamaji (1) 4
B1203.....5
Understanding performance limiting impacts in SOFCs - visualizing the nature of cathode/electrolyte interfaces using advanced focused ion beam/ scanning electron microscope (FIB-SEM) tomography techniques **5**
F. Wankmueller (1), J. Szasz (1), J. Joos (1), V. Wilde (2), H. Stoermer (2), D. Gerthsen (2), E. Ivers-Tiffée (1) 5
B1204 (Will be published elsewhere).....6
Experimental method to determine the changes of Ni content in operated SOFC anodes **6**
Paolo Piccardo (1,2), Alex Morata (3), Valeria Bongiorno (1,2), Jan Pieter Ouweltjes (4) 6
B1205 (Will be published elsewhere).....7
In-Situ Measurement of cPO_x Catalyst in Microtubular SOFC **7**
Lois Milner, Artur Majewski, Robert Steinberger-Wilckens 7
B1206 (Will be published elsewhere).....8
Tomography - beyond the pretty pictures to numbers for 3D SOFC Electrodes **8**
Farid Tariq (1)(2), Vladimir Yufit (1)(2), Xin An (1), Ed Cohen (1), Kristina Kareh (1), Antonio Bertei (1), Enrique Ruiz-Trejo (1), Nigel Brandon (1) (2) 8
B1207.....9
Determining the Oxygen Transport Kinetics of $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ by a Detailed Electrochemical Study **9**
Laura Almar, Julian Szász, André Weber, Ellen Ivers-Tiffée 9
B1210 (Abstract only).....10
Spatially Resolved Characterization of Anode Supported Solid Oxide Fuel Cells **10**
Patric Szabo (1), Günter Schiller (1), Dario Montinaro (2), Jan Pieter Ouweltjes (3) 10
B1211 (Will be published elsewhere).....11
Increase of the quality assurance of SOFC stacks by electrochemical methods **11**
C. Auer(1), M. Braig(1), M. Lang(1), S. Kurz(1), K. Couturier(2), E.R. Nielsen(3), Q. Fu(4), Q. Liu(5) 11
B1212 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....12
Model-based design and 3D characterization of a SOFC electrode microstructure **12**
Kristina Maria Kareh (1), Enrique Ruiz Trejo (1), Antonio Bertei (1), Farid Tariq (1,2), Vladimir Yufit (1,2), Nigel Brandon (1,2) 12
B1213 (Will be published elsewhere).....13
Four-point bending testing: estimation of the accuracy and identification of the mechanical properties of SOFC materials **13**
Fabio Greco, Arata Nakajo, Jan Van herle 13
B1214 (Will be published elsewhere).....14
Analysis and improvement on DRT reconstruction from Electrochemical Impedance Spectroscopy data **14**
Tommaso Ferrari (1), Roberto Spotorno (2,3), Paolo Piccardo (2,3), Cristiano Nicolella (1) 14
B1215.....15
Thin Film Thermocouple Array for Cathode Temperature Gradient of SOFC **15**
Erdogan Guk, Manoj Ranaweera, Vijay Venkatesan, Jung-Sik Kim 15
B1216 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....16
Influence of Working Parameters and Degradation on Anode-Supported Cells studied by Electrochemical Impedance Spectroscopy **16**
Roberto Spotorno (1,2), Tommaso Ferrari (3), Cristiano Nicolella (3), Paolo Piccardo (1,2) 16
B1217 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....17
Nucleation and crystallization processes of glass-ceramic sealants for SOFCs **17**
Jeerawan Brendt, Sonja M. Gross-Barsnick, Carole Babelot, Ghaleb Natour 17
B1218 (Abstract only).....18
New full ceramic kit for gas analysis and integrated steamer for SOEC **18**
Pierre Coquoz (1), André Pappas (1), Raphael Ihringer (1) 18
B1219.....19
Impedance insight into Ceres Power's Steel Cell technology: Latest results. **19**
Gavin Reade (1), Adam Bone (1), Andre Weber (2), Subhasish Mukerjee (1) and Mark Selby (1) 19

B1201 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

High spatial resolution monitoring of the temperature distribution from an operating SOFC

Manoj Ranaweera, Vijay Venkatesan, Erdogan Guk, Jung-Sik Kim
Department of Aeronautical and Automotive Engineering, Loughborough University
Epinal Way, Loughborough, LE11 3TU, United Kingdom
Tel.: +44 (0)1509 227 219 / Fax: +44 (0)1509 227 275
j.kim@lboro.ac.uk

Abstract

In situ monitoring of cell temperature distribution of an operating SOFC is crucial to understand its performance and degradation. The available efforts recorded in literature are incapable of measuring the temperature from electrodes. Instead, they measure the gas channel temperature from a selected few points, mainly, by inserting thermocouples into the stack, which significantly limits the spatial resolution of measurements and introduces disturbance to the SOFC's normal operation. To overcome these weaknesses, the authors developed a new temperature sensor architecture that shares the merits of thermocouple thermometry and measures temperature at $\{N^2\}$ points with only $\{2N\}$ number of thermoelements. This sensor is capable of measuring the electrode temperature distribution with greater spatial resolution than thermocouples. Using this sensor, authors are successful to measure the spatial cathode temperature distribution in high spatial resolution out of an SOFC test cell (50 mm x 50 mm, NextCell-5) under varying fuel flow rates (from 50 ml/ min at A to 250 ml/min at F&G). The temperature measurements were validated with commercial thermocouples. Correlations between cell temperatures, flow rate and, OCV were observed and analysed.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1202 (Will be published elsewhere)

Oxide ion blocking effect at $SrZrO_3$/YSZ and Y-doped $SrZrO_3$/YSZ interfaces

Katherine Develos-Bagarinao (1), Harumi Yokokawa (1, 2), Haruo Kishimoto (1)
Teruhisa Horita (1), Katsuhiko Yamaji (1)
(1) Research Institute for Energy Conservation, National Institute of Advanced Industrial Science and Technology
AIST Tsukuba Central 5, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8565 Japan
(2) Institute of Industrial Science, The University of Tokyo, 4-6-1 Komaba, Meguro-ku
Tokyo 153-8505 Japan
Tel.: +81-29-861-5721
Fax: +81-29-861-4540
develos-bagarinao@aist.go.jp

Abstract

Cell performance degradation of solid oxide fuel cells is usually ascribed to the degradation of electrode activity as well as ohmic losses associated with ionic and electronic paths in cells. In particular, degradation has been attributed to the formation of $SrZrO_3$ (SZ) at the interface of yttria-stabilized zirconia (YSZ) electrolyte and $(La_{0.6}Sr_{0.4})(Co_{0.2}Fe_{0.8})O_{3-\delta}$ (LSCF) cathode, but the specific effect of this phase on ionic flow is still not well understood. In this study, we examined the oxide ion transport behavior in $SrZrO_3$ (SZ) and Y-doped $SrZrO_3$ ($SrZr_{0.95}Y_{0.05}O_{3-x}$, SZY) thin films prepared using pulsed laser deposition on (100) YSZ single crystal substrates. Both films were highly oriented along the (*h*00) and exhibited nanocolumnar grains. ^{18}O isotope exchange labelling conducted in the temperature range of 400 °C to 800 °C, in conjunction with secondary ion mass spectroscopy (SIMS) depth profiling technique, was employed to probe oxide ion transport across SZ(Y)/YSZ. SIMS depth profile analyses indicated that the occurrence of thermally-induced Y diffusion from YSZ into SZ significantly altered the oxide ion diffusivity of the latter; at the highest temperature investigated (800 °C), almost analogous ^{18}O profiles were obtained for SZ and SZY. Furthermore, for either SZ or SZY a drastic drop in the ^{18}O concentration at the interface with YSZ was observed, revealing the existence of an oxide ion blocking effect. Plausible phase diagrams constructed based on thermodynamic considerations for the Sr-Y-Zr-O system suggested variability of the SZY/YSZ interface due to the high thermodynamic activity of Y, implying the co-existence of other oxide phases at the interface which could potentially block oxide ion transport. Moreover, as SZ is typically formed between GDC and YSZ in LSCF-GDC (gadolinia-doped ceria)-YSZ heterostructures which are commonly utilized in real industrial cells, we also examine in detail the properties of the GDC/SZ(Y) interface to clarify ionic flow across this type of heterointerface.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1203

Understanding performance limiting impacts in SOFCs - visualizing the nature of cathode/electrolyte interfaces using advanced focused ion beam/ scanning electron microscope (FIB-SEM) tomography techniques

F. Wankmueller (1), J. Szasz (1), J. Joos (1), V. Wilde (2), H. Stoermer (2), D. Gerthsen (2), E. Ivers-Tiffée (1)
(1) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Adenauerring 20b, D-76131 Karlsruhe/Germany
(2) Laboratory for Electron Microscopy (LEM), Karlsruhe Institute of Technology (KIT), Engesserstr. 7, D-76128 Karlsruhe/Germany
Tel.: +49-721-608-48784
florian.wankmueller@kit.edu

Abstract

The mixed ionic-electronic conducting cathode $(La,Sr)(Co,Fe)O_{3-\delta}$ (LSCF) is utilized worldwide for high performing intermediate temperature solid oxide fuel cells (SOFCs). The drawback of using LSCF are secondary phases at the interface to the Zirconia-based electrolyte (8 mol% Yttria stabilized Zirconia - 8YSZ). Although a thin diffusion barrier interlayer of $Gd_{0.2}Ce_{0.8}O_{2-\delta}$ (GDC) is introduced between cathode and electrolyte, the formation of the insulating $SrZrO_3$ phase cannot be prevented completely at this interface region. The resulting performance drop may unfavorably affect the outstanding charge transfer properties of LSCF. High resolution detection and 3D quantification of the spatial $SrZrO_3$ distribution is therefore of fundamental interest.
This contribution will introduce a new methodology of using FIB-SEM tomography for visualizing the nature of the diffusion barrier layer and of secondary phases at the cathode/electrolyte interface. The core feature is the choice of the microscope parameters using the Everhart-Thornley and Inlens detectors in combination with different primary electron energies that enables a broader spectrum of greyscale information between the primary and secondary material phases. The correct material assignment is supported by high-resolution composition mappings obtained by energy-dispersive X-ray spectroscopy in a transmission electron microscope. Besides the secondary phase $SrZrO_3$, also the interdiffusion of GDC and 8YSZ is detected and can be reconstructed individually resulting in a complete 3D reconstructed material data set including primary and secondary phases. This enables great possibilities of visualization and modeling of ionic transport through the cathode/electrolyte interface region. Furthermore, this methodology can be used to optimize the sintering temperature profiles of the entire manufacturing process – a further step towards understanding and improving state of the art SOFCs.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1204 (Will be published elsewhere)

Experimental method to determine the changes of Ni content in operated SOFC anodes

Paolo Piccardo (1,2), Alex Morata (3), Valeria Bongiorno (1,2), Jan Pieter Ouweltijes (4)
(1) Laboratory of Metallurgy and Materials, DCCI, University of Genoa, Genoa, Italy
(2) Institute for Energetics and Interphases, National Council of Research, Genoa, Italy
(3) IREC, Barcelona, Spain
(4) HTceramix SA, Yverdon, Switzerland
Tel.: +39-010-353-6145
paolo.piccardo@unige.it

Abstract

The performance of an anode supported SOFC during operation depends on the stability and reliability of the cell components vs. time. This paper focuses on the anode with special attention given to the active part at the interface with the electrolyte. An original method to quantify the local Ni content in the anode of solid oxide fuel cells is presented and documented with examples coming from its application on button cells aged in various conditions of fuel utilization and temperature. The results are compared with the original Ni amount in a as sintered state (i.e. green) cell, and a freshly reduced (i.e. pristine) cell.
The collected data describes with cost effective method the Ni content in the first 10 μm from the electrolyte and then in the remaining part of the anode. The first results obtained on operated and pristine cells has shown an initial Ni depletion homogeneously distributed on the whole volume. Important differences were noticed in cells operated for a few hundred hours especially in the active zone of the anode.
The method uses the quantitative data in weight percent obtained by a calibrated EDXS coupled with an SEM from frames recorded at 5000x of magnification (total corresponding area of 3018.75 μm^2) of a polished cross section of the anode. Adjacent areas from the interface with the electrolyte to the edge of the anode are analyzed. The method presented in this paper renders sensitive to local variations in the Ni content once the Zr content is assumed unaffected by cell production and cell operation.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1205 (Will be published elsewhere)

In-Situ Measurement of cPO_x Catalyst in Microtubular SOFC

Lois Milner, Artur Majewski, Robert Steinberger-Wilckens
Centre for Hydrogen and Fuel Cell Research
School of Chemical Engineering
The University of Birmingham
Edgbaston
United Kingdom
B15 2TT
Tel.: +44121 4147044
lxm101@bham.ac.uk

Abstract

Photoacoustic Spectroscopy (PAS) and Tuneable Diode Laser Spectroscopy (TDLS) are techniques that show promise for in-situ testing of gas compositions in Solid Oxide Fuel Cells (SOFC). Previous studies have used PAS to obtain kinetic data about catalytic reactions [1] [2]. PAS has advantages over conventional absorption based spectroscopic methods, as it does not rely on distinguishing the difference between incident and transmitted radiation. This results in a higher sensitivity. However, higher sensitivity comes at the cost of presenting a greater number of engineering hurdles.

Furthermore, miniaturisation of photoacoustic devices enhances performance, resulting in lower detection limits [3]. This unusual advantage is a result of the technique being dependent on temperature changes coupled to pressure changes; the smaller the sample cell, the stronger these two variables are related. However, miniaturisation along with high-temperature operation presents a unique set of engineering challenges. It is for this reason that TDLS is considered as a less sensitive but less challenging device to engineer.

The aim of this work is to develop a gas characterisation device capable of operating within a microtubular fuel cell running on pre-reformed methane. The device will be located between the pre-reformer and the fuel cell (Figure 1) and deliver real time data referring to the performance of the reforming catalyst. This device will both aid catalyst development and act as a feedback mechanism to prevent cell failure from catalytic degradation. We present an introduction to the possible techniques that could be used for this application and results which have led to the decision to take one technique forward.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1206 (Will be published elsewhere)

Tomography - beyond the pretty pictures to numbers for 3D SOFC Electrodes

Farid Tariq (1)(2), Vladimir Yufit (1)(2), Xin An (1), Ed Cohen (1), Kristina Kareh (1), Antonio Bertei (1), Enrique Ruiz-Trejo (1), Nigel Brandon (1) (2)
(1) Imperial College London
Prince Consort Road
London SW7 2AZ
Tel.: +44-207-594-5124
farid.tariq02@imperial.ac.uk

(2) IQM Elements Ltd
Quantitative Imaging Division
88-90 (Office 36) Hatton Garden Holborn
London EC1N 8PG
info@iqm-elements.com

Abstract

Direct imaging of solid oxide fuel cell (SOFC) materials and components can provide unprecedented insight into factors limiting performance and durability, inaccessible by other techniques. The performance of SOFC electrodes is dependent on their nano/micro-structure as electrochemical reactions occur within the electrodes. Furthermore, during processing or operation, microstructural evolution may degrade electrochemical performance. Tomographic techniques enable the 3D imaging and characterisation of complex microstructures at length scales down towards tens of nanometers.

However, although many studies have ultilised 3D imaging, there is a need to understand the information beyond elementary metrics. Increasingly large quantities of 3D data are being acquired and yet are poorly understood.

Characterisation of specific necks and interfaces within SOFC electrodes is derived. Micro/nano structural changes are followed to facilitate understanding of the differences which occur with shape, structures and morphology at high resolution. These are correlated with measured experimental values to provide insight into microstructure-property relationships. Our results also reveal that current manufacturing methods of ink preparation may cause particle clustering, and we show how this may be tracked. The ability to follow or understand these spatial variations within a 3D data volume provides a measurable method of following degradation associated with microstructural change in these electrodes, and thereby offer insight into how these may be mitigated in the future through intelligently designed microstructures.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1207

Determining the Oxygen Transport Kinetics of $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ by a Detailed Electrochemical Study

Laura Almar, Julian Szász, André Weber, Ellen Ivers-Tiffée
Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT),
Adenauerring 20b, D-76131 Karlsruhe/Germany
Tel.: +49-721-608-47714
Fax: +49-721-608-47492
laura.almar@kit.edu

Abstract

$Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (BSCF) is a mixed ionic-electronic conducting (MIEC) material widely studied for high temperature applications, such as porous functional coating in oxygen transport membranes (OTMs) for gas separation and as porous electrode in solid oxide fuel cells (SOFCs), due to its outstanding oxygen transport properties.

The essential parameters related to the oxygen transport kinetics i.e. chemical oxygen diffusion coefficient (D^{δ}) and oxygen surface-exchange coefficient (k^{δ}) are usually assessed by electrical conductivity relaxation (ECR) measurements. Thus, the authors believe a method capable of analyzing k^{δ} and D^{δ} using electrochemical impedance spectroscopy would be highly valuable, since the values are determined with the same microstructural parameters (porosity and active surface area) and operating conditions (time and thermal history) as in the application.

In this work, symmetrical cells based on BSCF electrodes and a doped-ceria electrolyte are fabricated and fully characterized by electrochemical impedance spectroscopy from 600 to 900 °C. By analysis of the distribution function of relaxation times (DRT) the individual processes taking place are identified. A physically meaningful equivalent circuit model could be established by conducting experiments with varying the oxygen partial pressure (pO_2 = 0.02-1 atm). Moreover, the specific microstructure characteristics of the porous BSCF layers were quantified by Focused Ion Beam (FIB) tomography after the impedance studies. Values of porosity, surface area and tortuosity are determined to calculate the specific k^{δ} and D^{δ}. The obtained values will be critically compared and discussed with the literature. The whole methodology followed in this work, represents a step forward towards the understanding and quantification of the individual processes taking place in porous BSCF layers applied either in OTM or SOFC.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1210 (Abstract only)

Spatially Resolved Characterization of Anode Supported Solid Oxide Fuel Cells

Patric Szabo (1), Günter Schiller (1), Dario Montinaro (2), Jan Pieter Ouweltjes (3)
(1) German Aerospace Center (DLR)
Pfaffenwaldring 38-40, D-70569 Stuttgart/Germany
Tel.: +49-711-6862494
Patric.szabo@dlr.de

(2) SOLIDpower S.p.A., Viale Trento, 115/117, 38017 Mezzolombardo, Italy
(3) SOLIDpower S.A., Avenue des Sports, 26, CH-1400 Yverdon-les-Bains, Switzerland

Abstract

The EU project ENDURANCE aims at increasing the reliability and long-term stability of SOFCs by better understanding degradation and lifetime fundamentals which is closely related to the application of sophisticated characterization techniques, accelerated testing strategies and degradation modelling. Based on these procedures early warning output signals (EWOS) will be identified and developed before the stack sustains permanent damage in order to be able to develop counter strategies which can alleviate the degradation effects.
Spatially inhomogeneous distributions of current density and temperature in solid oxide fuel cells (SOFC) can contribute significantly to accelerated electrode degradation, thermomechanical stresses, and reduced efficiency. This is particularly the case under technically relevant operating conditions. With spatially resolved measurements using segmented cell technology it is possible to investigate degradation processes locally and identify areas where degradation occurs first. If certain effects can be tied to special local areas the results can be used to improve the cell, the gas distribution or operation envelope.
In this respect spatially resolved measurements of anode supported cells from SOLIDpower in a 4×4-segmented cell arrangement with an area of 80 cm² area which are comparable to the cells used in stacks were performed. The measurement setup allows for integral and spatially resolved measurement of current density and voltage, the local and integral determination of impedance data, the local measurement of temperature and temperature distribution and the spatially resolved analysis of the fuel gas concentrations along the flow path. In order to determine the temperature at each segment, thermocouples are introduced in the metallic segments. Additionally, capillary tubes that correspond to the cathodic segments are integrated at the anode side at 16 measuring points to take samples of the anode gas to be analyzed by gas chromatography. The tests were performed in co-flow operation for various fuel gas compositions at the anode and air at the cathode. Local and global current-voltage relationships were measured in dependence of gas composition and fuel utilization.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1211 (Will be published elsewhere)

Increase of the quality assurance of SOFC stacks by electrochemical methods

C. Auer(1), M. Braig(1), M. Lang(1), S. Kurz(1), K. Couturier(2), E.R. Nielsen(3), Q. Fu(4), Q. Liu(5)
(1) German Aerospace Center (DLR), Institute for Technical Thermodynamics
Pfaffenwaldring 38-40, D-70569 Stuttgart / Germany
(2) CEA/Liten (France); (3) DTU (Denmark); (4) EIFER (Germany), (5) NTU (Singapore)
Tel.: +49-711-6862-8188
Fax: +49-711-6862-747
corinna.auer@dlr.de

Abstract

Many research facilities and industrial companies worldwide are engaged in the development and the improvement of solid oxide fuel cells/stacks (SOFC) and also of solid oxide electrolysis cells/stacks (SOEC). However, the different stacks cannot be easily compared due to non-standardized test programs. Therefore the EU-funded project “SOCTESQA” which was started in May 2014 aims to develop uniform and industry wide test procedures and protocols for SOC cells/stacks. In order to validate and optimize the test programs, which consist of different test modules, the project partners apply the developed test procedures on identical SOFC stacks. In this project 5-cell short-stacks with SOFC anode supported cells (ASC) are used, which are provided by an experienced stack supplier. The applied characterization methods consist of current-voltage characteristics (jV) and electrochemical impedance spectra (EIS). The paper compares the results of the different project partners in SOFC mode. One important aspect is the evaluation of the results in terms of reproducibility. Electrochemical properties e.g. open circuit voltage (OCV), area specific resistance (ASR), power density and impedance values are investigated and discussed in context to the input parameters. The results of EIS-spectra are compared with the results of the jV-characteristics. Similarities and differences of the results between the project partners are evaluated and discussed.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1212 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Model-based design and 3D characterization of a SOFC electrode microstructure

Kristina Maria Kareh (1), Enrique Ruiz Trejo (1), Antonio Bertei (1), Farid Tariq (1,2), Vladimir Yufit (1,2), Nigel Brandon (1,2)
(1) Imperial College London
Prince Consort Road
London SW7 2AZ
Tel.: +44-207-594-5124
kristina.kareh05@imperial.ac.uk
(2) IQM Elements Ltd
Quantitative Imaging Division
88-90 (Office 36) Hatton Garden Holborn
London EC1N 8PG
info@iqm-elements.com

Abstract

The characterization of SOFC performance and reliability has conventionally relied on bulk parameter measurements, such as fuel cell impedance and other electrochemical parameters. These bulk parameters, however, have increasingly been correlated with the porous microstructure of the electrodes but have yet to be fully linked to the degradation of the micro- and nanostructure of the electrodes during use.

In this work, a design led approach to electrode manufacture is implemented. A Ni-ScSZ scaffold was first produced using tape casting and characterised using FIB-SEM tomography in order to quantify the TPB density as well as the tortuosity of the phases. This initial microstructure was also used as an input in a physically-based electrochemical model to predict impedance. The electrode was then incorporated into a symmetrical cell and tested at 610°C to compare its performance to the one predicted by the physical model as well as to examine the degradation of the anode with time. The comparison allowed for a critical assessment of the assumptions of the electrochemical model and for the prediction of better performance with different phase fractions. This approach allows for a seminal pass at manufacturing electrodes with desired specific performance requirements using a predictive model.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1213 (Will be published elsewhere)

Four-point bending testing: estimation of the accuracy and identification of the mechanical properties of SOFC materials

Fabio Greco, Arata Nakajo, Jan Van herle
FUELMAT Group, Institute of Mechanical Engineering, Faculty of Engineering Sciences and Technology, EPFL Valais Wallis, Rue de l'industrie 17, CH-1951 Sion, Switzerland
Tel.: +41-21-695-8301
fabio.greco@epfl.ch

Abstract

Thermo-mechanical issues in solid oxide fuel cells (SOFCs) must be understood and overcome to meet the reliability standards for market implementation. Attempts have been made to investigate the mechanical failures of SOFCs experimentally. Thermo-mechanical characterization by numerical analysis is relevant to post-process measurements from targeted experiments and/or for the detailed analysis of SOFC stack design. In this context, the measurement of the mechanical properties of the most important component materials is essential for models. Ceramics are extensively used in SOFC stacks. The characterization of their mechanical properties requires specific precautions because of their brittleness: three-/four-point bending, ring-on-ring (ROR), ball-on-ring (BOR) and ball-on-3-balls setups are widely used.
This study is focused on the four-point bending test design, which has several advantages. However, intrinsic errors have to be considered when analysing the experimental data obtained with this setup. Finite element analysis (FEA) of the test can assist the quantification of these errors. Therefore, in this study the model of the sample together with the fixture of the four-point bending setup is analysed. The material behaviour implemented into the model is elasticity. A simplified identification of the mechanical properties is then proposed by analysing experimental data together with the modelling results.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1214 (Will be published elsewhere)

Analysis and improvement on DRT reconstruction from Electrochemical Impedance Spectroscopy data

Tommaso Ferrari (1), Roberto Spotorno (2,3), Paolo Piccardo (2,3), Cristiano Nicolella (1)
(1) Department of Civil and Industrial Engineering, University of Pisa, Pisa, Italy
(2) Laboratory of Metallurgy and Materials, DCCI, University of Genoa, Genoa, Italy
(3) Institute for Energetics and Interphases, National Council of Research, Genoa, Italy
Tel.: +39-050-2217814
tommaso.ferrari@for.unipi.it

Abstract

Reconstruction, from Electrochemical Impedance Spectroscopy (EIS), of the distribution of relaxation time of an electrochemical system is a frequently used technique to individuate the characteristics of the different processes involved. In particular Solid Oxide Fuel Cells (SOFC) present many different inner processes with a high degree of complexity. DRT is a transform of the EIS data into a function which is more favourable for a physical interpretation and modelling (e.g. reconstruction of equivalent circuit). This method is more complete and detailed than circuit reconstruction by fitting.
There are many approaches to numerically evaluate the DRT. Calculation of DRT is a typical inverse problem, which leads in the most cases to an ill-posed problem. The aim of this study is to formulate a procedure to obtain a more accurate DRT. In this work different aspects of DRT have been considered, with particular attention to the discretization of the continuous inverse problem. The noise due to the discretization and methods to reduce their effects on the results have been analysed. Two common algorithms used to solve the numerical problem have been studied. Also, it has been adopted ridge regression and the L-curve method to determine the optimal regularization parameter investigating its correlation with the algorithms and the nature of the noise.
The methodology has been widely described and has been tested on synthetic and real experimental data. The experimental data are EIS obtained from a anode-supported cell (Ni/8YSZ-cermet anode, 8YSZ electrolyte with GDC interlayer, LSCF cathode of 16 cm^2 area) measured under different conditions. Preliminary results of our simulations suggest the validity of the outlined strategy.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1215

Thin Film Thermocouple Array for Cathode Temperature Gradient of SOFC

Erdogan Guk, Manoj Ranaweera, Vijay Venkatesan, Jung-Sik Kim
Department of Aeronautical & Automotive Engineering Department
Loughborough University,
Epinal way, Loughborough, LE11 3TU, United Kingdom
Tel.:+44 (0) 1509 227 219
Fax: +44 (0) 1509 227 219
j.kim@lboro.ac.uk

Abstract

High thermal gradient is considered as the main reason for cell degradation and failure. A sizeable number of the available scientific work related to the problem in the literature is focused on using simulation or modelling to predict temperature distribution in the cell. THERMONO, a novel temperature monitoring sensor, has been developed by the authors' group. THERMONO is capable of monitoring *{N²}* temperature reading by using *{2N}* number of external wires, e.g. temperature measurement at 400 multiple points simultaneously can be done only using around 20 wires, whilst commercial thermocouple require 800 wires.

However, there are still difficulties in accurate and real time temperature measurement from a cell stack for practical implementation and desired resolution. Commercially available thermocouples, which are normally large in size, that are mounted on the cell electrode surface can make significant disturbance to gas flow and operating conditions. In this study, thin film thermocouple array sensor (THERMONO) was used to overcome these limitations associated with implementing the large sized wire sensors. Nano-scale thin film array was fabricated on the cell electrode surface, enabling a technique for in-situ temperature monitoring of the cell with higher spatial and temporal resolution compared to thermocouples.

The thin film array sensor architecture was directly deposited on a test cell's (50mmx50mm, NextCell-5) electrode surface via sputtering technique. As a result, the test cells' cathode in-situ temperature distribution was monitored during the normal operation. Two commercial thermocouples were also placed closely to sensor to validate the sensor reading. Temperature reading from the cell cathode electrode surface under different flow rate was obtained.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1216 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Influence of Working Parameters and Degradation on Anode-Supported Cells studied by Electrochemical Impedance Spectroscopy

Roberto Spotorno (1,2), Tommaso Ferrari (3), Cristiano Nicolella (3), Paolo Piccardo (1,2)
(1) Laboratory of Metallurgy and Materials, DCCI, University of Genoa, Genoa, Italy
(2) Institute for Energetics and Interphases, National Council of Research, Genoa, Italy
(3) Department of Civil and Industrial Engineering, University of Pisa, Pisa, Italy
Tel.: +39-010-353-6145
roberto.spotorno@edu.unige.it

Abstract

Electrochemical Impedance Spectroscopy (EIS) is one of the most common techniques to characterize Solid Oxide Fuel Cells (SOFCs) during operation and to evaluate the influence on their performances of several working conditions and degradation effects. However, process overlapping in the frequency domain makes it difficult to clearly distinguish the contributions from each part of the cell to the impedance spectra. Therefore, a precise attribution of the electrodes losses and their evolution during the cell degradation becomes challenging.
In this work a state of the art anode-supported cell [Ni/8YSZ-cermet anode, 8YSZ electrolyte with GDC interlayer, LSCF cathode] has been characterized by means of current-voltage curves and EIS under several working conditions.
The impedance spectra have been analyzed calculating their distribution function of relaxation times (DRT) allowing to separate 4 different loss mechanisms occurring at the cell electrodes. The processes attribution has been carried out varying the feeding gases composition at Open Circuit Voltage (OCV) and under the electrical current load of 500mAcm^{-1}. Such procedure allowed to identify the the anode as the most affected cell component to the degradation after 100 hours of aging test under polarization.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1217 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Nucleation and crystallization processes of glass-ceramic sealants for SOFCs

Jeerawan Brendt, Sonja M. Gross-Barsnick, Carole Babelot, Ghaleb Natour
Forschungszentrum Jülich GmbH
Central Institute of Engineering, Electronics and Analytics (ZEA) - Engineering and Technology (ZEA-1)
Wilhelm-Johnen-Straße, D-52425 Jülich/Germany
Tel.: 49-2461-61-3201
Fax: +49-2461-61-6816
j.brendt@fz-juelich.de

Abstract

A major challenge in the fabrication of solid oxide fuel cells (SOFCs) is the development of a robust sealant material showing a good performance under thermal cycling conditions and withstanding long-term operation. Several requirements need to be fulfilled by the material, i.e. electrical insulation, an adapted thermal expansion coefficient as well as mechanical and thermochemical stability. Glass-ceramic sealants can meet most of the above mentioned properties.
During the joining of the SOFC components, the glass-ceramic sealant can partially or fully crystallize. The standard glass composition developed at Forschungszentrum Jülich is based on the BaO-CaO-SiO_2 system. The reference glass “H” contains additives of ZnO and V_2O_5 in the glass matrix and is used as a composite material with yttria–stabilized zirconia fibers (YSZ) as fillers. Currently, the crystallization process of this material is very slow. A faster crystallization would lead to a shorter heat treatment of the stack in the start-up procedure, which would be favorable in terms of industrialization. A variation of glass H with a simplified composition was prepared (glass “I”) in order to study the impact of the compositional additives on the crystallization process.
To study the nucleation and crystallization behavior, powders of the glasses were analyzed by differential scanning calorimetry (DSC) and X-ray diffraction (XRD). Further experiments have been carried out to characterize the surface and bulk crystallization of the amorphous system by preparing pressed powder pellets and drops of molten glass. These specimens were heat treated at different temperatures for different periods of time and finally quenched. The microstructure’s cross-section of the samples was examined using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX). All methods lead to the identification of the crystalline phases. Following predominate phases were analyzed: $2BaO{\cdot}3SiO_2$, walstromite, and celsian. It was found that Zn/V-additions to the glass composition as well as YSZ fibers in a composite mixture retard the crystallization of glass H to higher temperatures.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1218 (Abstract only)

New full ceramic kit for gas analysis and integrated steamer for SOEC

Pierre Coquoz (1), André Pappas (1), Raphael Ihringer (1)
(1) Fiaxell Sàrl
PSE-A EPFL Innovation Park, CH-1015 Lausanne
Tel.: +41-21-693-8613
info@fiaxell.com

Abstract

Fiaxell is developing a new full ceramic kit for SOFC and electrolysis experiments with the Open Flanges™ test Set-Up. This paper presents the different characteristics of the latter such as pure alumina for gas inlet/outlet and integrated steamer on both electrode sides. Picture 1 show the 3-rings soft vermiculite easily dismountable sealing arrangement, where pressure on cell edge and electrodes can be adjusted separately. The integrated steamer allows for a smooth flow of water vapor. A commercial cell was tested with the integrated steamer. During operation under galvanostatic conditions, voltage peaks could be observed and were studied. It appears that these fluctuations (amplitude and periodicity) are linked to different parameters as water utilization (WU) and type of peristaltic pump head (3 rollers or 10 rollers). Correlation between peristaltic pump head rotation and voltage peaks periodicity are presented through different graphs.

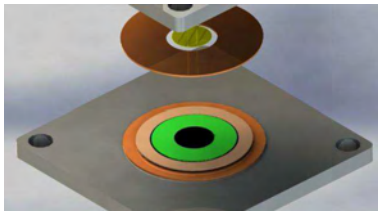


Figure 1: New full ceramic kit for gas analysis, with integrated steamer on both electrode sides and pure alumina gas inlet/outlet

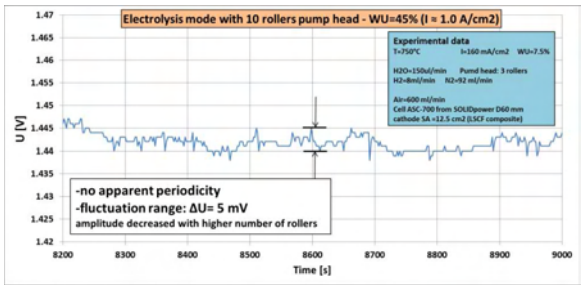


Figure 2: Attenuation of voltage peak obtained at high WU (fluctuations of 5 mV; no apparent peak periodicity)

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1219

Impedance insight into Ceres Power's Steel Cell technology: Latest results.

Gavin Reade (1), Adam Bone (1), Andre Weber (2), Subhasish Mukerjee (1) and Mark Selby (1)
(1) Ceres Power Limited
Viking House,
Foundry Lane,
Horsham RH13 5PX /UK
(2) Dr.-Ing. André Weber
Lauenburger Strasse 67
76139 Karlsruhe/ Germany
Tel.: +44-1403-273463
Fax: +44-1403-327860
gavin.reade@cerespower.com

Abstract

Ceres Power is continuing to develop its unique, low-temperature metal supported SOFC design (the 'Steel Cell') for multiple applications. This paper will discuss the latest results from Impedance studies and distribution of relaxation times (DRT) analysis that allows for deeper insight into the Steel cell performance improvements. This poster will include data from both small, specialised cell and full sized cell in stacks which help in the understanding and mitigation of resistances arising from the cell and stack. This paper illustrates the power of electrochemical impedance spectroscopy in design development of the Steel cell for "real world" applications. This is critical for the commercialisation of this technology as the mechanistic insight from tools like impedance spectroscopy allows for validating design improvements for lower cost as well as validating life for the product.

Next **EFCF** Events

6th European
PEFC & ELECTROLYSER
Forum 4 - 7 July 2017

13th European
SOFC & SOE
Forum 3 - 6 July 2018

Lucerne Switzerland

Chapter 11 - Sessions B13, B14

B13: Anodes: State-of-the-art & novel materials I
B14: Anodes: State-of-the-art & novel materials II

Content **Page B13, B14 - ..**

B1301 (Abstract only, published elsewhere) 4
Evolution of the electrochemical interface in Solid Oxide Cells **4**
John TS Irvine (1), Dragos Neagu (1), Maarten C Verbraeken (1), Christodoulos Chatzichristodoulou (2), Christopher Graves (2), Mogens B Mogensen (2) 4
B1302 (Will be published elsewhere) 5
Elucidating structure-property-function relationships in cermet anodes through independent variation of metal and ceramic composition and microstructure **5**
Paul Boldrin (1), Farid Tariq (1), Mengzheng Ouyang (1), Tanapa Konuntakiet (2), Nigel P. Brandon (1) 5
B1303 (Will be published elsewhere) 6
Accessible Triple-Phase Boundary Length in Solid Oxide Fuel Cell Anodes **6**
A. Nakajo (1,2), A.P. Cocco (1), M.B. Degostin (1), P. Burdet (3), A.A. Peracchio (1), B. N. Cassenti (1), M. Cantoni (3), J. Van herle (2), W.K.S. Chiu (1) 6
B1304 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 7
Development of Solid Oxide Fuel Cells Anode Ni-Based Alloys **7**
Rizki Putri Andarini (1), Robert Steinberger-Wilckens (1), Aman Dhir (1) 7
B1305 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 8
Sulfur tolerant LSCM-based composite cathode for high temperature electrolysis/co-electrolysis of H_2O and CO_2 **8**
Chee Kuan Lim (1,2,3), Qinglin Liu (1,2), Juan Zhou (1,2), Qiang Sun (1,4), Siew Hwa Chan (1,2,3) 8
B1306 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 9
Characterization of Solid Oxide Electrolyser Cells nanocomposite electrodes based on mesoporous ceramic scaffolds infiltration **9**
M. Torrell, E. Hernández, A. Slodczyk, A. Morata, A. Tarancón 9
B1307 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 10
Recent advancements in the utilization of dry biofuel for SOFCs **10**
Massimiliano Lo Faro (1), Sabrina C. Zignani (1), Stefano Trocino (1), R. M. Reis (2), G.G.A. Saglietti (2), E.A. Ticianelli (2), Antonino S. Aricò (1) 10
B1308 (see B1406) 11
B1309 (Will be published elsewhere) 12
Fracture toughness and creep of SOFC anode substrates **12**
Jianping Wei, Goran Pećanac, Jürgen Malzbender 12
B1310 (Will be published elsewhere) 13
High Performance Solid Oxide Electrolyzer Cell with $Ba_{0.9}Co_{0.7}Fe_{0.2}Nb_{0.1}O_{3-\delta}$ Anode Based on YSZ/GDC Bilayer Electrolyte **13**
Zehua Pan (1, 2), Qinglin Liu (2), Siew Hwa Chan (1, 2) 13
B1311 14
Engineering Ceramic Scaffolds for Solid Oxide Fuel Cells and Solid Oxide Electrolysis Cells **14**
Graham R. Stevenson, Enrique Ruiz-Trejo, Nigel P. Brandon 14
B1312 (Abstract only) 15
Exploring oxygen-deficient Ruddlesden-Popper $La_{1-x}Sr_{1+x}NiO_{4-\delta}$ nickelates as oxygen electrode materials for SOFC/SOEC **15**

Aleksey Yaremchenko (1), Ekaterina Kravchenko (1,2), Kiryl Zakharchuk (1), Jekabs Grins (3), Gunnar Svensson (3), Vladimir Pankov (2) 15
B1313 16
Properties of perovskite with high value of A-site cation size mismatch obtained under different synthetic conditions **16**
K. Vidal (1), A. Morán-Ruiz (1), A. Larrañaga (1), M. A. Laguna-Bercero (2), R.T. Baker (3), M. I. Arriortua (1),(4) 16
B1314 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 17
Cerium-Cobalt-Copper oxides based SOFC anodes for the direct utilisation of methane as fuel **17**
Bernardo Jordão Moreira Sarruf (1,2), Jong-Eun Hong (1), Robert Steinberger-Wilckens (1), Paulo Emílio Valadão de Miranda (2) 17
B1315 (Abstract only) 18
Local geometric structure effects on the stability of LSM and LSF electrodes **18**
Cheng-Zhi Guan (1), Xin-Bing Chen (1), Hong-Liang Bao (1), Jing Zhou(1), Guo-Ping Xiao(1), Cheng Peng(1), Jian-Qiang Wang*(1), Zhi-Yuan Zhu(1,2) 18
B1316 (Abstract only) 19
Synthesis and electrical properties of Ti-doped Sr_2FeMoO_6 as an anode material for solid oxide fuel cells **19**
Afizul hakem bin karim (1), Abdalla Mohamed Abdalla (1), Shahzad Hossain (1), Hidayatul Qayyimah Hj Hairul Absah (1), Mohamad Iskandar Petra (2), Abul Kalam Azad(1) 19
B1318 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 20
Ni-YSZ anode impregnated with molybdenum for direct use of bio-ethanol in SOFC **20**
Rosana Zacarias Domingues (1), Rubens Moreira (1) Antônio de Pádua (1), Edyth da Silva (1), Tulio Matencio (1) 20
B1319 (Abstract only) 21
Single triple-phase-boundary and platinum–yttria stabilized zirconia composite as cathodes for IT-SOFCs **21**
Yan Yan (1), Paul Muralt (2) 21
B1320 (Abstract only, published elsewhere) 22
Highly efficient and durable hydrogen production of SOECs using layered perovskite electrodes **22**
Guntae Kim 22
B1321 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 23
Role of dopants on ceria-based anodes for IT-SOFCs powered by hydrocarbon fuels **23**
Araceli Fuerte (1), Rita Ximena Valenzuela (1), María José Escudero (1) 23
B1322 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) 24
Operation of ceria-electrolyte solid oxide fuel cell on simulated biogas mixtures **24**
M.J. Escudero (1), A. Fuerte (1) 24
B1323 25
Paper-structured catalyst for the stable operation of direct-internal reforming SOFC running on biofuels **25**
Taku Kaida (1), Mio Sakamoto (2), Hao Le (1), Quang-Tuyen Tran (2), Yusuke Shiratori (1,2) 25
B1324 (Abstract only) 26
Enhancement of Long-term Stability of Ni-YSZ based SOFC Anode by Infiltration of Transition Metals **26**
Seung-Bok Lee (1,2), Muhammad Shirjeel Khan (1), Rak-Hyun Song (1,2), Jong-Won Lee(1,2), Tak-Hyoung Lim(1,2), Seok-Joo Park(1,2) 26

B1401.....27
Fabrication of Ni-based anodes with tunable microstructures using polymeric precursor deposition 27
Viola I. Birss (1), Aligul Buyukaksoy (1, 2) 27
B1402 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....28
Redox-stable SOFC anode materials based on La-doped $SrTO_3$ oxide with impregnated catalysts 28
Xuesong Shen (1) and Kazunari Sasaki (1-4) 28
B1403 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....29
SMART catalyst based on doped Sr-titanite for advanced SOFC anodes 29
Dariusz Burnat (1), Roman Kontic (1), Lorenz Holzer (2), J. Andreas Schuler (3), Andreas Mai (3), Andre Heel (1) 29
B1404 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB).....30
Influence of multifunctional layers on the performance of solid oxide fuel cell anodes based on $Zr_xCe_{1-x}O_{2-\delta}$ 30
Selma A. Venâncio, George G. Gomes Jr. and Paulo Emílio V. de Miranda 30
B1405 (Will be published elsewhere).....31
Development and Testing of an Impregnated $La_{0.20}Sr_{0.25}Ca_{0.45}TiO_3$ Anode for Improved Performance and Sulfur Tolerance 31
Robert Price (1), Mark Cassidy (1), J. Andreas Schuler (2), Andreas Mai (2), John T. S. Irvine (1) 31
B1406 (Will be published elsewhere).....32
Controlling TPB Length through Calcination Temperature, and its Influence on the Microstructure and Electrochemical Performance of Ni Infiltrated CGO anodes 32
Mengzheng Ouyang(1), Paul Boldrin(1), Nigel P. Brandon(1) 32

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1301 (Abstract only, published elsewhere)

Evolution of the electrochemical interface in Solid Oxide Cells

John TS Irvine (1), Dragos Neagu (1), Maarten C Verbraeken (1), Christodoulos Chatzichristodoulou (2), Christopher Graves (2), Mogens B Mogensen (2)
(1) School of Chemistry, University of St Andrews, St Andrews, Fife KY16 9ST, UK
(2) Department of Energy Conversion and Storage, Technical University of Denmark, Frederiksborgvej 399, 4000 Roskilde, Denmark
Tel.: +44 1334 463817
jtsi@st-and.ac.uk

Abstract

High operating temperatures place significant constraints on electrodes, electrolyte and interconnect materials for Solid Oxide Cells (SOC) so limiting choice to maintain several important requirements. All materials must not be reactive with adjacent components at the high operating temperature, and must have compatible thermal expansion coefficient. Interconnects and electrolytes must be impermeable to gas, show high conductivities to minimize losses (electronic and ionic respectively), and be stable in both reducing and oxidizing atmospheres. Electrodes must show high electrocatalytic activity and must be designed with an extended active surface area (Triple Phase Boundary points). Electrodes must fulfil some important requirements to ensure high and durable power output. To extend the TPB area, electrodes are fabricated as mixed ionic and electronic conductors (MIEC) porous ceramics or ceramic-metallic composites. An ideal microstructure would offer the highest triple phase boundary (TPB) length for electrochemical reactions, an optimized contact between the electrolyte and the electrode, and be dimensionally stable during operation (mechanically, chemically and thermally).

It is particularly important to note that normally the critical region determining the performance and efficiency of SOC devices is the-region of the electrode at the electrode/electrolyte interface. Typically this only extends a few microns and for best performance involves intricate structures on the nanoscale. Here we address the nature and activity of this interface and its electrochemistry, paying particular attention to new developments in controlling and modifying this interface to optimise both performance and durability.

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1302 (Will be published elsewhere)

Elucidating structure-property-function relationships in cermet anodes through independent variation of metal and ceramic composition and microstructure

Paul Boldrin (1), Farid Tariq (1), Mengzheng Ouyang (1), Tanapa Konuntakiet (2), Nigel P. Brandon (1)
(1) Department of Earth Science & Engineering, Imperial College London, London, UK
(2) Department of Chemical Engineering, Imperial College London, London, UK
Tel.: +44-20 7594 9695
p.boldrin@imperial.ac.uk

Abstract

The impregnation of porous oxide-ion-conducting scaffolds with metal nitrates offers an interesting route to allowing independent control over the metal and ceramic microstructures in cermet-based SOFC anodes. In turn, this allows decoupling of the effects of materials selection and microstructure on the catalytic and electrocatalytic properties of the anode. We present results from a series of CGO scaffolds impregnated with nickel nitrate. The porosity of the ceramic scaffold is varied through the use of different pore formers and ink formulations, while the nickel microstructure is varied through measures including use of organic molecules such as urea in the impregnation solution, different calcination temperatures and amounts of nickel. Results of a suite of ex situ and in situ tests is presented, including metal surface area measurements, SEM and symmetrical cell tests.

Our results show that it is possible to independently vary the structures of the metal and ceramic phases using these impregnated ceramic scaffolds, which is important for elucidating structure-property-function relationships. We find that the activity of Ni-CGO anodes is largely independent of the dispersion of the nickel, and more closely linked to the microstructure of the CGO scaffold. Varying the pore former used had a large effect on the performance, with a mixture of large and small pores producing good results. The effect of using nanoparticles was negative.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1303 (Will be published elsewhere)

Accessible Triple-Phase Boundary Length in Solid Oxide Fuel Cell Anodes

A. Nakajo (1,2), A.P. Cocco (1), M.B. Degostin (1), P. Burdet (3), A.A. Peracchio (1), B. N. Cassenti (1), M. Cantoni (3), J. Van herle (2), W.K.S. Chiu (1)
(1) Department of Mechanical Engineering, University of Connecticut, Storrs, USA
(2) Fuelmat Group, Faculty of Engineering Sciences and Technology STI, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
(3) Interdisciplinary Centre for Electron Microscopy, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
arata.nakajo@epfl.ch

Abstract

The density of electrocatalytic sites available for reaction and their accessibility by the transport of reactants and products informs on the relationships between the microstructure and performance of heterogeneous materials for solid oxide fuel/electrolysis cell (SOFC/SOEC) electrode materials. Currently, the connected triple-phase boundary (TPB) length and effective transport properties can be measured directly on digital 3-D reconstructions of the materials obtained by x-ray or electron microscopy. Their implementation in continuum electrode models allow for the estimating and analyzing of material electrochemical performance. A shortcoming of such averaged property-based approaches is that all the TPBs are treated as equally accessible and therefore information on the effects of local geometry and network topology may be lost.

In this study, the accessible TPB length is defined and proposed as a new performance metric that allows for the detailed characterization and comparison of material performance. The measurement method combines geometrical and physical considerations to quantify the access to TPB sites. It consists in applying an analytical electrochemical fin model to a 3-D discrete representation of the heterogeneous structure provided by skeleton-based partitioning to probe the resistance of the pathways to each TPB, within each phase separately. Combination of the accessible TPB within the phases yields the combined and total accessible TPB, which further inform on the electrochemical performance of the material.

The sensitivity of the accessible TPB length to local geometry and topology that standard measurements cannot capture is illustrated using 3-D data of a Ni-YSZ anode imaged by focused ion beam-scanning electron microscopy (FIB-SEM) serial sectioning in pristine state and after short stack operation for 4700 h. The results show that the accessible TPB is not uniform. The variation exceeds one order of magnitude and few connected TPBs can be even passivated because of diffusion limitations. Preferential pathways are clearly detected, which suggests a non-uniform utilization of the phases that is potentially detrimental for the performance and the resilience of the material to alterations caused by degradation operation. These effects are investigated by comparing the accessible TPB length in pristine and aged samples.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1304 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Development of Solid Oxide Fuel Cells Anode Ni-Based Alloys

Rizki Putri Andarini (1), Robert Steinberger-Wilckens (1), Aman Dhir (1)
(1) SOFC Fuel Cell Research Group, School of Chemical Engineering
The University of Birmingham, B15 2TT, UK
Tel.: +44-121-414-3344
Fax: +44-121-414-3971
rpa563@student.bham.ac.uk

Abstract

Nickel-based catalysts are an essential part of internal methane steam reforming in solid oxide fuel cells (SOFCs). Unfortunately, nickel is a very good catalyst not only for methane reforming, but also for methane cracking. Progressive progress on anode-supported SOFCs has been made for the last two decades to discover alternative Ni-based alloys that prevent coking from occurring on the catalysts surface. Sn has been known as one of the prospective anode dopants to reduce the nickel poisoning from carbon formation. Several observations and modelling calculations from various researchers offer the theory of Sn latch on to the Nickel on the anode surface. The role of Sn-infiltration in the Ni-cermet anode is observed in this study to give better perspective and understanding towards this approach.

Using commercially available Ni/YSZ-based anode supported half cells, Sn-infiltrated Ni/YSZ SOFCs were manufactured. $SnCl_2$ diluted in ethanol was used to make the dopant solution. Pipette drop technique was used to dope the Sn into anodes due to its simplicity and cost-effectiveness. The characterisation results using SEM-EDX shows that Sn is successfully deposited using this method. Observations point at the possibility that Sn adheres to both NiO and ZrO_2 surfaces and whilst it is not affected by the morphology of the surface. Al threads found on the Sn-doped cells after calcination lead to the theory of impurities sublimation when manufacturing the doped cell. These results will serve as supplementary background data for future developments of Ni-based alloys research.

Keywords: Nickel-based, Sn-infiltration, anode, SOFCs

Acknowledgments:
This work was supported by Indonesia Endowment Fund for Education (LPDP)

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1305 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Sulfur tolerant LSCM-based composite cathode for high temperature electrolysis/co-electrolysis of H_2O and CO_2

Chee Kuan Lim (1,2,3), Qinglin Liu (1,2), Juan Zhou (1,2), Qiang Sun (1,4), Siew Hwa Chan (1,2,3)
(1) Singapore-Peking University Research Centre, Campus for Research Excellence & Technological Enterprise (CREATE), Singapore 138602, Singapore
(2) Energy Research Institute at NTU (ERIAN), Nanyang Technological University, Singapore, 639798, Singapore
(3) School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, 639798, Singapore
(4) College of Engineering, Peking University, Beijing 100871, China
Tel.: +65-93201654
kevi0016@e.ntu.edu.sg

Abstract

The cathode performance of various LSCM-based composites for high temperature H_2O electrolysis has been studied by examining their electrochemical behavior under current loading using three-electrode electrolysis cells with Pt as counter and reference electrodes. Experimental results among pure LSCM, LSCM-GDC, LSCM-YSZ and LSCM-(GDC-YSZ) have shown that LSCM-GDC exhibits the highest H_2O electrolysis performance. The ratio between LSCM and GDC is further optimized and it is shown that the LSCM-GDC with 50-50 wt% for each component exhibits the highest performance. Benchmarking with a 60-40 wt% Ni-YSZ cathode have shown that the optimized LSCM-GDC cathode exhibits better performance for H_2O electrolysis with a lower area specific resistance. Under a cathodic current of 100 $mAcm^{-2}$, the optimized LSCM-GDC cathode shows much slower degradation, about 10 times slower as compared to the Ni-YSZ cathode when exposed to 10 ppm of SO_2 for up to 72 hr. All the above electrochemical tests have been conducted at 800°C and 70/30 pH_2O/pH_2. Without the use of reducing agent, the optimized LSCM-GDC cathode also shows promising performance for co-electrolysis of H_2O and CO_2 at high current densities and stable performance with 5 ppm of SO_2 in the feedstock gas.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1306 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Characterization of Solid Oxide Electrolyser Cells nanocomposite electrodes based on mesoporous ceramic scaffolds infiltration

M. Torrell, E. Hernández, A. Slodczyk, A. Morata, A. Tarancón
Catalonia Institute for Energy Research (IREC), Jardins de les Dones de Negre, 1, 08930 Sant Adrià de Besòs, Barcelona, Spain

Abstract

Reverse operation of the solid oxide fuel cells (SOFC) as electrolysers to efficiently convert wasted renewable energy into chemical fuels is presented as one of the most efficient routes for chemical energy storage routes. Among the production of high purity H_2 by steam electrolysis, solid oxide electrolyser cells (SOEC) allow also reducing different mixtures of H_2O and CO_2 (co-electrolysis) to produce syngas ($CO+H_2$), which is a precursor of synthetic fuels among others high added values chemicals [1].
The operation of the solid oxide cells in electrolyser mode has been demonstrated to be more demanding in terms of electrodes materials activity and stability than the SOFC operation. This is due to the higher operation voltages, higher diffusion resistances and endothermic nature of the reactions that take place [2]. For these reasons, the improvement of the long term stability of electrode materials and their catalytic activity is a major concern for the SOEC technology application.
The aim of this work is to study the performance of $Sc_{0.4}Yb_{0.6}SZ$ electrolyte supported SOEC based on mesoporous nanocomposite electrodes synthetized through infiltration or impregnation of the mesoporous ceramic scaffold fabricated as Kit-6 replica. Such electrodes present homogeneous triple phase boundaries (TPBs) distribution in a high mechanical and thermal stable structure, improving the electrodes activity and stability [3]. The study of different approaches and attachment temperatures is presented in this work in order to overcome the issues of adhesion between the mesoporous electrodes and the electrolyte, while keeping nanostructured electrodes [4]. Particular attention was paid to the optimization of mesoporous $Sm_{0.2}Ce_{0.8}O_2$ (SDC) -$Sm_{0.5}Sr_{0.5}CoO_3$ (SSC) oxygen electrode by fabricating symmetrical cells. Electrochemical characterization operating under steam electrolysis and co-electrolysis modes is presented and discussed in terms of the electrodes nanostructures, studied by Brunauer–Emmett–Teller (BET), Small Angle X-ray Scattering (SAXS) and scanning electron microscopy (SEM).

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1307 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Recent advancements in the utilization of dry biofuel for SOFCs

Massimiliano Lo Faro (1), Sabrina C. Zignani (1), Stefano Trocino (1), R. M. Reis (2), G.G.A. Saglietti (2), E.A. Ticianelli (2), Antonino S. Aricò (1)
(1) CNR-ITAE, via Salita S. Lucia sopra Contesse 5, 98126 Messina, Italy
(2) USP-IQSC, Av. Trab. São-carlense, 400 CEP 13560-970 São Carlos, SP, Brasil
Tel.: +39-090-624231
Fax: +39-090-624247
lofaro@itae.cnr.it

Abstract

This communication complies with the general trend on SOFC about the utilization of low cost fuels. A possible scenario for the near future is the direct utilization of biofuels in SOFC stack. At the present, the conventional Ni-YSZ/YSZ/YDC/LSFC cells are affected from several constraints in the direct utilization of such fuels mainly consisting in the carbon formation and sulphur contamination of the anode. For this reason, in the short and medium terms a possible solution to these issues is the utilization of a barrier layer attached to the outermost side of the anode. At this scope, the pre-layer materials must show properties that may comply requirements such as mechanical, thermal and electrochemical properties at least similar to the Ni-YSZ. In addition, the catalyst must be deposited at very thin level in order to mitigate the ohmic constraint of an addition layer. Ni-based alloys (Ni-M, M=Ni, Co, and Fe) in combination with gadolinia-doped ceria is reported to be a valuable material for the oxidation of biofuels including the oxidation of sulphur compounds. Therefore, the investigation of such catalysts as protective layer becomes of interest in order to maintain the well established manufacturing technology around the SOFCs. With this preface, this communication will report the strategy adopted for the preparation of catalyst with a proper composition at the atomic level, the catalytic properties and physico-chemical properties of catalyst, as well as the electrochemical investigation of performances for the protected cells in comparison to that achieved for a bare cell.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1308 (see B1406)

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1309 (Will be published elsewhere)

Fracture toughness and creep of SOFC anode substrates

Jianping Wei, Goran Pećanac, Jürgen Malzbender
Forschungszentrum Jülich GmbH, IEK-2
Wilhelm-Johnen-Straße
52428 Jülich, Germany
Tel.: +49-2461-61-9399
Fax: +49-2461-61-3699
j.wei@fz-juelich.de

Abstract

Mechanical stability of the anode substrate is crucial for the reliable operation of solid oxide fuel cells (SOFCs). In particular, facture toughness and creep behaviour as the major mechanical aspects for this application attract the research attention, where the current work focused on Ni(O)-8YSZ anode substrate material. The fracture toughness of the material was determined via a double torsion test for the oxidized and reduced state at room temperature and 800 °C. Creep of porous Ni-YSZ composite has been investigated under H_2/Ar atmosphere at typical operating temperatures, where different loading configurations such as compression, four-point bending and ring-on-ring bending have been used to assess the effect of compressive and tensile stresses. In the creep study, Ni-8YSZ materials with different porosities and Ni/8YSZ ratios were tested in order to investigate material´s composition and porosity effects. The results were systematically compared and discussed with the aid of complementary crack path and microstructural investigations.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1310 (Will be published elsewhere)

High Performance Solid Oxide Electrolyzer Cell with $Ba_{0.9}Co_{0.7}Fe_{0.2}Nb_{0.1}O_{3-\delta}$ Anode Based on YSZ/GDC Bilayer Electrolyte

Zehua Pan (1, 2), Qinglin Liu (2), Siew Hwa Chan (1, 2)
(1) School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, 639798, Singapore
(2) Energy Research Institute at NTU (ERIAN), Nanyang Technological University, Singapore, 639798, Singapore
Tel.: +65-88699251
Fax: +65-67924062
zpan001@e.ntu.edu.sg

Abstract

Ba1-x(Co1-y-zFeyNbz)O3-δ (BCFN) perovskite has been recently proposed as cathode for solid oxide fuel cells due to its high performance. Most recently, it has also demonstrated good performance as anode on doped lanthanum gallate electrolyte in solid oxide electrolyzer cells. However, its performance based on traditional yttria stabilized zirconia (YSZ) electrolyte has not been reported yet. In this work, chemical compatibility test was conducted in the first place which showed that BaZrO3 formed between BCFN and YSZ after heat treatment at 1000 ℃ for 5 h. Electrochemical test on symmetrical cells presented very low polarization resistances of BCFN electrode on gadolinium doped ceria (GDC) electrolyte. Thus, YSZ/GDC bilayer electrolyte was developed by co-sintering to prevent the interfacial reaction between YSZ electrolyte and BCFN electrode. By adding 0.5 at % Fe2O3 into GDC slurry, fully dense GDC layer was achieved at a lower sintering temperature of 1300 ℃ due to improved sinterability of GDC. The reduced sintering temperature was important to mitigate the interfacial diffusion between YSZ and GDC. The cathode-supported eletrolyzer cell consisting of Ni-YSZ cathode, YSZ/GDC bilayer electrolyte and BCFN anode was evaluated for water electrolysis using a feedstock of 60%H2O/40%H2. Under open circuit condition, the cell showed total area specific resistances of 0.515, 0.305 and 0.195 Ω cm2 at 700, 750 and 800 ℃, respectively. At electrolysis current density of -1 A cm-2, the cell voltages were 1.43, 1.23, 1.13 V at 700, 750 and 800 ℃, respectively. At last, short-term stability test was conducted under -1 A cm-2 electrolysis current at 800 ℃ and no microstructure changes were observed by scanning electron microscopy, indicating that such a cell is very promising and worth further investigation.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1311

Engineering Ceramic Scaffolds for Solid Oxide Fuel Cells and Solid Oxide Electrolysis Cells

Graham R. Stevenson, Enrique Ruiz-Trejo, Nigel P. Brandon
Imperial College London, Department of Earth Science and Engineering, London SW7 2AZ
Tel: +447585556806
g.stevenson15@imperial.ac.uk

Abstract

In recent SOFC and SOEC electrode design experiments, all-ceramic electrodes have shown increasingly promising performance under testing. The perovskite group $La_{1-x}Sr_xTi_{1-y}M_yO_{3-\delta}$ with an A-site deficiency has been proven to have the potential to electronically conduct upon reduction and can ex-solve the M dopant as shown previously with metals such a nickel and iron.
In this paper, the wet synthesis of $La_{0.4}Sr_{0.4}Ti_{0.94}Ni_{0.06}O_{3-\delta}$ is discussed along with characterisation of the resulting product to ensure phase purity. Heat treatment and ex-solving through reduction is then performed and the results are discussed.

B1312 (Abstract only)

Exploring oxygen-deficient Ruddlesden-Popper $La_{1-x}Sr_{1+x}NiO_{4-\delta}$ nickelates as oxygen electrode materials for SOFC/SOEC

Aleksey Yaremchenko (1), Ekaterina Kravchenko (1,2), Kiryl Zakharchuk (1), Jekabs Grins (3), Gunnar Svensson (3), Vladimir Pankov (2)
(1) CICECO, Department of Materials and Ceramic Engineering, University of Aveiro 3810-193 Aveiro, Portugal
(2) Department of Chemistry, Belarusian State University Leningradskaya 14, 220030 Minsk, Belarus
(3) Department of Materials and Environmental Chemistry, Stockholm University SE-106, 91 Stockholm, Sweden
Tel.: +351-234-370235
Fax: +351-234-370204
ayaremchenko@ua.pt

Abstract

Perovskite-related nickelates derived from Ruddlesden-Popper $Ln_2NiO_{4+\delta}$ (Ln = La, Pr, Nd) combine redox stability with noticeable oxygen stoichiometry changes, yielding enhanced mixed transport and electrocatalytic properties. These unique features are promising for applications as oxygen electrodes with good electrochemical performance in reversible SOFC/SOEC (solid oxide fuel/electrolysis cell) systems. The present work was focused on the assessment of strontium-rich side of $La_{2-x}Sr_xNiO_{4\pm\delta}$ system for possible use as materials for reversible oxygen electrodes.
$La_{1-x}Sr_{1+x}NiO_{4\pm\delta}$ (x = 0-0.6) ceramics were prepared by Pechini method with repeated annealings at 650-1100°C, and sintered at 1250°C for 5 h under oxygen atmosphere. Variable-temperature XRD studies confirmed that all studied compositions retain tetragonal K_2NiF_4-type structure in the temperature range 25-1000°C under oxidizing conditions. It was found that, contrary to parent $La_2NiO_{4+\delta}$, $La_{1-x}Sr_{1+x}NiO_{4-\delta}$ nickelates exhibit oxygen deficiency in high-temperature range which increases with temperature and with strontium content and reaches ~1/8 of oxygen sites for x = 0.6 at 1000°C in air. Oxygen losses on heating under inert gas atmosphere induce reversible oxygen vacancy ordering accompanied by a contraction of the lattice and a decrease of its symmetry to orthorhombic. Average thermal expansion coefficients were calculated from the XRD data to vary in the range $(10.8\text{-}11.7)\times10^{-6}$ K^{-1} in air being compatible with that of common solid electrolytes. $La_{1-x}Sr_{1+x}NiO_{4-\delta}$ ceramics exhibit a p-type metallic-like electrical conductivity at 500-1000°C under oxidizing conditions, with the highest conductivity (270 S/cm at 800°C in air) observed for x = 0.2. High level of oxygen deficiency in Sr-rich $La_{1-x}Sr_{1+x}NiO_{4-\delta}$ implies enhanced mixed ionic-electronic transport favorable for electrode applications. Electrochemical performance of porous electrodes was evaluated by electrochemical impedance spectroscopy employing symmetrical solid electrolyte cells.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1313

Properties of perovskite with high value of A-site cation size mismatch obtained under different synthetic conditions

K. Vidal (1), A. Morán-Ruiz (1), A. Larrañaga (1), M. A. Laguna-Bercero (2), R.T. Baker (3), M. I. Arriortua (1),(4)
(1) Universidad del País Vasco/ Euskal Herriko Unibertsitatea (UPV/EHU). Facultad de Ciencia y Tecnología. Sarriena s/n, 48940 Leioa, Spain
(2) Instituto de Ciencia de Materiales de Aragón (ICMA), CSIC-Universidad de Zaragoza. Pedro Cerbuna 12, 50009 Zaragoza, Spain
(3) School of Chemistry, University of St Andrews, St Andrews, Fife KY16 9ST, UK
(4) BCMaterials Parque Tecnológico de Zamudio, Ibaizabal Bidea, Edificio 500–Planta 1, 48160 Derio, Spain
Tel.: +34-94-601-5984
Fax: +34-94-601-3500
karmele.vidal@ehu.es

Abstract

The perovskite $La_{0.15}Sm_{0.35}Sr_{0.08}Ba_{0.42}FeO_{3-\delta}$ has been prepared by a glycine nitrate route, varying the fuel/oxidizer ratio and cooling rate, in order to study the sample preparation influence on the properties in the context of their application as an electrode material for SOFCs. The obtained materials have been characterized by high-resolution synchrotron X-ray powder diffraction (SXRPD), scanning electron microscopy (SEM) and electrical measurements. This characterization was performed from room temperature (r.t.) up to 700 and 800ºC (typical operating temperatures for the application of these materials in SOFC technology). It was found that the prepared samples present a cubic crystal structure at the studied temperatures. As expected, the oxygen stoichiometry decreases as temperature increases, being a little smaller for the quenched sample. SEM images show a well-necked morphology of the powders which are composed of nanosized particles and agglomerations of grains. The electronic conductivity values are characteristic of samples with these high values of $\sigma^2(r_A)$.

B1314 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Cerium-Cobalt-Copper oxides based SOFC anodes for the direct utilisation of methane as fuel

Bernardo Jordão Moreira Sarruf (1,2), Jong-Eun Hong (1), Robert Steinberger-Wilckens (1), Paulo Emílio Valadão de Miranda (2)
(1) Centre for Fuel Cell and Hydrogen Research, School of Chemical Engineering, University of Birmingham, Edgbaston, Birmingham, West Midlands B15 2TT, UK
(2) Hydrogen Laboratory COPPE, Metallurgical and Materials Engineering, Federal University of Rio de Janeiro - 21942-971 Rio de Janeiro, RJ, Brazil
Tel.: +44 (0) 7899 357 747, +55 (21) 9 9386 8750
sarruf@labh2.coppe.ufrj.br

Abstract

Solid oxide fuel cells – SOFCs – are capable of converting methane directly by internal reforming. New materials development aim to reduce the difficulties of fuel pre-processing by allowing the direct utilisation of anhydrous fuels. This avoids the addition of water, thus reducing system complexity and operational costs.

A CeO_2-Co_3O_4-CuO based electrocatalyst powder synthesised by the amorphous citrate method has been investigated as SOFC anode for direct operation with anhydrous methane. The catalysts studied were characterised using X-ray diffraction (XRD) and thermogravimetric analysis (TGA).

Furthermore, electrochemical properties of the electrocatalyst were evaluated under hydrogen from 700 to 850°C, as well as with mixtures of anhydrous methane and hydrogen and also with pure methane as fuels at 850 and 950 °C. Composition was analysed with scanning electron microscopy and energy dispersive X-ray spectroscopy (SEM/EDX) at the anode material. In addition, coarsening observations were assessed on as-sintered pellet anode samples.

It was found that the Cerium-Cobalt-Copper oxide based materials are able to operate as anode electrocatalyst in SOFC whilst fed either with hydrogen or anhydrous methane as fuels. The utilisation of pure methane has shown to be a viable condition whilst operating above 800 °C. The eventual presence of carbon deposition was assessed by Raman spectroscopy.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1315 (Abstract only)

Local geometric structure effects on the stability of LSM and LSF electrodes

Cheng-Zhi Guan (1), Xin-Bing Chen (1), Hong-Liang Bao (1), Jing Zhou(1), Guo-Ping Xiao(1), Cheng Peng(1), Jian-Qiang Wang*(1), Zhi-Yuan Zhu(1,2)
(1) Shanghai Institute of Applied Physics, Chinese Academy of Sciences.
2019 Jia Luo Road, Jiading district, Shanghai 201800, P. R. China
(2) Shanghai Branch, Chinese Academy of Sciences.
319 Yueyang Road, Shanghai 200031, P. R. China
Tel.: +86-21-3919-4051
wangjianqiang@sinap.ac.cn

Abstract

Reversible solid oxide cells (SOCs) can operate in both electrolysis cell (EC) mode and fuel cell (FC) mode for storage and generation of clean energy, respectively. A great deal of ABO_3-structure perovskite materials are chosen as oxygen electrodes of SOCs for their excellent catalytic activity in the oxygen reduction reaction (ORR). With Sr^{2+} substitutions in the A-site, $La_{1-x}Sr_xMnO_3$ and $La_{1-x}Sr_xFeO_3$, possess much better O^{2-} transport abilities and lower polarization resistances. However, Sr segregation under the operating conditions, decreasing the stability of the electrodes, is commonly observed.
To enhance the understanding of Sr surface segregation (SSS) in perovskite electrodes, this work places emphasis on the relationship between local geometric structure and the stability of Sr atoms in $La_{0.6}Sr_{0.4}MnO_3$ (LSM) and $La_{0.6}Sr_{0.4}FeO_3$ (LSF). The materials were synthesized via a traditional sol-gel method. X Ray Absorption Spectroscopy (XAS) analysis was used to character the local geometric structure of Sr atoms, including the coordination number of oxygen bonded to Sr (CN (Sr-O)) and the bond length of Sr-O. A relatively smaller CN (Sr-O) and a longer bond length of Sr-O were found in LSF, which demonstrated that it was easier for Sr-O band in LSF to be broken. Postern analysis of the electrodes after 20 hours anodic polarization was performed to identify the segregation of Sr on the surfaces of the electrodes. The molar ratio of Sr/La on the LSF surface was much larger than that on the LSM surface, indicating that more Sr atoms in the bulk of LSF immigrated to the surface, in accordance with the XAS data.

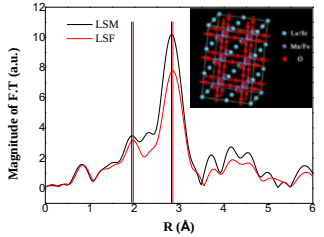


Fig.1 Fourier transforms of the EXAFS spectra at Sr K-edge in LSM and LSF

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1316 (Abstract only)

Synthesis and electrical properties of Ti-doped Sr_2FeMoO_6 as an anode material for solid oxide fuel cells

Afizul hakem bin karim (1), Abdalla Mohamed Abdalla (1), Shahzad Hossain (1), Hidayatul Qayyimah Hj Hairul Absah (1), Mohamad Iskandar Petra (2), Abul Kalam Azad(1)

(1) Department of chemical and process engineering, Faculty of Integrated Technology, University Brunei Darussalam, Gadong B.E 1410, Brunei Darussalam

(2) Department of systems engineering, Faculty of Integrated Technology, University Brunei Darussalam, Gadong B.E 1410, Brunei Darussalam

Tel.: +6738913760

14h0952@ubd.edu.bn

Abstract

Solid oxide fuel cell (SOFC) is an efficient power generator which converts the chemical energy of a fuel into electricity directly with very low environmental pollution. The double perovskite sample of composition $Sr_2Fe_{1-x}Ti_xMoO_6$ (x=0, 0.25, 0.5, 0.75 & 1) has been prepared by the solid state sintering method. The obtained materials were then characterized by using X-ray diffraction (XRD), scanning electron microscope (SEM), themalgravimetric analysis (TGA) and electrical measurement. X-ray powder diffraction (XRD) in Fig.1 shows that all the compounds have a tetragonal symmetry (space group – I4/m). SEM top view of surface morphology shows a smooth surface with a large grain size but with pores. To our knowledge, the effect of titanium substitution for iron at the B-site on the electrochemical activity for the hydrogen oxidation has not been done yet. SOFC anodic behavior in hydrogen and hydrocarbon fuels will be performed and discussed during the conference.

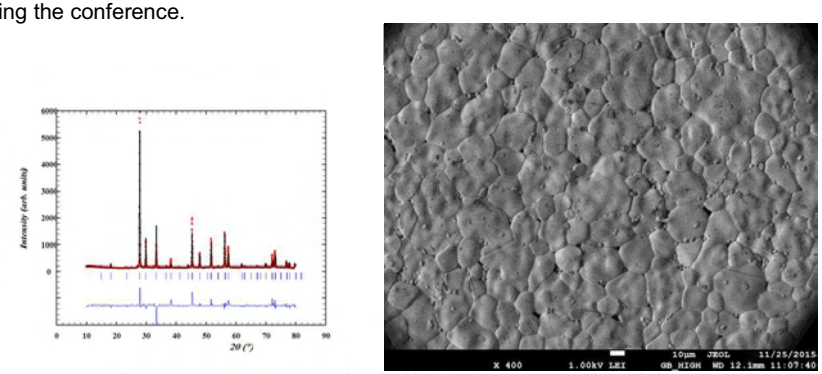


Fig 1. Refined XRD intensity profile (left) and SEM image (right) for Sr_2FeMoO_6

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1318 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Ni-YSZ anode impregnated with molybdenum for direct use of bio-ethanol in SOFC

Rosana Zacarias Domingues (1), Rubens Moreira (1) Antônio de Pádua (1), Edyth da Silva (1), Tulio Matencio (1)

1) Universidade Federal de Minas Gerais - Departamento de Química Av. Pres. Antônio Carlos, 6627, Belo Horizonte/Minas Gerais, Brazil

Tel.: +55 31 34096383

Fax: +55 31 34095700

rosanazd@yahoo.com.br

Abstract

NiO-YSZ powder was impregnated with molybdenum in order to evaluate its bio-ethanol reform capacity during a solid oxide fuel cell operation. Initially, powders of NiO and YSZ in the ratio of 56/44% w/w were mixture and then added into an ammonium molybdate solution. After, the suspension was dried and the resulting powder was used to prepare a Ni/YSZ anode impregnated with 2.5% w/w molybdenum. The powders were characterized by X-ray diffraction (XRD), and dynamic light scattering (LDS). An organic slurry was then prepared and deposited on a YSZ electrolyte by screen printing. The cathode was prepared from a LSM slurry that was deposited on the CGO layer, both deposited by screen-printing. The morphology and thickness of the anode layer was analyzed by scanning electron microscopy (SEM). The electrochemical tests were performed on SOFC test setup Fiaxell at 750 °C. The cathode was feed with 400 mL min^{-1} of air and the anode was feed with 200 $mLmin^{-1}$ of hydrogen or 12.5 $mLmin^{-1}$ of a solution of ethanol: water in a volume ratio of 1:3. The polarization curves show that the cell performance when fed with ethanol (17 $mWcm^{-2}$ at 0.7 V) corresponded to 65,4% of the achieved when fueled by hydrogen (26 $mWcm^{-2}$ at 0.7 V). This result points out to a potential use of molybdenum as a catalyst for reform of bio-ethanol in SOFC.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1319 (Abstract only)

Single triple-phase-boundary and platinum–yttria stabilized zirconia composite as cathodes for IT-SOFCs

Yan Yan (1), Paul Muralt (2)
(1) Faculty of Materials and Energy
Southwest University, 2 Tian Sheng Street, Bei Bei District, 400715 Chong Qing/China
Ceramics Laboratory,
Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne/Switzerland
Tel.: +86-23-6825-3204
Fax: +86-23-6825-3204
yanyan2013@swu.edu.cn

Abstract

Micro-solid oxide fuel cell (μSOFC) structures with annular Pt electrodes have been fabricated by means of silicon micromachining. The annular cathodes contained a defined triple phase boundary (TPB) length, which allowed the derivation of the ionic current per length of TPB as 1.24 mA m^{-1}, measured at 450°C at maximal power. Considering literature values for oxygen diffusion activation on Pt, the active zone supplying atomic oxygen to the triple phase boundary was calculated to be 22nm wide at most. The anode function was provided by a CGO layer, known to be electrically conductive at reducing conditions, with annular Pt current collector. The TPB length was increased by adding a Pt-YSZ composite cathode layer covering the complete YSZ/CGO membrane. The peak power density was increased by a factor of 5 to reach 5 mW cm−2 with an open circuit voltage of 0.68 V at 450°C. It was observed that the Pt grains re-crystallized to large grains, leading to a loss of electrical connectivity in the composite layer. The composite cathode layer was thus inadequate to contact the complete membrane area, leading to a too large area specific resistance (ASR) in the interior of the cell.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1320 (Abstract only, published elsewhere)

Highly efficient and durable hydrogen production of SOECs using layered perovskite electrodes

Guntae Kim
School of Energy and Chemical Engineering
UNIST, 50 UNIST-gil, Republic of Korea
Tel.: +82-52-217-2917
Fax: +82-52-219-2909
gtkim@unist.ac.kr

Abstract

In recently years, there has been an increased focus on renewable energy sources as a solution of global warming due to release of excess amounts of carbon dioxide into the atmosphere arising from the production and consumption of fossil fuels. Hydrogen is attracted as a leading candidate for alternative future fuels because it has the potential to address the environmental and energy security issues associated with fossil hydrocarbon fuels. Solid oxide electrolysis cells (SOECs), which are essentially solid oxide fuel cells (SOFCs) operated in reverse, are one of the promising technology for the efficient production of H_2 that can produce hydrogen at a fast chemical reaction rate with relatively low electrical energy because electrolysis at elevated temperatures is advantageous for both thermodynamic and kinetic reasons. Recent significant interest in steam electrolysis has been largely concerned with performance, stability and degradation issues relating to highly developed SOFC materials. The state-of-the-art commercial or lab-studied oxide ion-conducting SOEs use Ni-YSZ (yttria-stabilized zirconia) as the fuel electrode material. Ni-YSZ electrode exhibits inherent redox instability, agglomeration and coarsening of nickel particles, and degradation under electrolysis applications. Moreover, the activity of Ni particle is not sufficient for an intermediate temperature SOEC. In this study, we report the successful use of the layered perovskite as both electrodes of SOEC using a $LaGaO_3$ based oxide electrolyte, showing a significant cell performance with superior performance stability.

Remark: Only the abstract is available, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1321 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Role of dopants on ceria-based anodes for IT-SOFCs powered by hydrocarbon fuels

Araceli Fuerte (1), Rita Ximena Valenzuela (1), María José Escudero (1)
(1) Energy Department, CIEMAT.
40 Complutense Avenue, 28040 Madrid/Spain
Tel.: +34-91-496-2607
Fax: +37-91-346-6269
araceli.fuerte@ciemat.es

Abstract

In recent years, researches on SOFC technology have been focused on lowering the operating temperature, primarily driven by the cost and durability of components. Unfortunately operation at lower temperature creates problems associated with the increase in the electrolyte resistance and the electrode polarisation as well as decrease in the rate of electrocatalytic reactions. Furthermore, the direct use of alternative fuels to hydrogen, such as gas natural or biogas, is still limited due to the catalyst deactivation by coking or fuel impurity poisoning. Different strategies have been proposed to avoid the deactivation for carbon deposition, for instance by replacing Ni with electronic conductors that no catalyse carbon formation, such as copper or conducting oxides. Unfortunately, it is difficult to achieve sufficient conductivity with oxides under reducing conditions of the anode. Cu-ceria based anodes have allowed to achieve reasonable power densities working on hydrocarbons however, they are limited to relative low operation temperatures (<800 ◦C), because their tendency to sinter together with the low catalytic activity of copper for C–H scission. A possible solution to these problems involves the use of anodes based on metal alloys or bimetallic systems. The evaluation of Cu–Ni alloys demonstrated that carbon formation was strongly suppressed compared to nickel anodes but their stability were limited in the presence of hydrocarbons. Therefore, it is necessary to continuously search for novel anode materials having superior electro-catalytic activity in the intermediate temperature range and less-prone to deactivation.
In this sense, the present work explores the effect of different dopants on the properties of Cu-ceria based anodes for IT-SOFCs powered by hydrocarbon fuels. Four dopants atoms (Co, Ca, Ag and Rh) with different properties and concomitant varied effects on properties of the final material are studied. They have been selected in order to improve the electrical and textural properties of anode material as well as the catalytic activity for hydrocarbon oxidation. For example, Co and Ni have similar catalytic properties for hydrocarbon reactions; but the Cu–Co and Cu–Ni (widely studied) systems provide an interesting contrast in that Cu and Ni are completely miscible while Cu and Co are not, being of great interest for SOFC anode development. Results revealed a strong dependence of the final properties of the anode formulation and mechanism involved in the electro-oxidation of the different fuels. Different doping successfully improves the behavior of anode material for IT-SOFCs powered by hydrocarbon fuels.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1322 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Operation of ceria-electrolyte solid oxide fuel cell on simulated biogas mixtures

M.J. Escudero (1), A. Fuerte (1)
(1) CIEMAT, Avda Complutense 22, 28040, Madrid, Spain
Tel.: +34-91-346-6622
Fax: +34-91-346-6269
m.escudero@ciemat.es

Abstract

From a biogas-user technology perspective, solid oxide fuel cells (SOFCs) are an attractive energy conversion system because of their high electric and CHP efficiency, their low heat-to-power ratio, fuel flexibility and the relatively higher tolerance to impurities if compared with other types of fuel cells. In addition, the high operating temperature (600-850 °C) allows direct or indirect internal reforming of fuels such as hydrocarbons and alcohols. Doped ceria, particularly samaria doped ceria (SDC) and gadolinia doped ceria (GDC), is considered as the promising electrolyte material for solid oxide fuel cells (SOFCs) due to its high oxygen-ion conductivity and high catalytic activity for both oxygen reduction and fuel reforming. On the other hand, in a previous study, a WNi alloy combined with cerium oxide (WNi-Ce) was synthesized by coprecipitation within reverse microemulsion method and exhibited a good catalytic activity for CO_2 reforming of methane (also known as dry reforming).

In this study, a samarium cerium electrolyte-supported solid oxide fuel cell (SOFC) was assembled with a 400 µm thick $Ce_{0.8}Sm_{0.2}O_{2-\delta}$ (SDC) electrolyte, $La_{0.58}Sr_{0.4}Fe_{0.8}Co_{0.2}O_{3-\delta}$ (LSCF) as cathode and WNi-Ce as anode. A porous layer of SDC between anode and electrolyte was used to improve adhesion of the anode ink. The cell performance was investigated with hydrogen and three simulated biogas mixtures ($CH_4/CO_2/H_2$ 70/25/5, 60/35/5 and 50/45/5) on the anode and static air on the cathode at 750 ºC. In addition, the effect of H_2S (10 ppm) incorporation in the biogas on the cell performance has been examined. The electrochemical behaviour of the cell has been evaluated using IV curves, impedance spectroscopy and load demands. The results revealed that the best performance was obtained with the biogas composition richer in CH_4 due to probably the higher catalytic activity of WNi-Ce in this operation condition. Furthermore, the addition of H_2S in biogas causes an important decrease on the cell performance owing to the sulphuration reactions of anodic material. However, the stability tests under load demands revealed that the cell does not suffer degradation under any studied operation conditions (biogas composition and H_2S in the fuel). This suggests that WNi-Ce could be a suitable anode material for ceria-electrolyte SOFC direct feeding of biogas.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1323

Paper-structured catalyst for the stable operation of direct-internal reforming SOFC running on biofuels

Taku Kaida (1), Mio Sakamoto (2), Hao Le (1), Quang-Tuyen Tran (2), Yusuke Shiratori (1,2)
(1) Department of Hydrogen Energy System, Faculty of Engineering, Kyushu University
(2) International Research Center for Hydrogen Energy, Kyushu University
Motooka 744, Nishiku, Fukuoka 819-0395, Japan
Tel.: +81-92-802-3058
Fax: +81-92-802-3094
y-shira@mech.kyushu-u.ac.jp

Abstract

Direct internal reforming SOFC (DIR-SOFC) operated with bio-oil, attractive as a transportable fuel for carbon-neutral SOFC power generation, was studied. Bio-oil, water emulsion of tar-like hydrocarbon produced by thermal decomposition of woody biomass mixed with additional H_2O (S/C = 1.0), was supplied directly to anode-supported cell (ASC) as droplets at the cell temperature of 900 ^oC. However, stable voltage could not be obtained due to severe coking within the porous Ni-YSZ anode. In order to overcome this issue, paper-structured catalyst (PSC), flexible planar-shaped catalyst, was applied in front of SOFC. By the application of Ru-loaded $BaTiO_3$-dispersed PSC (Ru loading: 2.4 mg), power density of ASC fuelled by bio-oil at 700 mV was risen from 33 to 149 mW cm^{-2} with area specific resistance (ASR) nearly identical to that for humidified-H_2, and stable operation was achieved under 100 mA cm^{-2}.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1324 (Abstract only)

Enhancement of Long-term Stability of Ni-YSZ based SOFC Anode by Infiltration of Transition Metals

Seung-Bok Lee (1,2), Muhammad Shirjeel Khan (1), Rak-Hyun Song (1,2), Jong-Won Lee(1,2), Tak-Hyoung Lim(1,2), Seok-Joo Park(1,2)
(1) Fuel Cell Research Center, Korea Institute of Energy Research, 102, Gajeong-ro, Yuseong-gu, Daejeon 305-343, Republic of Korea
(2) Department of Advanced Energy Technology, University of Science and Technology, 217 Gajeong-ro, Yuseong-gu, Daejeon 305-350, Republic of Korea

Tel: +82-42-860-3466
Fax: +82-42-860-3297
sblee@kier.re.kr

Abstract

Evaporation of Ni in the form of Nickel Hydroxide (Ni(OH)2) in Solid Oxide Fuel Cell (SOFC) anodes (Ni-YSZ) is one of the major causes of anode degradation. We employed transition metals such as Fe, Cr and Co which can act as sacrificial anodes for Ni, because of their lower Gibbs Free Energy values for the formation of their corresponding volatile hydroxides as compared to Ni(OH)2.The transition metals were added to porous Ni-YSZ anode scaffold by infiltration method. Nano-sized particles were sporadically dispersed on the Ni-YSZ surface, confirmed by Scanning Electron Microscopy (SEM). X-Ray Diffraction (XRD) patterns show a very good chemical compatibility between the added metals and Ni-YSZ anodes. Symmetric cells were then prepared and the Area-Specific Resistance (ASR) was monitored at 1000 °C, with a fuel gas containing 25 vol.% H2, 75 vol.%N2, for more than 250 h . To control accelerated evaporation condition of anode, relative humidity in anode gas was fixed at 12 %. The difference in the amount of the added metal before and after long-tern test was determined by EDS analysis. Change in the grain size distribution of Ni particles and Triple Phase Boundary (TPB) density, before and after long term test were calculated by image analysis. Well defined relations were obtained among ASR change rate determined from electrochemical measurements and grain size distribution, TPB density change rate calculated from image analysis.

Remark: Only the abstract was available at the time of completion. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1401

Fabrication of Ni-based anodes with tunable microstructures using polymeric precursor deposition

Viola I. Birss (1), Aligul Buyukaksoy (1, 2)
(1) Department of Chemistry
University of Calgary, Calgary, Alberta T2N 1N4, Canada
(2) Department of Materials Science and Engineering
Gebze Technical University, Gebze, Kocaeli, 41400, Turkey
Tel.: +1 (403) 220-7306
Fax: +1 (403) 289-9488
birss@ucalgary.ca

Abstract

Ni is a very active electrocatalyst for the oxidation of hydrogen at high temperatures (700-900 °C) and hence is widely used in solid oxide fuel cell (SOFC) anodes. To achieve a high triple phase boundary (tpb) length and consequently a low anode polarization resistance, Ni is used as a component of a composite with the ionically conductive yttria stabilized zirconia (YSZ) electrolyte material. Ni-YSZ composites are normally fabricated by the co-sintering of NiO and YSZ powders at elevated temperatures (1200-1450 °C), followed by *in situ* reduction of the NiO phase to Ni. This processing route yields a composite with micrometer scale particles and pores, exhibiting very good performance at high operating temperatures (700-900 ˚C). However, this structure is susceptible to damage due to morphology changes at high fuel consumption or when the anode is inadvertently exposed to air. Here, the fabrication of a variety of Ni-based anodes using non-conventional methods, specifically polymeric precursor deposition, is demonstrated, also examining the resulting microstructure and electrochemical activity. These anodes include single phase metallic Ni films prepared by the deposition of the polymeric precursor onto flat YSZ substrates, Ni-YSZ composites prepared by the deposition of the same precursor into previously formed porous YSZ scaffolds, and nanocomposite Ni-YSZ thin films prepared by the deposition of a mixture of Ni and YSZ polymeric precursors onto flat YSZ substrates. This study demonstrates the versatility of the polymeric precursor deposition technique for Ni-YSZ anode construction, as well as the critical importance of microstructure in determining electrochemical activity.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1402 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Redox-stable SOFC anode materials based on La-doped $SrTO_3$ oxide with impregnated catalysts

Xuesong Shen (1) and Kazunari Sasaki (1-4)
Kyushu University
(1) Department of Hydrogen Energy Systems
(2) International Research Center for Hydrogen Energy
(3) Next-Generation Fuel Cell Research Center (NEXT-FC)
(4) International Institute for Carbon-Neutral Energy Research (WPI-I2CNER)
744 Motooka Nishi-ku Fukuoka/Japan
Tel.: +81-92-802-3143
Fax: +81-92-802-3223
sasaki@mech.kyushu-u.ac.jp

Abstract

40wt% $(ZrO_2)_{0.89}(Sc_2O_3)_{0.1}(CeO2)_{0.01}$ (SSZ)-$Sr_{0.9}La_{0.1}TiO_3$ (SLT) cermet was prepared as anode backbone for SSZ electrolyte-supported SOFC single cells. $Ce_{0.9}Gd_{0.1}O_2$ (GDC) was impregnated to totally cover the SSZ-SLT anode backbone surface acting as a catalyst, and the cell voltage achieved 0.865V at 200 $mAcm^{-2}$ for 3%-humidified hydrogen fuel at 800°C, using $(La_{0.75}Sr_{0.25})_{0.98}MnO_3$ (LSM)-SSZ cathode. Cell performance was substantially improved from 0.865V to > 0.97V when 0.03$mgcm^{-2}$ Pd or Ni was further incorporated as a secondary catalyst into the anode layer. 250 redox cycles were performed to investigate redox stability of this high-performance anode. It was found that even after the 250 redox-cycle degradation test, cell voltage at 200$mAcm^{-2}$ was retained around 0.93V, higher than the cell performance using the fresh Ni-SSZ anode. I-V curve of single cell using 0.03 $mgcm^{-2}$ Pd or Ni impregnated oxide anode before and after 250 redox cycles was measured. The catalytically-active reaction sites at ceria-Pd or ceria-Ni may account for the excellent performance, and the extremely low metal catalyst concentration prevent serious metal aggregation in achieving excellent redox stability.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1403 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

SMART catalyst based on doped Sr-titanite for advanced SOFC anodes

Dariusz Burnat (1), Roman Kontic (1), Lorenz Holzer (2), J. Andreas Schuler (3), Andreas Mai (3), Andre Heel (1)
(1) IMPE - Institute for Materials and Process Engineering,
(2) ICP – Institute for Computational Physics, ZHAW – Zurich University of Applied Sciences, Technikumstrasse 9, CH-8401, Winterthur
Tel.: +41-58-934-6150
dariuszArtur.Burnat@ZHAW.CH
(3) Hexis A.G., Zum Park 5 | CH-8404 Winterthur

Abstract

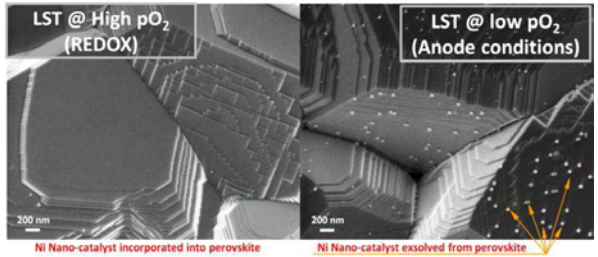


Figure 1. HR-SEM showing Exsolution and incorcopartion of Ni catalyst

To increase the durability of SOFC stacks, robust anodes with high catalytic performance and redox tolerance are needed. Among all alternatives, La-doped strontium titanate (LST) materials were recognized to possess good electronic conductivity and high tolerance to redox cycles[1,2], but modest electro-catalytic activity, which can be enhanced in conjunction with an appropriate catalyst. Nevertheless, anodes with conventional composite microstructures (e.g. LST with equally sized Ni-phase) are still prone to sulphur poisoning, coking and to coalescence of the Ni phase over time.

The authors present recent advances of a SMART material concept with a catalytic and microstructural self-regeneration effect, in which nanosized nickel catalyst is repeatedly exsolved from and incorporated back into the LST perovskite host structure. Ni-nanoparticles are exsolved from LST at low pO_2 (i.e. at SOFC anode conditions) and the Ni is re-incorporated hat high pO_2. Since titanates are highly tolerant to changes of the oxygen partial pressure, application of controlled redox cycles could therefore lead to the burn-off of harmful sulphides and/or carbon deposits and at the same time the incorporation-exsolution cycles also help circumventing the catalysts coarsening problem. We present the concept in which Ni-doped LST is applied to repetitively exsolute and re-incorporate the Ni catalyst, hence offering a microstructural self-regeneration mechanism.

1. Burnat, D.; Heel, et al.T. *J. Power Sources* **2012,** 201, 26-36.
2. Neagu, D.; Irvine, J. T. S. *Chemistry of Materials* **2011,** 23, (6), 1607-1617

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1404 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Influence of multifunctional layers on the performance of solid oxide fuel cell anodes based on $Zr_xCe_{1-x}O_{2-\delta}$

Selma A. Venâncio, George G. Gomes Jr. and Paulo Emílio V. de Miranda
The Hydrogen Laboratory-Coppe – Department of Metallurgy and Materials Engineering
Federal University of Rio de Janeiro,
P.O. Box 68505 - 21942-971 Rio de Janeiro, RJ, Brazil
Tel.: + 55-21-3938-8791
selma@labh2.coppe.ufrj.br, george@labh2.coppe.ufrj.br, pmiranda@labh2.coppe.ufrj.br

Abstract

Singular multifunctional anodes for solid oxide fuel cells (SOFCs) were produced and structurally analyzed with the objective of allowing the direct utilization of ethanol as fuel. The compositional effect of specific multifunctional layers of Cu-($Zr_xCe_{1-x}O_{2-\delta}$-Al_2O_3-8YSZ, 8%mol yttria stabilized zirconia) based anodes on the SOFC's electrochemical performance was investigated. The anode multifunctional layers were designed considering that the $Zr_xCe_{1-x}O_{2-\delta}$ solid solution´s stoichiometry directly influences the structure, the microstructure and the electrochemical behavior of such a SOFC.

Three types of SOFCs were produced and tested, each one possessing anodes with different functional layers that were fabricated utilizing ceramic suspensions composed of CeO_2-Al_2O_3-8YSZ, in addition to pore former and a terpineol-based vehicle. Increase in conductivity of the mixed ionic-electronic conductor porous electrode was approached with successive copper nitrate impregnations to reach 20%wt. of copper. Scanning Electron Microscopy was used for microstructural characterization, while X-Ray diffraction and Raman spectroscopy were performed for phase quantification and structural analyses. The single SOFC electrochemical behavior was determined at temperatures ranging from 750 to 950 °C with the direct utilization of anhydrous ethanol as fuel. No significant carbon coking and clogging was observed. It was inferred that strong interaction takes place between 8YSZ and ceria in which case the Zr^{+4} ions substitute Ce^{+4} ions when the Cu-($Zr_xCe_{1-x}O_{2-\delta}$-Al_2O_3) anode is formed. Therefore, the multifunctional SOFC anode performance is possibly directly related to the Zr^{+4} concentration in the $Zr_xCe_{1-x}O_{2-\delta}$ solid solution.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1405 (Will be published elsewhere)

Development and Testing of an Impregnated $La_{0.20}Sr_{0.25}Ca_{0.45}TiO_3$ Anode for Improved Performance and Sulfur Tolerance

Robert Price (1), Mark Cassidy (1), J. Andreas Schuler (2), Andreas Mai (2), John T. S. Irvine (1)
(1) School of Chemistry, University of St Andrews, St Andrews, Fife, KY16 9ST, UK
(2) Hexis AG, Zum Park 5, CH-8404 Winterthur, Switzerland
Tel.: +441334 463814
rp63@st-andrews.ac.uk

Abstract

A Solid Oxide Fuel Cell anode comprising a $La_{0.20}Sr_{0.25}Ca_{0.45}TiO_3$ (LSCT) 'backbone', impregnated with Ni and CGO, has previously been tested on a full system scale at HEXIS AG, Switzerland. Testing in the HEXIS Galileo 1000 N µ-CHP unit (60 electrolyte-supported cells), using reformed natural gas, showed promising initial performance, achieving ~700 W of the nominal 1kW power output. Unfortunately, this performance degraded to ~250 W after 600 hours of operation and was attributed to very thin, dense anode microstructures, leading to poor current distribution as well as the agglomeration of the Ni electrocatalyst particles[1]. However, this study also demonstrated that poisoning of the anode material, by sulfur, was reversible (albeit with diminished performance upon introduction of H_2S)[1]; a particularly important observation, considering that many anode materials are irreversibly poisoned by sulfur in natural gas.

Currently, we are focusing on improving the properties and durability of the fuel electrode within the aforementioned electrolyte-supported cells. In this research, ceramic processing techniques have been used as the primary method in controlling and improving the porous LSCT 'backbone' microstructure. By optimising the rheological properties of screen printing inks, the screen printing conditions and the sintering protocol employed, an LSCT 'backbone' microstructure, capable of delivering a high 'effective' electrical conductivity upon reduction, was produced[2]. Furthermore, impregnation of this LSCT 'backbone' with combinations of CGO ($Ce_{0.8}Gd_{0.2}O_{1.9}$) and a variety of metal electrocatalysts (including Ru, Rh, Ni and $Ni_{0.75}Fe_{0.25}$) increased the electrocatalytic activity of the anode substantially. Fuel cell testing in humidified hydrogen has shown very promising results, with overall resistances of 0.56 Ω cm^2 being achieved at 900 °C.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1406 (Will be published elsewhere)

Controlling TPB Length through Calcination Temperature, and its Influence on the Microstructure and Electrochemical Performance of Ni Infiltrated CGO anodes

Mengzheng Ouyang(1), Paul Boldrin(1), Nigel P. Brandon(1)
(1)Department of Earth Science and Engineering,
Imperial College London, London, SW7 2AZ, United Kingdom
m.ouyang15@imperial.ac.uk

Abstract

$Gd_{0.1}Ce_{0.9}O_{1.95}$ ceramic scaffold is prepared by tape casting on YSZ electrolytes followed by sintering at 1350 °C, then 20 wt% Ni/CGO electrodes are prepared by the infiltration method using $Ni(NO_3)_2.6H_2O$ as a precursor before being calcined at different temperatures (600 °C-1300 °C) followed by hydrogen reduction. A range of characterization techniques are used to follow the change in triple phase boundary (TPB) length through the variation of calcination temperature by changing the metal particle size and contact surface area between the metal and the scaffold and to determine its impact on electrochemical performance.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

Chapter 12 - Session B15

Cathodes: State-of-the-art & novel materials

Content **Page B15 - ..**

B1501 ... 3

Oxygen Exchange on Real Electrode Surfaces; experimentally-guided computational insight **3**

John Kilner (1,2), Aleksandar Staykov (1), John Druce (1), Helena Téllez (1) Taner Akbay (3), Tatsumi Ishihara (1,3) 3

B1502 (Will be published elsewhere) ... 4

High-Performance Cathode/Electrolyte Interfaces for SOFC **4**

Julian Szasz (1), Florian Wankmüller (1), Virginia Wilde (2), Heike Störmer (2), Dagmar Gerthsen (2), Ellen Ivers-Tiffée (1) 4

B1503 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 5

Synthesis through electrospinning of $La_{1-x}Sr_xCo_{1-y}Fe_yO_{3-\delta}$ ceramic fibers for IT-SOFC electrodes **5**

Anna Enrico (1), Bahar Aliakbarian (1), Alberto Lagazzo (1), Alessandro Donazzi (2), Rodolfo Botter (1), Patrizia Perego (1), Paola Costamagna (1) 5

B1504 (Will be published elsewhere) ... 6

Effect of microstructural parameters on a performant SOFC cathode: Modelling vs Experiments **6**

Özden Çelikbilek (1,2), David Jauffres (2), Laurent Dessemond (1), Monica Burriel (3), Christophe L. Martin (2), Elisabeth Djurado (1) 6

B1505 ... 7

Quantifying the surface exchange coefficient of cathode materials in ambient atmospheres **7**

Sam J. Cooper (1), Mathew Niania (1), Franca Hoffmann (2,3) and John A. Kilner (1) 7

B1506 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB) ... 8

SOFC Cathode Degradation Studies Using Impedance Spectroscopy Genetic Programming **8**

Boxun Hu (1), Yoed Tsur (2)*, Prabhakar Singh (1) 8

B1508 (Will be published elsewhere) ... 9

High-throughput screening of SOFC cathode materials **9**

Aitor Hornés (1), Aruppukottai Bhupathi Saranya (1), Alex Morata (1), Albert Tarancón (1) 9

B1509 (Will be published elsewhere) ... 10

Chromium Poisoning of Non-Manganiferous Cathode Materials for Solid Oxide Fuel Cells **10**

K. Schiemann, I. C. Vinke, R.-A. Eichel, L.G.J de Haart 10

B1510 (Will be published elsewhere) ... 11

Development of LCFCN system perovskites as interconnect and cathode materials for SOFCs **11**

Abhigna Kolisetty, Zhezhen Fu, Rasit Koc 11

B1511 ... 12

Evaluation of cathode performance in co-sintered inert substrate-supported SOFC **12**

Eric Matte (1), Piero Lupetin(1)(*), Detlef Stolten (2) 12

B1512 (Will be published elsewhere) ... 13

Thermodynamic aspects of Cr poisoning for LSCF cathodes **13**

Xiaoyan Yin, Lorenz Singheiser, Robert Spatschek 13

B1513 ... 14

Optimization of GDC interlayer against $SrZrO_3$ formation in LSCF/GDC/YSZ triplets **14**

Jeffrey C. De Vero(1), Katherine Develos-Bagarinao (1), Haruo Kishimoto (1), Do-Hyung Cho (1), Katsuhiko Yamaji (1), Teruhisa Horita (1), Harumi Yokokawa (1,2) 14

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1501

Oxygen Exchange on Real Electrode Surfaces; experimentally-guided computational insight

John Kilner (1,2), Aleksandar Staykov (1), John Druce (1), Helena Téllez (1) Taner Akbay (3), Tatsumi Ishihara (1,3)
(1) International Institute for Carbon-neutral Energy Research (WPI-I2CNER), Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395 Japan
(2) Department of Materials, Imperial College London, London, SW7 2AZ, United Kingdom
(3) Advanced Research Centre for Electric Energy Storage, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395 Japan
Tel.: +44-207-594-6745
Fax: +44-207-594-5017
j.kilner@imperial.ac.uk

Abstract

The exchange of oxygen across the gas/solid interface is a process of crucial importance in the application of mixed conducting perovskites as air electrodes in SOECs and SOFCs. We have used a model system that displays an outer surface layer equivalent to that of a practical air electrode to provide important insights into this critical process. Density Functional Theory (DFT) and Low Energy Ion Scattering (LEIS) spectroscopy were applied to study the mechanisms of oxygen dissociation on the SrO-terminated surfaces of strontium titanate ($SrTiO_3$) and iron-doped strontium titanate ($SrTi_{1-x}Fe_xO_{3-\delta}$). Our study reveals that while O_2 dissociation is not favored on the stoichiometric SrO-terminated perovskite surface, oxygen vacancies can act as active sites and catalyze the O-O bond cleavage. Electron transfer from lattice oxygen atoms to the O_2 molecule, mediated by the subsurface transition metal cations, plays an important role in the resulting formation of surface superoxo species. The O_2 molecule dissociates to produce oxygen ions, which are incorporated into the perovskite lattice, and highly active oxygen radicals on the perovskite surface, which further recombine to O_2 molecules. Whereas most theoretical studies have focused on the transition metal terminated surfaces (e.g. the TiO_2), which is assumed to be more catalytically active, our focus on the SrO terminated surface (figure 1), is driven by experimental observation using LEIS spectroscopy. This revealed that the surface of $SrTiO_3$ after high temperature heat treatment, as for many Sr containing air electrode materials, is SrO-terminated. Given the similarity in the composition of the surface exposed to the gas phase, we expect our results on STO to correspond directly to the mechanism of oxygen exchange in real solid oxide electrodes.

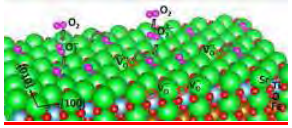


Figure 1 Active species on the (001) SrO terminated surface

B1502 (Will be published elsewhere)

High-Performance Cathode/Electrolyte Interfaces for SOFC

Julian Szasz (1), Florian Wankmüller (1), Virginia Wilde (2), Heike Störmer (2), Dagmar Gerthsen (2), Ellen Ivers-Tiffée (1)
(1) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Adenauerring 20b, D-76131 Karlsruhe/Germany
(2) Laboratory for Electron Microscopy (LEM), Karlsruhe Institute of Technology (KIT), Engesserstr. 7, D-76131 Karlsruhe/Germany
Tel.: +49-721-608-48796
Fax: +49-721-608-48148
julian.szasz@kit.edu

Abstract

High-performance solid oxide fuel cells (SOFC) mostly utilize the mixed conducting cathode $La_{1-x}Sr_xCo_{1-y}Fe_yO_{3-\delta}$ (LSCF). The drawback of LSCF however lies in the formation of an ion-blocking layer of Strontiumzirconate ($SrZrO_3$ - SZO) when it is directly applied on Y_2O_3 stabilized ZrO_2 electrolyte (YSZ). This secondary phase reaction can in practise be prevented by inserting a dense Gd-doped Ceria (GDC) between LSCF and YSZ [1,2,3]. Commonly, the GDC interlayer is screen printed and correct density is assured by subsequent sintering. This high temperature treatment however causes a low ionic conducting GDC-YSZ interdiffusion phase (ID) [4, 5]. The correct balance between GDC-density and GDC-YSZ interdiffusion is crucial for achieving highly functional GDC interlayers.

In this study, the characteristics of LSCF/GDC/YSZ interfaces were substantially modified by a variation in GDC sintering temperature [6]. Evidently, the nature of the GDC barrier layer depends strongly on sintering temperature and alterations of the area specific resistance of the cathodic polarization over two orders of magnitude (~6-7 $m\Omega \cdot cm^2$ to ~7 $\Omega \cdot cm^2$ at 800 °C) were measured [7,8,9].

Our findings confirm a complex heterogeneous cathode/electrolyte interface consisting of primary phases (LSCF, GDC and YSZ) and secondary phases (SZO and ID). Still, in technical relevant processes secondary phases inherently appear and their detrimental impact which overshadows every high-performing material property points to the necessity of understanding the interplay between chemical composition, processing and microstructure for individual cell concepts.

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1503 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Synthesis through electrospinning of $La_{1-x}Sr_xCo_{1-y}Fe_yO_{3-\delta}$ ceramic fibers for IT-SOFC electrodes

Anna Enrico (1), Bahar Aliakbarian (1), Alberto Lagazzo (1), Alessandro Donazzi (2), Rodolfo Botter (1), Patrizia Perego (1), Paola Costamagna (1)
(1) Department of Civil, Chemical and Environmental Engineering, University of Genoa
Via Opera Pia 15, 16145 Genoa, Italy .
(2) Energy Department, Politecnico di Milano
Via Lambruschini 4, 20156 Milan, Italy
Tel.: +39-010-353-2922
Fax: +39-010-353-2586
paola.costamagna@unige.it

Abstract

We synthesize $La_{1-x}Sr_xCo_{1-y}Fe_yO_{3-\delta}$ (LSCF) fibers through the electrospinning method. This technique applies high voltage to induce the formation of a liquid charged flow, which is then ejected with evaporation of the solvent and simultaneous formation of solidified, continuous, ultra-thin fibers. The formation of nanofibers is a function of the operating parameters, i.e. the rotation speed of the support, the solution feeding rate, and the operating voltage, which are investigated in this work. The results indicate that a rotation speed of 750 rpm, a solution feeding rate of 0.5 ml/h, and an operating voltage of 17 kV allow to obtain fiber diameter in the range 500 nm – 1500 nm, with linear and one-directionally oriented fibers. Since the fibers must undergo heat treatment, their behavior during the calcination processes is investigated as well through TGA. The results show exothermic peaks which we interpret as solvent evaporation and perovskite structure formation, and suggest to perform calcination slowly in the temperature range 250-550 °C. The final goal of this research is to couple the experimental results described here to a previously developed theoretical model, in order to gain a better understanding of the fundamental electrochemistry of the processes occurring in fibrous electrodes for IT-SOFC applications.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1504 (Will be published elsewhere)

Effect of microstructural parameters on a performant SOFC cathode: Modelling vs Experiments

Özden Çelikbilek (1,2), David Jauffres (2), Laurent Dessemond (1), Monica Burriel (3), Christophe L. Martin (2), Elisabeth Djurado (1)
(1) Univ. Grenoble Alpes, LEPMI, CNRS, F-38000 Grenoble, France
(2) Univ. Grenoble Alpes, SIMAP, CNRS, F-38000 Grenoble, France
(3) Univ. Grenoble Alpes, LMGP, CNRS, F-38000 Grenoble, France
Tel.: +33 4 76 82 66 84
Fax: +33 4 76 82 67 77
ozden.celikbilek@lepmi.grenoble-inp.fr

Abstract

The present study concerns the influence of the micro/nano-structural properties of LSCF ($La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$) and 60:40 vol.% LSCF/CGO ($Ce_{0.9}Gd_{0.1}O_{2-\delta}$) composite cathode films on their electrochemical behavior. Electrostatic spray deposition technique is used to deposit 10 µm-thick functional films as shown in Figure 1. Contrary to expectations, pure LSCF has a better response compared to the composite. It presents an Area Specific Resistance (ASR) value as low as 0.021 and 0.068 Ω cm^2 at 650 ˚C and 600 ˚C respectively, which to the best of our knowledge is one of the lowest reported values to date for LSCF-6428 composition in OCV condition.[1] To better comprehend the complex relationships between material properties, processing, micro/nano structure and electrode performances, a simplified geometry representing the porous columns of the electrodes is modelled by 3D finite element (FEM).[2] Electrode performance is computed as a function of real microstructural parameters obtained from 3D FIB/SEM technique. On the other hand, ASR is calculated by a simple volume-averaged analytical model (1D-ALS model)[3] within an assumed macrohomogeneous geometry. The computed ASRs with these two relatively simple models are compared to experimental results and the relevancy of such models for columnar microstructures is discussed.

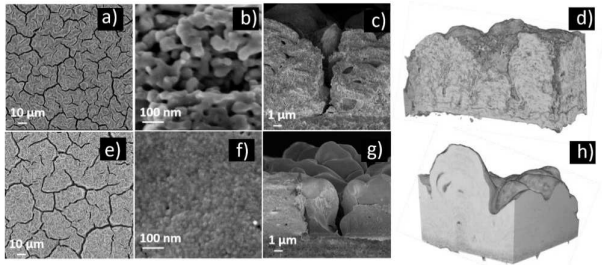


Figure 1 Microstructural characterization of the films a-c) LSCF, e-g) 60/40 vol.% LSCF/CGO composite films viewed by SEM. 3D reconstructed images by FIB/SEM technique of (d) LSCF and (h) 60:40 LSCF/CGO composite.

1. Celikbilek, O., Jauffres, D., Siebert E., Dessemond, L., Burriel, M., Martin, C.L., Djurado, E.,(2016), to be submitted
2. Haffelin, A., Joos, J., Ender, M., Weber, A., Ivers-Tiffee, E. (2013). J. Electrochem. Soc. 160, F867–F876
3. Adler, S. B., Lane, J. A. & Steele, B. C. H. (1996). J. Electrochem. Soc. 143, 3554–3564

Remark: This is not a full publication, because the authors chose to publish elsewhere. Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1505

Quantifying the surface exchange coefficient of cathode materials in ambient atmospheres

Sam J. Cooper (1), Mathew Niania (1), Franca Hoffmann (2,3) and John A. Kilner (1)
(1) Department of Materials, Royal School of Mines,
Imperial College London, London, SW7 2AZ, UK
(2) Cambridge Centre for Analysis, University of Cambridge,
Wilberforce Road, Cambridge CB3 0WA, UK
(3) Department of Mathematics, South Kensington Campus,
Imperial College London, London, SW7 2AZ, UK
Tel.: +44-20-7594-6745
sjc08@ic.ac.uk

Abstract

Isotopic exchange has been used for over 30 years to quantify the effective surface exchange, k^*, and self-diffusion, D^*, coefficients of SOFC materials. Typically, however, the nominal exchange environment in the literature is pure, dry oxygen, which is not representative of realistic SOFC operating conditions. A novel two step exchange process, “back-exchange”, has been developed to overcome this limitation. The first step is a conventional exchange in pure, dry $^{18}O_2$, but the second step can be in any environment with the same pO_2. A new analytical expression was found for the special case of back-exchange in which the parameters k^* and D^* were constant across the two exchanges. However, in order to fit the data obtained from exposing the sample to ambient conditions in the second step, a 1-dimensional, Crank-Nicholson type, finite-difference simulation was constructed.

Fitting the data from two experiments against the simulation suggested a 2× increase in the value of k^* in the ambient environment compared to pure dry $^{18}O_2$. The analytical solutions, simulations and fitting procedures, as well as a host of data analysis tool, have been packaged by the author into a MatLab application called *TraceX*, which is freely available upon request. The results of this study highlights the significance of the back-exchange technique, but further work must be done to determine the origin of the observed augmentation in surface exchange.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1506 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

SOFC Cathode Degradation Studies Using Impedance Spectroscopy Genetic Programming

Boxun Hu (1), Yoed Tsur (2)*, Prabhakar Singh (1)
(1) Center for Clean Energy Engineering, Department of Materials Science and Engineering, University of Connecticut, 44 Weaver Road, Storrs Mansfield, CT 06269–5233, USA
(2) Department of Chemical Engineering and Grand Technion Energy Program, Technion, Israel Institute of Technology, Haifa, Israel
Tel.: +972-4-8293586
tsur@technion.ac.il

Abstract

In this technical contribution, we will present electrochemical impedance spectra of LSM/YSZ/Pt cells tested in different environment atmospheres and their analysis results by an Impedance Spectroscopy Genetic Programming technique. Electrochemical spectra under the different cathode ambient environments (dry air only, 3% H2O/air, and 3%H2O/air with Cr vapor) have been measured during 100-hour tests. A novel impedance spectroscopy Genetic Programming technique has been utilized for the analyses of these electrochemical impedance spectra. The best model for each typical impedance spectrum has been generated by this technique. EIS spectra of the Tests C and D (absence and presence of chromium getters) show opposite trends of semi- arc at low frequency range. Both distribution function of relaxation times (DFRTs) of the Tests B and C show a peak at log τ range of -10 to -9, indicating both water and chromium attribute to an increase of resistance. The presence of getters in the cathode gas stream has effectively improved the electrochemical performance by lowering the resistance.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1508 (Will be published elsewhere)

High-throughput screening of SOFC cathode materials

Aitor Hornés (1), Aruppukottai Bhupathi Saranya (1), Alex Morata (1), Albert Tarancón (1)
(1) Catalonia Institute for Energy Research (IREC),
Department of Advanced Materials for Energy
Jardins de les Dones de Negre 1, 2nd floor
08930-Sant Adrià de Besòs, Barcelona /Spain
Tel.: +34 933 562 615
Fax: +34 933 562 615
ahornes@irec.cat

Abstract

Lanthanum and strontium manganites, cobaltites and ferrites (LSM, LSC and LSF, respectively) have been extensively used as oxygen electrodes in solid oxide fuel cells (SOFCs) [1]. None of them provide all the requirements for operating by themselves as cathodic material due to issues related with low ionic conductivity, low stability and/or incompatibility with the rest of constitutive SOFC materials. One of the approaches followed to overcome these inconveniences has been the combination among them, aiming to obtain mixed properties. A successful example of this strategy is the LSCF which presents mixed conductivity at intermediate temperature [1] and nowadays is commonly used as cathode in IT-SOFCs. However, when LSCF is employed a protective layer is needed to screen the YSZ electrolyte due to the reactivity between them.
Following this approach, in this work a high-throughput methodology is employed for the preparation of a LSM, LSC and LSF ternary compositional map. Combinatorial Pulsed Laser Deposition is a very efficient procedure that allows the fabrication of multiple samples with different compositions in a single experiment [2]. Previous works showed the benefits of this method applied to a LSM + LSC binary system [3]. In this case in which a ternary system is studied, additional features are expected due to the likely natural trend of different stoichiometric samples to give rise to a variety of structures, properties or even phases.
Initially, the simulation of the deposition process will allow us to determine the best configuration to obtain the largest compositional distribution throughout the wafer area. Besides, prediction of thickness and composition gradient is anticipated. In this initial stage of the work, assessments of phase purity, thin film stability and morphology and, compositional map generation are shown.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1509 (Will be published elsewhere)

Chromium Poisoning of Non-Manganiferous Cathode Materials for Solid Oxide Fuel Cells

K. Schiemann, I. C. Vinke, R.-A. Eichel, L.G.J de Haart
Forschungszentrum Jülich GmbH
Institute of Energy and Climate Research, Fundamental Electrochemistry (IEK-9)
Wilhelm-Johnen-Straße, 52428 Jülich, Germany
Tel.: +49 2461 61-96395
Fax: +49 2461 61-9550
k.schiemann@fz-juelich.de

Abstract

Chromium poisoning accompanied with cathode degradation has been identified as a major cause for reduced SOFC stack/component lifetimes. In-depth knowledge of the mechanisms has been obtained for the $(La,Sr)MnO_3$ based cathode materials. It was long thought, that the $(La,Sr)(Co,Fe)O_3$ based cathodes materials were less susceptible to chromium poisoning, because of other mechanisms, i.e. mainly the formation of $SrCrO_4$. Recently, however, similar poisoning effects as seen for LSM have been observed for LSCF as well, urging us to perform another in-depth analysis of the mechanisms of chromium poisoning in non-manganiferous cathode materials.

In this initial study standard anode substrate cells with $(La,Sr)(Co,Fe)O_3$ cathodes were characterized via current-voltage measurements and impedance spectroscopy at various conditions (e.g current density, temperature). In a next step anode supported cells were manufactured using these cathode materials and characterized via impedance spectroscopy at various conditions (e.g. current density, temperature, oxygen partial pressure and humidity) in the presence and absence of chromium sources. The impedance spectra recorded for a non-chromium exposed sample revealed multiple time constants depending on the operating temperature. A charge-transfer process could be identified based on the temperature dependence.

First current-voltage measurements performed on a chrome source exposed sample revealed already directly after cell reduction a decreased cell performance. Additional long-term tests and variations in the operating parameters however have to give more detailed information.

Remarks:

At the time of completion of these proceedings the planned experiments with "*various (La,Sr)(Co,Fe)O3 cathode materials with different stoichiometries", "various conditions (e.g., […] oxygen partial pressure and humidity)", "3-probe setup", "long-term tests (> 3000 h)*", were delayed. Therefore only first initial results could be presented in the extended abstract. Additional results of running experiments are shown on the poster during the European Fuel Cell Forum 2016.

The Authors do not want to publish their full contribution in these proceedings and possibly have published it in a journal. Please contact the authors directly for further information.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1510 (Will be published elsewhere)

Development of LCFCN system perovskites as interconnect and cathode materials for SOFCs

Abhigna Kolisetty, Zhezhen Fu, Rasit Koc
Department of Mechanical Engineering and Energy Processes
Southern Illinois University Carbondale
1230 Lincoln Drive, Carbondale, Illinois, 62901, US
Tel.: +1-618-453-7011
Fax: +1-618-453-7658
kocr@siu.edu

Abstract

Over the past few decades solid oxide fuel cells (SOFCs) have attracted much attention due to their huge potential for clean power generation in stationary, portable, transport applications and also our increasing need for sustainable energy resources. The purpose of this research is to develop an interconnect and cathode material for use in SOFCs which demonstrates desired properties of high electrical conductivity, excellent chemical stability at high temperatures, desirable thermal expansion characteristics and which can be easily manufactured by sintering in conditions acceptable with other cell components. This research is important because there are a few shortcomings in the materials that are currently being used as cathodes and interconnects in the SOFCs. In this study, five different perovskite oxides comprising of lanthanum in combination with chromium, iron, cobalt and nickel oxides powders ($LaCr_{0.7}Co_{0.1}Fe_{0.1}Ni_{0.1}O_3$, $LaCo_{0.7}Cr_{0.1}Fe_{0.1}$ $Ni_{0.1}O_3$, $LaFe_{0.7}Cr_{0.1}Co_{0.1}Ni_{0.1}O_3$, $LaNi_{0.7}Cr_{0.1}Co_{0.1}Fe_{0.1}O_3$, and $LaCr_{0.25}Co_{0.25}Fe_{0.25}Ni_{0.25}O_3$) were synthesized through Pechini method. Obtained powders were characterized by X-ray diffraction (XRD) to observe crystal structure and microstructure. XRD results show that all materials are single phase few with rhombohedral and few with orthorhombic crystal structure. Powders feature with nano particle size through TEM micrographs. The resulting powders were then sintered at a temperature of 1400°C in air. Properties of sintered samples, including relative density, mechanical properties, and electrical conductivity from room temperature to 800°C were studied and evaluated. The material which has the desired properties is considered and elemental modifications can be done to it for application in practical purposes.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

B1511

Evaluation of cathode performance in co-sintered inert substrate-supported SOFC

Eric Matte (1), Piero Lupetin(1)(*), Detlef Stolten (2)
(1) Robert Bosch GmbH, Robert-Bosch-Campus 1, Renningen, Germany
(2) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK), D-52428 Jülich / Germany
(*)piero.lupetin@de.bosch.com

Abstract

The demand for energy-efficient power production is expected to grow throughout the coming years. Therefore, interest in SOFC-based combined heat and power systems is constantly rising. Hence, improvement of their lifetime as well as cost reduction are crucial factors to make them attractive for the market. The aim of this work is to evaluate the degree of maturity of cost-effective cells. The cell is mechanically supported by an inert porous oxide layer on the air side made of cheap silicate. The low sintering temperature of this support enables a one-step co-sintering process of the entire cell at temperatures between 1100°C and 1400°C.
In this contribution, we present the current status of cathode performances in this nascent cell concept. The performance of a traditional LSM-YSZ cathode on a silicate support is investigated by means of electrochemical impedance spectroscopy (EIS) at 750°C on a symmetrical cell geometry. A polarization resistance (Rp) of 2.82 Ω·cm² is measured in stagnant air. For comparison, an Rp of 1.95 Ω·cm² is measured for an electrolyte supported cell sintered under identical conditions.
The formation of secondary phases in the cathode layer due to interaction with the silicate is identified as a reason for the high Rp in inert substrate-supported cells and possible solutions for performance improvement are under development.
Although co-sintered inert substrate-supported SOFCs are at an early stage of development, and further work is required for their optimization, our first results are promising when the advantages in terms of cost and lifetime of the new concept are taken into account.

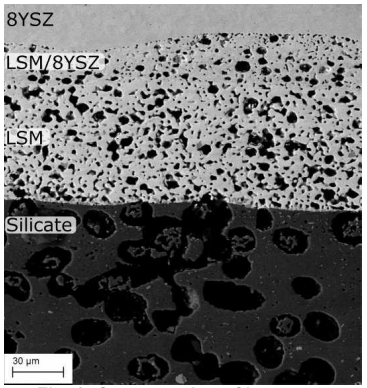


Fig. 1: Cross-section of inert substrate-supported cathode in a half-cell

B1512 (Will be published elsewhere)

Thermodynamic aspects of Cr poisoning for LSCF cathodes

Xiaoyan Yin, Lorenz Singheiser, Robert Spatschek
Forschungszentrum Jülich GmbH, IEK-2, 52425 Jülich, Germany
x.yin@fz-juelich.de

Abstract

Cr-poisoning of solid oxide fuel cell (SOFC) cathodes in stacks with metallic interconnects is a serious issue for degradation and long term operation. During operation, gaseous Cr-species, which consist of CrOx(OH)y and/or CrOx, evaporate from the Cr_2O_3-containing scale of ferritic interconnect. The evaporated Cr-species deposit on the surface of and inside LSCF cathode as $SrCrO_4$ and/or Cr_2O_3. The formed secondary phases result in degradation of the cathode material and subsequent loss in electrical conductivity.
Thermodynamic aspects of cathode Cr-poisoning are studied. The effect of different influence factors (temperature, oxygen partial pressure, water vapor partial pressure) on the equilibrium vapor pressures of different possible gaseous Cr-species over Cr_2O_3(s) is assessed numerically using FactSage and discussed. The subsequent deposition of gaseous Cr-species is analyzed by thermodynamic calculations in terms of: 1) deposition of evaporated Cr-species directly as Cr_2O_3(s) and 2) reaction between evaporated Cr-species and SrO in cathode material.
From the calculation, the hexavalent Cr-species such as CrO_3(g) and $CrO_2(OH)_2$(g), are the dominating gaseous Cr-species evaporating in dry and humid conditions, respectively. The partial pressure of CrO_3 depends stronger on temperature than $CrO_2(OH)_2$. During the Cr-species deposition, the thermodynamic activity of SrO in the cathode material is a decisive factor for the secondary phase formation.

Remark: This is not a full publication, because the authors chose to publish elsewhere.
Please see Presentations on www.EFCF.com/LIB or contact the authors directly.

12th European SOFC & SOE Forum www.EFCF.com/Lib ISBN 978-3-905592-21-4 5 - 8 July 2016, Lucerne/Switzerland

B1513

Optimization of GDC interlayer against $SrZrO_3$ formation in LSCF/GDC/YSZ triplets

Jeffrey C. De Vero(1), Katherine Develos-Bagarinao (1), Haruo Kishimoto (1), Do-Hyung Cho (1), Katsuhiko Yamaji (1), Teruhisa Horita (1), Harumi Yokokawa (1,2)
(1) National Institute of Advanced Industrial Science and Technology
Tsukuba, Ibaraki 305-8565, Japan
(2) Institute of Industrial Science, The University of Tokyo
Tokyo, Japan
Tel.: +81-029-861-2838
Fax: +81-029-861-4540
jeffrey-devero@aist.go.jp

Abstract

Gadolinia-doped ceria (GDC) thin films were prepared using pulsed laser deposition in order to study its stability as an interlayer against $SrZrO_3$ formation in $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$ (LSCF)/GDC/yttria-stabilized zirconia (YSZ) triplets. Dense GDC interlayer was utilized to minimize the complexity arising from a porous interlayer. The GDC films were pre-annealed at 1000ºC to 1400ºC for 1 h to 10 h in air. The as-grown GDC interlayer showed nanocolumnar microstructure. At low temperature (1000ºC), GDC did not fully densify; instead, microcracking and nanoporosity arising from nanocolumnar microstructure became pronounced. At high temperature (1400ºC), crack formation and grain boundaries were minimized. However, pore formation became severe. The LSCF cathode layer was screen printed on top of these differently annealed GDC/YSZ couples and fired at 1080ºC for 3.5 h in air. We find that the high density of microcracks, as well as severe pore formation in GDC, is detrimental to preventing $SrZrO_3$ (SZO) formation in LSCF/GDC/YSZ triplets. To avoid this problem, we implemented a multi-step heat profile consisting of annealing at 1400ºC for 1.5 h followed by 1000ºC for 10 h in air. We obtained an interlayer with reduced pores and microcracks preventing the severe SZO formation at the GDC/YSZ interface. On the other hand, SIMS analysis revealed that the heat treatment of GDC interlayers led to enhanced Zr mobility indicating the possible formation of a small amount of SZO phase at the LSCF/GDC interface. Hence, a delicate trade-off optimization of PLD-grown GDC interlayer is necessary for preventing the severe SZO formation across the interfaces.

List of Authors

Related with submitted Extended Abstracts by 17 June 2016

12th EUROPEAN SOFC & SOE FORUM 2016

5 - 8 July 2016

Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

Abdalla Abdalla Mohamed - B1316
Agersted Karsten - A0804
Ahn Kook-Young - A1320, B0828, B1108
Akbari-Fakhrabadi Ali - A0818
Akbay Taner - B1501
Akebono Hiroyuki - B0627
Albrecht Kevin J. - B1102
Aliakbarian Bahar - B1503
Almar Laura - B1207
Almeida Rubens Moreira de - B0618, B1318
Alnegren Patrik - B0510
Al-sagheer Yousif - B0813
Amaha Shinji - A1104
An Xin - B1206
Andarini Rizki Putri - B1304
Anelli Simone - B0514
Ansar Asif - A0606
Antonnetti Yannik - B0512
Aravind P.V. - B1103, B1107, B1109
Aricò Antonino S. - A1203, B1307
Arifin Nor - B0305
Arreola Manuel Jimenez - B1101
Arriortua M. I. - B0321, B1313
Asghar Muhammad Imran - A0905, B0623
Åström Kim - A0509, A1406
Atanasiu Mirela - A0203
Atkinson Alan - A0901, B0520
Auchlin Maxime - B0513
Auer C. - A1412, B1211
Aydın Özgür - B0820
Azad Abul Kalam - B0625, B1316
Azzolini Andrea - A1413
Baade Jens - A0601, A1306
Babaei Alireza - B0819
Babelot Carole - B1217
Bae Joongmyeon - B0314, B0318
Bae Seon Young - A0813
Baek Jong Dae - B0302
Bagchi Biswajoy - B0624
Baker Richard T. - B0610, B1313
Baldinelli Arianna - A0816
Ballesteros B. - A0903
Banerjee Aayan - B0809
Baniassadi Majid - B0819
Bao Hong-Liang - B1315
Barbir Frano - A0913
Bardi Nicolas - A0504, A0507
Barelli Linda - A0816
Barthel Markus - A1306
Bassat J. M. - A0903
Basu Rajendra N. - B0624
Basu S. - A1410
Basu Suddhasatwa - A0905, B0623
Batfalsky Peter - A1101
Bause Tim - A1201
Beckert W. - A0908
Beeaff D.R. - B0301
Beez Alexander - A1101
Bellusci Mariangela - B0631
Berger Cornelius M. - A1404, A1405
Berger Robert - B0614, B0903
Bernard C. - B1104
Bertei Antonio - A1402, B0801, B1206, B1212
Bertoldi Massimo - A0304
Bianco Manuel - B0513, B0603, B0605, B0613, B0619, B0621
Bidini Gianni - A0816
Bienert Christian - A0501, A0908
Biert L. van - B1103
Billen Pieter - A1411
Birss Viola I. - B1401
Bistritzki Victor - A0607, A0610
Blanes M. - A0917

Blennow Peter - A0804, A1102, A1508, B0501
Blum Ludger - A0603, A0803, A1101, A1201, A1205, A1312, A1405, A1501
Boldrin Paul - A1402, B1302, B1406
Bone Adam - A0303, B0902, B1219
Bongiorno Valeria - B1204
Borglum Brian - A0302
Bosch Timo - A1313
Bossel Ulf - A1503
Botter Rodolfo - B1503
Bouzek Karel - B0316, B0808
Bozza Francesco - B0605
Braig M. - A1412, B1211
Bram Martin - A1405, A1404, B0906, B0901
Brandner Marco - A0501, B0901, A0908
Brandon Nigel P. - A1402, B0520, A0102, A0901, A1601, B0801, B1107, B1206, B1212, A1603, B0310, B0521, B1311, B1302, B1406
Brandys Irad - B1119
Braun Robert J. - B1102
Brendt Jeerawan - B1217
Brisse Annabelle - A0801, A0802
Brodersen K. - B0903
Brouwer Jacob - B0828
Brown Casey - A1505
Brus Grzegorz - B0517
Bucheli Olivier - A0101, A0304, A1602, A1603, A1605
Bucheli Olivier - A0101
Bucheli Olivier - A0101
Bucher E. - A0810, B0503
Burdet Pierre - A0802, A0913, B1303
Burnat Dariusz - B1403
Burriel Monica - B1504
Button Tim - B0305
Buyukaksoy Aligul - B1401
Calero J.A. - A0815
Caliandro Priscilla - A0910
Campanari Stefano - B0823
Canovic Sead - B0611
Cantoni M. - B1303
Carlini Maurizio - B0603, B0620, B0628, B0631
Carpanese Maria Paola - B0514
Carré Maxime - A1313
Cassenti B. N. - B1303
Cassidy Mark - B1405
Çelikbilek Özden - B1504
Chade Daniel - A1204
Chakrabarti Mohammed Harun - B1107
Chan Shuk Han - A1502
Chan Siew Hwa - B1305, B1310
Chang Daeic - A1510
Chatroux A. - B1104
Chatzichristodoulou Christodoulos - B0802, B1301
Chen Chun-Da - A1209
Chen J. - B0520
Chen Ming - A0804, A0902, B0630
Chen Xin-Bing - B1315, A1507
Chen Zhangwei - A0901
Cheng Yung-Neng - A1209
Chiu W.K.S. - B1303
Chlup Zdeněk - A0915
Cho Do-Hyung - B1513
Choi Keunwon - B1108
Choi Mihwa - A0914
Choi Wonjoon - B0822
Chung Kyung Sil - B0616
Claquesin Julien - B0604
Clare Andy - A0303
Clark Laurie - A1403
Cocco A.P. - B1303
Cohen Ed - B1206
Colella Whitney G. - A1504, A1509, B1116
Coles-Aldridge Alice V. - B0610
Colldeforns B. - A0815, A0917
Comodi Gabriele - B0827
Cooke Kevin - B0605, B0613
Cooper Sam J. - B1505, A0807
Coquoz Pierre - B1218
Costa Remi - A0606, B0629, B0504, B0511, B0904
Costamagna Paola - A1302, B1503
Couturier K. - B1211
Croiset Eric - B0616
Dale Nilesh - B0602
Das Debasish - B0624
Davidson Alan - B0317
Davoli Ivan - B0628
Dawson Dr Richard - B0815

de Miranda Paulo Emílio V. - B1314, B1404
Defner Bsc Beppino - A1304
Degostin M.B. - B1303
Deibert Wendelin - A1407
Deja Robert - A1312
Delai Alessandro - B0605, A1413
Demircan Oktay - B1118
Demirezen Gulsun - B1118
Denonville C. - B0301, B0905
Denzler Roland - A0301
Dessemond Laurent - B0511, B0904, B1504
Deutschmann Olaf - B0809
Develos-Bagarinao Katherine - B1202, B1513
Dhir Aman - B0515, B1304
Dickel Thorsten - A1307, B0507
Dierickx Sebastian - B0502
Diethelm Stefan - A0802, A0910, B0513
Djurado Elisabeth - B1504
Dlouhý Ivo - A0915
Dohkoh Tatsuki - A1301
Domingues Rosana Zacarias - B0618, A0610, A0607, B1318
Donazzi Alessandro - B1503
Dosch C. - A0908, A1306
Doucek Aleš - A0608
Druce John - B1501
Duan Chuancheng - B1102
Dubois Alexis - B1102
Duhn Jakob Dragsbæk - B0810
Dunst Bsc Dominik - A1304
Ebbesen Sune D. - A0902
Egger Andreas - A0809, B0503
Eichel Rüdiger-A. - B1509, A1416
Elangovan S. Elango - A1403, A1411, B0602
Elwell Jessica - A1403, A1411
Engelbracht Maximilian - A1501
Enrico Anna - B1503
Escudero María José - B1321, B1322
Falk-Windisch Hannes - B0604
Fang Qingping - A0603, A0803, A1201, A1205
Faro Massimiliano Lo - A1203, B1307
Federmann D. - B0609
Fendt Sebastian - A0817, B1101
Fernandes Marina Domingues - A0607, A0610
Ferrari Tommaso - B1214, B1216
Ferrero Domenico - B0804
Fleischhauer Felix - A0301
Fontaine M.-L. - B0301, B0905
Fontell Erkko - A0509, A1406
Founti Maria - A1108
Frandsen Henrik Lund - B0802
Frangini Stefano - B0603, B0605, B0620, B0628
Frank Matthias - A1312
Friedrich K. Andreas - A0606, A0911, A1103, A1309, B0504, B0807, B0811
Froitzheim Jan - B0510, B0604, B0611, B0903
Fu Qingxi - A0802, B1211
Fu Zhezhen - B1510
Fuchs Franz-Martin - B0632
Fuerte Araceli - B1321, B1322
Fujita Kenjiro - A1301
Fujita M. - A0604
Garcia Eric Marsalha - B0618
Geis Michael - A0817, B1101
Geisler Helge - A1107, B0803, B0903
Gelbstein Yaniv - B1119
Gerthsen Dagmar - B1203, B1502
Ghezel-Ayagh Hossein - A0302
Giannopoulos Dimitrios - A1108
Göös Jukka - A0503, A0909, A1204
Graves Christopher - B0501, B1301
Greco Fabio - A0913, B1213
Grins Jekabs - B1312
Groß-Barsnick Sonja-Michaela - A1101, B0609, B1217
Gruber Manuel - A1108
Gspan C. - A0810, B0503
Gu Lingyi - B0616
Guan Cheng-Zhi - B1315, A1507
Guillon O. - A1404, B0906
Guk Erdogan - B1201, B1215
Gupta Mohit - B0304
Haart Bert de - A1416
Haart L.G.J de - B1509
Hagen Anke - A0812
Haider M. Ali - A1410
Haim Yedidia - B1119

Hairul Absah Hidayatul Qayyimah Hj - B1316
Hajimolana Yashar S. - B1107
Hallanoro Paul - A0503, A1204
Hammer Eva - A0303
Han Feng - B0511, B0904
Hansen John Bøgild - A1506
Hart David - A0201
Hartmann Mathias - A1306
Hartvigsen Joseph - A1403, A1411
Hashim Mohd Ali - B1107
Hashimoto Shinichi - B0519
Hatae Toru - A1104
Hauch Anne - A0812, A0902
Haugsrud R. - B0905
Hayashi A. - A0604
He Hongpeng - A1505
Hébert Cécile - B0512
Heddrich Marc P. - A0911, A1309, A0606, B0807
Heel Andre - B1403
Heinzel Angelika - A1313
Heiredal-Clausen Thomas - A1102, A1506, A1508
Hendriksen Peter Vang - A0804, A0902, B0630, B0802
Henke Moritz - A0911, A1309
Herbrig Kai - A0305
herle J. Van - B1303
Hernández E. - B1306
Herrmann Stephan - A0817, B1101
Himanen Olli - B0605, B0613, B0619
Hjelm Johan - B0501
Hochenauer Christoph - B0508, B0818
Hoerlein Michael P. - A1103, B0811
Hofer F. - A0810, B0503
Hoffmann Alex C. - B0315
Hoffmann Franca - B1505
Holstebroe Majken - A1506
Holzer Lorenz - B1403
Hong Jae-Woon - A0912, A0914, B0612, B0615
Hong Jong-Eun - B0603, B0605, B0613, B0621, B0631, B1111, B1314
Hong Jongsup - B0822
Hong Sung Gwan - A0918
Hong Wen-Tang - A1317
Horita Teruhisa - B1202, B1513
Hornauer S. - B0903
Hornés Aitor - A0907, B1508
Höschen T. - A0810, B0503
Hossain Shahzad - B0625, B1316
Hosseini Mehdi - B1115
Hou Fan-Lin - B0627
Hou Yushan - B0509
Hoven Ingo - A1501
Hu Boxun - B1506
Hussain Mohd Azlan - B1107
Hwang Ho Jung - A0904
Hwang Jun Young - A1319
Hyun Sang-Hoon - A0904
Ide Takahiro - A1301
Ihringer Raphael - B1218
Ikeda Sou - A1206
Ikeda Yoichi - A1301
Im Ha-Ni - A0912, A0914, B0612, B0615
Immisch Christoph - A0909
Iora Paolo - B0823
Iorio S. Di - B1104
Irvine John T. S. - A1604, B0903, B1301, B1405
Ishihara Tatsumi - B1501
Ivanova Mariya E. - A1407
Ivers-Tiffée Ellen - B1203, A1107, B0502, B0507, B0803, B1207, B1502
Iwai Hiroshi - A0906, B0517, B0824
Jahn Matthias - A0601, A0908
James Sean - A0701
Jamil Zadariana - B0310
Jang Hansaem - B0518
Jang Jeong Seok - A0904
Janssens Jean-Paul - A1303
Jauffres David - B1504
Jaworski Zdzislaw - B1115, B0816
Jensen Anker Degn - B0810
Jensen Michael Ulrik Borg - A1506
Jeon Ok Sung - A0904
Jeon Sang-Yun - A0914
Jindal Nik - B0320
Joia Tahir - A1505
Joos Jochen - A1107, B0803, B1203
Jørgensen Peter Stanley - B0802
Jr. George G. Gomes - B1404

Jr. Mark K. King - B0320
Kaida Taku - B1323
Kang Juhyun - B0314, B0318
Kang Kyungtae - A1319
Kang Sanggyu - A1320, B0828, B1108
Karas Filip - B0316, B0808
Kareh Kristina Maria - B0521, B1206, B0801, B1212
karim Afizul hakem bin - B1316
Kawabata T. - A0604
Kawada Tatsuya - B0519
Kendall K. - A0907
Kesler Olivera - B0304
Khan Ieeba - A0905, B0623
Khan Muhammad Shirjeel - B1324
Kiebach Wolf-Ragnar - B0630
Kiefer T. - B0903
Kilner John A. - B1505, A1408, B1501
Kim Bumsoo - B0629
Kim Byung-Kook - B0822
Kim Guntae - B1320
Kim Hyoungchul - B0822
Kim In-Ho - A0912, B0612, B0615
Kim Jong Kuk - A1510
Kim Jongwook - A0609
Kim Jung-Sik - B1201, B1215
Kim Young Jin - A0813
Kim Yu Seung - B0602
Kishimoto Haruo - B1513, B1202
Kishimoto Masashi - A0906, B0824
Kitahara Tatsumi - A1206, B0820
Kiviaho Jari - A1202, B0619
Kluge Claus Peter - A1307
Koc Rasit - B1510
Kodým Roman - B0808
Kolisetty Abhigna - B1510
Kontic Roman - B1403
Konuntakiet Tanapa - B1302
Konysheva Elena - B0509
Kotisaari Mikko - A1202
Kravchenko Ekaterina - B1312
Kreller Cortney - B0602
Krivy Mark - A1505
Kuhn Joel - B0304
Kumari Neetu - A1410
Kume Takao - A1301
Küngas Rainer - A0804, A1102, A1508
Kurz S. - A1412, B1211
Kushi Takuto - A1301
Kusnezoff Mihails - A0601, A0908, B0516, B0606
Kwok Kawai - B0802
Labonnote-Weber Sophie - B0306
Lagazzo Alberto - B1503
Laguna-Bercero M. A. - B1313
Lang M. - A1412, B1211
Lankin Mike - A0303
Lanzini Andrea - B0804
Lapicque François - A1313
Larrañaga A. - B0321, B1313
Larring Y. - B0905
Larsen Dennis - A1403, A1411, B0602
Le Hao - B1323
Leah Robert - A0303, B0902
Lee Hae-Weon - A0202
Lee Hee Lak - B0607
Lee How-Ming - A1209
Lee Insung - B0629
Lee Jaeyoung - B0518
Lee Jin Goo - A0904
Lee Jong Dae - A1316
Lee Jong-Ho - B0822
Lee Jongseong - A1510
Lee Jong-Won - A1315, A1415, B1324
Lee Kanghun - A1320, B1108
Lee Kunho - B0314, B0318
Lee Kwan Soo - B0602
Lee Ruey-Yi - A1209, A1317
Lee Sanghun - B0314
Lee Sanghyeok - B0822
Lee Seongkon - A0609
Lee Seung-Bok - A1315, A1415, B1324
Lee Su Jeong - B0607
Lee Yeyeon - A0904
Lee Youngduk - A1320, B0828, B1108
Lefebvre-Joud F. - A0605
Lehner Franz - A0201
Lehnert W. - A1205
Lein Hilde - B0306
Leites Keno - A1305
Li Kang - B0319
Li Tao - B0319
Lim Chee Kuan - B1305

Lim Dae-Kwang - A0912, B0615
Lim Hyung-Tae - A0813
Lim Kyoung Tae - B0607
Lim Tak-Hyoung - A1315, A1415, B1324
Lima Fernandes Antonio de Padua - B0618
Lin Chih-Kuang - B0627
Lindermeir Andreas - A0909
Lipman Timothy - A1502
Liu Chien-Kuo - A1209
Liu Qinglin - B1211, B1305, B1310
Liu Ting-Wei - A1317
Liu Wei - B0509
Liukkonen Matti - A0509, A1406
Lo Shih-Kun - A1317
Loll Isabell - A1416
Long Tran Dang - B0826
Lu Xuekun - B0319
Luc Khun - A1505
Lucci Massimiliano - B0628
Ludwig Christian - A0808
Lund Peter D. - A0905, B0623
Lundberg Mats W. - B0614, B0903
Lupetin Piero - B1511
Madi Hossein - A0808
Mahapatra Manoj K. - B0320
Mai Andreas - A0301, B0504, B1403, B1405
Maity Shambhu Nath - B0624
Majewski Artur J. - B0515, B1205
Malzbender Jürgen - B0609, B1309
Manchili Swathi Kiranmayee - B0510
Margaritis Nikolaos - A0603
Markocsan Nicolaie - B0304
Martin Christophe L. - B1504
Masci Amedeo - B0620, B0628
Maserati A. - A1402
Masi Andrea - B0603, B0605, B0620, B0621, B0628, B0631
Masini Alessia - A0915
Mastropasqua Luca - B0823
Matencio Tulio - A0607, A0610, B0618, B1318
Mathe Jörg - A0502
Matsuda J. - A0604
Matsui Yuki - A0906
Matsumoto Hiroshige - A1208
Matsuzaki Yoshio - A1104, A1208, B1112
Matte Eric - B1511
Mayyas Ahmad - A1502
McPhail Stephen J. - B0827, B0620, B0628
Megel Stefan - A0601, A0908
Meisel Peter - A0305
Menzler Norbert H. - A0803, A1101, A1404, A1405, B0906
Mermelstein Joshua - A0306
Meruane Viviana - A0818
Michaelis Alexander - A0908, B0516, B0606
Miguel-Pérez V. - A0815, A0903
Mikkola Jyrki - B0619
Miller Byron - A1411
Milner Lois - B1205
Mitchell Evan - A1411
Miyamae Takuma - B0824
Miyara Kengo - A1104
Mogensen Mogens B. - A0902, B1301
Molin Sebastian - B0630
Monforte Giuseppe - A1203
Monterde M.C. - A0815
Montinaro Dario - A0802, A0903, A1202, A1413, B1210
Morales M. - A0815, A0903
Morán-Ruiz A. - B0321, B1313
Morata Alex - A0815, A0903, A0907, A0917, B1204, B1306, B1508
Mori Masashi - B0601
Morita Hiroshi - A0814
Mosby James - A1411
Mougin J. - A0605, B1104
Mugikura Yoshihiro - A0814, A1104
Mukerjee Subhasish - A0303, B0902, B1219
Mukundan Rangachari - B0602
Muñoz Carlos Boigues - B0827
Muñoz Delia - A1414
Muralt Paul - B1319
Nagato Keisuke - B0303, B0821
Nakajima Hironori - A1206, B0820
Nakajima Tatsuya - A1301
Nakajo Arata - A0913, B1213, B1303
Nakamura Kazuo - A1301
Nakao Masayuki - B0303
Näke Ralf - A1306, A1309

Natour Ghaleb - B1217
Neagu Dragos - B0903, B1301
Nerlich Volker - A0301
Nguyen Van Nhu - A1312
Ni Na - A0807
Niania Mathew - B1505
Nicolella Cristiano - B1214, B1216
Nielsen E.R. - B1211
Nielsen J. - B0903
Niewolak Leszek - A1101
Nikumaa Maria - B0611
Nishihara M. - A0604
Noponen Matti - A0503, A0909, A1204
Norby T. - B0301
Nørby Tobias Holt - A1102, A1508
Norby Truls - A1414
O'Hayre Ryan - B1102
Oberholzer Stefan - A0103
Ogasawara Kei - A1301
Ohmori Makoto - A1104
Opitz Alexander - B0901
Orellana Marcelo - A0818
Oshima Toshihiro - A0604, A1104
Otani Yuki - B0517
Oum Melissa - B0605, B1111
Õunpuu Enn - A0503
Ouweltijes Jan Pieter - B1204, B1210
Ouweltjes J. P. - A0903
Ouyang Mengzheng - B1302, B1406
Oveisi Emad - A0802
Packbier Ute - A1201
Padella Franco - B0631
Pâdua Antônio de - B1318
Paidar Martin - B0316, B0808
Pan Zehua - B1310
Pankov Vladimir - B1312
Pappas André - B1218
Papurello Davide - B0804
Park Jun-Young - B0626
Park Ka-Young - B0626
Park Manho - B0629
Park Seok-Joo - A1315, A1415, B1324
Park SungBum - A0918
Park Yong-il - A0918
Park Youngeun - B0518
Pećanac Goran - B0609, B1309
Pecunia Andrea - B0514
Peng Cheng - B1315
Peracchio A.A. - B1303
Perego Patrizia - B1503
Persson Å. H. - B0903
Peters Roland - A0603, A1312, A1501
Petitjean M. - B1104
Petra Mohamad Iskandar - B1316
Pfeifer Thomas - A0601, A1306
Pianko-Oprych Paulina - B0816, B1115, B1117
Piccardo Paolo - B0514, B1204, B1214, B1216
Ploner Alexandra - A0812
Poitel Stéphane - B0512
Pöpke Hendrik - B0632
Posdziech Oliver - A0305, A0306
Postlethwaite Oliver - B0902
Price Robert - B1405
Primdahl Søren - A1102, A1508
Pugliese Federico - A1302
Pumiglia Davide - B0620, B0827
Quadakkers Willem J. - A1101
Quang Tran Tuyen - B1323
Rahman Mahfujur - A0303
Ramos F. - A0917
Ramousse S. - B0903
Ranaweera Manoj - B1201, B1215
Rapini Márcia - A0607, A0610
Rass-Hansen Jeppe - A1102, A1506, A1508
Rautanen Markus - B0619
Ravagni Alberto V. - A0304
Reade Gavin - B1219
Reale Priscilla - B0631
Recalde Mayra - B1109
Rechberger Jürgen - A0502, A1304, B0901, B0903
Reis R. M. - B1307
Reiss G. - B0903
Reissig Michael - A0502
Reiter Bernd - A0502
Reytier M. - A0605, B1104
Richter Andreas - A1407, B0306
Riedel Marc - A0911
Riegraf Matthias - B0504
Rinaldi Giorgio - A0802

Rodríguez D. - A0917
Roehrens D. - B0906
Rolland Mélanie - A1413
Rost Axel - B0606
Roux G. - A0605, B1104
Rozain Caroline - A0504, A0507
Rubio Diego - B0315
Ruiz-Trejo E. - A1402
Rüttinger Matthias - A0501
Sachitanand Rakshith - B0611, B0903
Saglietti G.G.A. - B1307
Saito Motohiro - A0906, B0517, B0824
Sakamoto Mio - B1323
Santarelli Massimo - B0804
Santhanam Srikanth - B0807
Santoni Francesca - B0827
Saranya Aruppukottai Bhupathi - B1508
Sarda Venkatesh - A1416
Sarruf Bernardo J. M. - B1314
Sasaki Kazunari - A0604, A1104, A1208, B1112, B1402
Sato Koki - A1104
Sato Kouki - A1208
Schafbauer Wolfgang - A0501, B0906
Scharrer Michael - A1307
Schauperl Richard - A1304, B0903
Schefold Josef - A0801
Schiemann Kevin - B1509
Schiller Günter - A0606, A1103, B0504, B0811, B1210
Schilm Jochen - B0606
Schimanke Danilo - A0305
Schlegl Dr Harald - B0815
Schluckner Christoph - B0508, B0818
Schmitz Rolf - A0103
Schrödl Nina - A0809, A0810, B0503
Schroettner Hartmuth - B0508
Schuler Alexander - A0301
Schuler J. Andreas - A0301, B1403, B1405
Schulmeyer W. V. - A0908
Selby Mark - A0303, B0902, B1219
Selcuk Ahmet - A0303
Semerad Robert - B0511, B0904
Serra J.M. - B0301
Sglavo Vincenzo Maria - A1413
Shakeri Mohsen - B0819
Shearer Neil - B0317
Shearing Paul - B0319
Shen Xuesong - B1402
Shen Zonghao - A1408
Shikazono Naoki - B0303, B0821
Shimura Takaaki - B0303, B0821
Shin Hoyong - B0318
Shin Hyeong Cheol - B0607
Shirai Marie - A1301
Shiratori Yusuke - A0604, B0826, B1323
Shul Yong Gun - A0904
Sigl Lorenz S. - A0501, A0908
Silva Edyth da - B1318
Singh Prabhakar - B0320, B1506
Singheiser Lorenz - B1512
Sinha Nishant - A1410
Sinisterra Rubén - A0607, A0610
Sitte Werner - A0809, A0810, B0503
Skafte Theis L. - B0501
Skinner Stephen - A0807, A1401, A1408
Skrabs S. - A0908
Slodczyk A. - A0907, B1306
Somekawa Takaaki - A1104, A1208, A1301, B1112
Son Ji-Won - B0822
Song Bowen - B0521
Song Rak-Hyun - A1315, A1415, B1324
Song Shinae - A1319
Song Sun-Ju - A0912, A0914, B0612, B0615
Spatari Sabrina - A1411
Spatschek Robert - B1512
Spirig Michael - A0101, A1602, A1605, A1603
Spliethoff Hartmut - A0817, B1101
Spotorno Roberto - B0514, B1214, B1216
Stam Jelle Nicolas - B1107
Stamatiadou Marianna - A1108
Stange M. - B0905
Staykov Aleksandar - B1501
Steedman Dale - A1505
Stefan E. - B0903, B0905
Steffen Michael - A1313
Stehlík Karin - A0608
Steilen Mike - A1309
Steinberger-Wilckens Robert - B0305, B0603, B0605, B0613, B0621, B0631,

B0813, B1111, B1114, B1205, B1304, B1314
Steinmann Walter - A0103
Stenberg Henri - A0509, A1406
Stevenson Graham R - B1311
Stoeckl Bernhard - B0508
Stoermer H. - B1203
Stolten Detlef - A1201, A1501, B1511, A1312
Störmer Heike - B1502
Strandbakke R. - B0301
Strohbach Thomas - A0305
Su Pei-Chen - B0302
Subotić Vanja - B0508, B0818
Suciu Crina - B0315
Suda Eisaku - B0601
Sudireddy B.R. - B0903
Sugeta Atsushi - B0627
Sumi Hirofumi - B0601
Sumi Hiroshi - A1104
Sun Qiang - B1305
Sun Xiufu - A0902
Svensson Gunnar - B1312
Svensson Jan-Erik - B0510, B0604, B0611, B0903
Syvertsen-Wiig Guttorm - A1407, B0306
Szabo Patric - B0511, B0629, B0904, B1210
Szasz J. - B1203
Szász Julian - B1502, B1207
Szmyd Janusz S. - B0517
Tachikawa Yuya - A0604, A1208, B1112
Tafazoli Mehdi - B0819
Taku Shumpei - A1301
Tallgren Johan - B0605, B0613, B0619
Tan Hsueh-I - A1317
Tang Eric - A1505
Taniguchi Shunsuke - A0604, A1104, A1208, B1112
Tao Youkun - A0902
Tarancón A. - A0815, A0903, A0917, B1306, A0907, B1508
Tariq Farid - B0521, B0801, B1206, B1212, B1302
Taroco Hosane Aparecida - B0618
Téllez Helena - B1501
Thomann Olivier - A1202
Thydén K. - B0903
Ticianelli E.A. - B1307
Tiedemann Wilfried - A1501
Ting Huan-Chan - A1317
Tkáč Martin - A0608
Tokariev Oleg - A1404
Tonekabonimoghadam Seyedehmina - B1107
Tong Jianhua - B1102
Toor Sannan - B0616
Torrell M. - A0815, A0903, A0907, A0917, B1306
Torri Pauli - A1204
Trejo Enrique Ruiz - B0521, B1212, B0310, B0801, B1206, B1311
Trimis Dimosthenis - A1108
Trocino Stefano - A1203, B1307
Trofimenko Nikolai - B0516, A0908
Trucco Andrea - A1302
Tsai Tsang-I - B1114
Tseng Ling-yuan - A1511
Tsur Yoed - B1506
Turnbull Rob - B0317
Tuyen Tran Quang - B0826
Tyagi Sarika - A1414
Udomsilp D. - B0906
Vähä-Piikkiö Heikki - A1204
Valenzuela Rita Ximena - B1321
Van herle Jan - A0802, A0808, A0910, A0913, B0512, B0513, B0603, B0605, B0613, B0619, B0621, B1213
Vaßen Robert - A1101
Venâncio Selma A. - B1404
Venkatachalam Vinothini - B0630
Venkataraman Vikrant - B0813
Venkatesan Vijay - B1201, B1215
Verbraeken Maarten C - B1301
Vero Jeffrey C. De - B1513
Vešović Toni - A0913
Vidal K. - B0321, B1313
Vigen C. - B0301
Vik Arild - B0315
Vinke Izaak C. - B1509, A1416
Visser K. - B1103
Vøllestad E. - B0301
Vos Yves De - A1303
Vulliet J. - A0605

Waernhus Ivar - B0315
Wain A. - B0321
Walter Christian - A0305
Wang Chun-Hsiu - A1209
Wang Jian-Qiang - A1507, B1315
Wang Lei - B0303
Wang Xin - A0901, B0520
Wankmueller F. - B1203
Wankmüller Florian - B1502
Weber André - A0908, A1107, A1307, B0502, B0507, B0803, B0903, B1207, B1219
Wedel Stig - B0810
Wei Jianping - B1309, B0609
Wei Max - A1502
Weissen Ueli - B1405
Westlinder Jörgen - B0614, B0903
Wilde Virginia - B1502, B1203
Wilson Callum - B0317
Wilson Mahlon - B0602
Windisch H. F. - B0903
Wix Christian - B0810
Wong Chi Ho - A1401
Woo Hangsoo - A1510
Wood Tony - A1505
Wousdtra Theo - B1109
Wu Szu-Han - A1209, B0627
Wuillemin Zacharie - B0512
Xiao Guo-Ping - B1315, A1507
Yamaji Katsuhiko - B1202, B1513
Yamamoto Tohru - A0814
Yan Y. - A1205
Yan Yan - B1319
Yang Peng - B0627
Yang Shicai - B0605, B0613
Yaremchenko Aleksey - B1312
Yashiro Keiji - B0519
Yasumoto Kenji - A0814
Yildiz Saffet - A1416
Yin Xiaoyan - B1512
Yokokawa Harumi - A0602, A1104, B1202, B1513
Yoo Young-Sung - A0914
Yoon Kyung Joong - B0822
Yoon Yong-Jin - B0302
Yoshida Hideo - A0906, B0517, B0824
Yoshikawa Masahiro - A0814, A1104
Yu Ching-Tsung - A1209
Yu Ji Haeng - B0607
Yu Jun Ho - A1319
Yufit Vladimir - B0801, B1206, B1212
Yurkiv Vitaliy - A1103, B0504, B0511, B0811, B0904
Zaini Juliana Hj - B0625
Zaitsu A. - A0604
Zakharchuk Kiryl - B1312
Zakrzewska Barbara - B1117
Zhang Xiaomei - B0509
Zhao Fei - B0519
Zhou Jing - B1315
Zhou Juan - B1305
Zhu Zhi-Yuan - B1315
Zignani Sabrina C. - A1203, B1307
Zinko Tomasz - B0816

Become again an author:

7th European PEFC & ELECTROLYSER Forum 4 - 7 July 2017

13th European SOFC & SOE Forum 3 - 6 July 2018

List of Participants

12th EUROPEAN SOFC & SOE FORUM 2016

5 - 8 July 2016

Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

Registered until 16 June 2016

Akbarifakhrabadi Ali Dr.
Mechanical Engineering
Universidad de Chile
Beauchef 851, Torre Poniente
8370456 Santiago
CHILE
+56229784690
aliakbarif@ing.uchile.cl

Almar Laura
Institut für Angewandte Materialien - Werkstoffe der Elektrotechnik (IAM-WET)
Karlsruher Institut für Technologie (KIT)
Adenauerring 20b
76131 Karlsruhe
GERMANY
+49 721 608-47714
laura.almar@kit.edu

Al-Sagheer Yousif
School of Chemical Engineering
University of Birmingham
Edgbaston
B15 2TT Birmingham
UNITED KINGDOM

Andarini Rizki
School of Chemical Engineering
University of Birmingham
Edgbaston
B15 2TT Birmingham
UNITED KINGDOM

Apweiler Stefan
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
+49 2461 61 3777
s.apweiler@fz-juelich.de

Asghar Muhammad Imran Dr.
Applied Physics
Aalto University
Puumiehenkuja 2
02150 Espoo
FINLAND
+358503441659
imran.asghar@aalto.fi

Astrom Kim
Convion Ltd
Tekniikantie 12
02150 Espoo
FINLAND
+358408453072
kim.astrom@convion.fi

Atkinson Alan Professor
Materials
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
02075946780
alan.atkinson@imperial.ac.uk

Auer Corinna
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 68628188
corinna.auer@dlr.de

Aydin Ozgur
Hydrogen Energy Systems
Kyushu University
Graduate School of Engineering
819-0395 Fukuoka
JAPAN
+81 92 80 23 234
ozgur.aydin@mech.kyushu-u.ac.jp

Bagarinao Katherine Dr.
National Institute of Advanced Industrial Science and Technology
AIST Tsukuba Central 5
305-8565 Tsukuba
JAPAN
+81 29 861 5721
develos-bagarinao@aist.go.jp

Baldinelli Arianna
Dipartimento di Ingegneria
Università degli Studi di Perugia
Via Duranti 93
06125 Perugia
ITALY
+393203079629
arianna.baldinelli@gmail.com

Banerjee Aayan
Institute of Chemical Technology and Polymer Chemistry
Karlsruhe Institute of Technology
Engesserstr. 20
76131 Karlsruhe
GERMANY
+4972160842399
aayan.banerjee@kit.edu

Baumann Maja
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND

Berger Robert
AB Sandvik Materials Technology
Sandvik
811 81 Sandviken
SWEDEN
+46 706415847
robert.berger@sandvik.com

Bertei Antonio
Earth Science and Engineering
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
a.bertei@imperial.ac.uk

Betz Thomas
CeramTec AG
CeramTec-Platz 1-9
73207 Plochingen
GERMANY
T.Betz@Ceramtec.de

Bianco Manuel
Fuelmat Group
EPFL
Rue de l'industrie 17
1951 Sion
SWITZERLAND
+41216958273
manuel.bianco@epfl.ch

Bindi Massimiliano Dr.
Research, Development & Innovation
Edison S.p.A.
via Giorgio La Pira,2
I-10028 Trofarello-Turin
ITALY
+390116482836
massimiliano.bindi@edison.it

Birth Soren
NOVUM engineerING GmbH
Schnorrstrasse 70
01069 Dresden
GERMANY
s.birth@novum-engineering.biz

Bistritzki Victor
Rua Pérsion Babo de Rezende 144
31310-560 Belo Horizonte
BRAZIL
+491714484776
victor.bistritzki@gmail.com

Blennow Peter Dr.
New Business R&D
Haldor Topsoe A/S
Haldor Topsøes Allé 1
2800 Kgs. Lyngby
DENMARK
+4525529424
pebl@topsoe.dk

Blum Ludger Prof.
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
+49 2461 616709
l.blum@fz-juelich.de

Boldrin Paul
Earth Science and Engineering
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
p.boldrin@imperial.ac.uk

Bond Steve
Flexitallic Ltd
Hunsworth Lane Cleckheaton
BD19 4LN West Yorkshire
UNITED KINGDOM
jhoyes@flexitallic.eu

Bone Adam Dr.
Fuel Cell Devleopment
Ceres Power
Viking house
RH13 5PX Horsham
UNITED KINGDOM
+441403273463
adam.bone@cerespower.com

Bosch Timo
CR/AEB
Robert Bosch GmbH
Robert-Bosch-Campus 1
71272 Renningen
GERMANY
+49172 579 7450
timo.bosch@de.bosch.com

Bossel Ulf Dr.
ALMUS AG
Morgenacherstrasse 2F
5452 Oberrohrdorf
SWITZERLAND

Bram Martin Dr.
Institute IEK-1
Forschungszentrum Jülich GmbH
Wilhelm Johnen Strasse
52425 Jülich
GERMANY
+49 2461 61 68 58
m.bram@fz-juelich.de

Brandon Nigel Prof.
Imperial College London
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
n.brandon@imperial.ac.uk

Brandys Irad
NRCN
P.O.Box 9001
8419001 Beer Sheva
ISRAEL
+972 50 6244207
iradbr@gmail.com

Brendt Jeerawan
Wilhelm-Johnen-Strasse
52425 Juelich
GERMANY
+492461613201
j.brendt@fz-juelich.de

Brisse Annabelle Dr.
EIFER
EMMY-NOETHER-STRASSE 11
76131 Karlsruhe
GERMANY
+49 72161051317
brisse@eifer.org

Brus Grzegorz Dr.
Department of Fundamental Research in Energy Engineering
AGH University of Science and Technology
30 Mickiewicza Ave
30-059 Krakow
POLAND
+48 12 6175052
brus@agh.edu.pl

Bucheli Olivier
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND
o.bucheli@efcf.com

Büchler Joana
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND

Cai Qiong Dr.
Chemical and Process Engineering
University of Surrey
Faculty of Engineering and Physical Sciences
GU2 7XH Guildford
UNITED KINGDOM
+44 1483686561
q.cai@surrey.ac.uk

Caliandro Priscilla
Fuelmat Group
EPFL
Rue de l'industrie 17
1951 Sion
SWITZERLAND
+41216958273
priscilla.caliandro@epfl.ch

Cavoto Lorenzo
Bronkhorst (Schweiz) AG
Nenzlingerweg 5
4153 Reinach
SWITZERLAND
d.peyer@bronkhorst.ch

Celikbilek Ozden
LEPMI
University of Grenoble Alpes
1130 Rue de la Piscine
38402 St Martin D'Heres
FRANCE
+33751127099
ozden.celikbilek@lepmi.grenoble-inp.fr

Chen Shuoshuo
CHAOZHOU THREE-CIRCLE(GROUP)CO.,LTD
Sanhuan Industrial district, fengtang
515646 Chaozhou
CHINA
+867686859255
jennifer@cctc.cc

Chen Jingyi
Materials
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
jingyi.chen12@imperial.ac.uk

Chen Ming Dr.
Department of Energy Conversion and Storage
Technical University of Denmark
Frederiksborgvej 399
DK4000 Roskilde
DENMARK
+4546775757
minc@dtu.dk

Christiansen Niels Dr.
NCCI innovation
Violvej 3
2820 Gentofte
DENMARK
+4522754085
info@ncci.dk

Chun Sonya
Europe Office
C & I Tech
Untermosenstrasse 52
8820 Waedenswil
SWITZERLAND
+41787360055
lindenhof129@gmail.com

Chung Kyung Sil Leah
Chemical Engineering
University of Waterloo
1110-300 Regina St. N.
N2J4H2 Waterloo
CANADA
+14168713901
ks2chung@uwaterloo.ca

Coles-Aldridge Alice
School of Chemistry
University of St Andrews
North Haugh
KY16 9ST Fife
UNITED KINGDOM
+441334463811
aca4@st-andrews.ac.uk

Cooley Nathan
fuelcellmaterials
404 Enterprise Drive
43035 Lewis Center
UNITED STATES
n.cooley@fuelcellmaterials.com

Corwin Chris
fuelcellmaterials
404 Enterprise Drive
43035 Lewis Center
UNITED STATES
c.corwin@fuelcellmaterials.com

Costa Remi Dr.
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 6862733
remi.costa@dlr.de

Costamagna Paola Prof.
DICCA - Department of Civil, Chemical and Environmental Engineering
University of Genoa
Via Opera Pia, 15
16145 Genoa
ITALY
+393292104460
paola.costamagna@unige.it

De Haart L.G.J. Bert Dr.
IEK-9
Forschungszentrum Jülich
Wilhelm Johnen Str
52428 Jülich
GERMANY
+492461616699
l.g.j.de.haart@fz-juelich.de

De Vos Yves
BOSAL ECI
Kamerling Onnesweg 5
4131 PK Vianen
NETHERLANDS
Yves.DeVos@eur.bosal.com

Demirezen Gülsün
Bogazici University Kuzey Kampüs 4. Kuzey Yurdu Oda A304
34342 İstanbul
TURKEY
+905308777229
gulsun.demirezen@boun.edu.tr

Dickel Thorsten Dipl.-Ing.
Institut für Angewandte Materialien - Werkstoffe der Elektrotechnik (IAM-WET)
Karlsruher Institut für Technologie (KIT)
Adenauerring 20b
76131 Karlsruhe
GERMANY
+49 721 608-48793
thorsten.dickel@kit.edu

Dierickx Sebastian Dipl.-Ing.
Institut für Angewandte Materialien - Werkstoffe der Elektrotechnik (IAM-WET)
Karlsruher Institut für Technologie (KIT)
Adenauerring 20b
76131 Karlsruhe
GERMANY
+49 721 608-48148
sebastian.dierickx@kit.edu

Disch Clemens Disch
Werner Mathis AG
Rütisbergstrasse 3
8156 Oberhasli
SWITZERLAND
cdisch@mathisag.com

Dubois Alexis
Colorado School of Mines
1500 Illinois Street
80401 Golden
UNITED STATES
+17204761675
adubois@mines.edu

Dubois Alexis
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND

Duhn Jakob
Tech. Developm and Plant Design
Haldor Topsøe A/S
Nymøllevej 55
2800 Kgs. Lyngby
DENMARK
+45 25529471
jadd@topsoe.dk

Edera Masaru
Japan science and technology agency
K's Gobancho, 7,chiyoda-ku, Tokyo 102-0076
Japan
102-0076 Tokyo
JAPAN
+81 3 6261 2215
masaru.edera@jst.go.jp

Egger Andreas Dr.
Chair of Physical Chemistry
Montanuniversitaet Leoben
Franz-Josef-Strasse 18
8700 Leoben
AUSTRIA
+43 3842 402 4814
andreas.egger@unileoben.ac.at

Ekdahl Ron
Praxair Surface Technologies, Inc.
16130 Wood-Red Road
98072 Woodinville, WA
UNITED STATES
Ron_Ekdahl@praxair.com

Elangovan Elango Dr.
Ceramatec, Inc.
2425 South 900 West
84119-1517 Satl Lake City
UNITED STATES
+1 801 978 2162
elango@ceramatec.com

Elwell Jessica
Fuel Cells/Fuel Processing
Ceramatec Inc
2145 South 900 West
84119 Salt Lake City
UNITED STATES
+12628808411
jelwell@ceramatec.com

Engelbracht Maximilian
Institute of Energy and Climate Research (IEK)
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
+492461614652
m.engelbracht@fz-juelich.de

Ernst Johannes Dr.
CeramTec AG
CeramTec-Platz 1-9
73207 Plochingen
GERMANY
J.Ernst@Ceramtec.de

Escudero Maria Jose Dr.
Avda Complutense 40
CIEMAT
Avda Complutense 40
28040 Madrid
SPAIN
+34913466622
m.escudero@ciemat.es

Falk-Windisch Hannes
Chemistry and Chemical Engineering
Chalmers University of Technology
Kemivägen 10
41296 Gothenburg
SWEDEN
+46723595450
hannes.windisch@chalmers.se

Fang Qingping Dr.
IEK-3
Forschungszentrum Jülich
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
+49 2461 611573
q.fang@fz-juelich.de

Fernandes Marina
Rua Persio Babo de Resende, 144
31310560 Belo Horizonte
BRAZIL
+55 3134987408
marinadomingues2609@gmail.com

Ferrari Tommaso Dr.
Department of Industrial and Civil Engineering
University of Pisa
LARGO LUCIO LAZZARINO, 2
56122 Pisa
ITALY
+393883483961
toms.ferr@gmail.com

Ferrero Domenico Dr.
DENERG
Politecnico di Torino
Corso duca degli Abruzzi, 24
10129 Torino
ITALY
+390110904560
domenico.ferrero@polito.it

Fleischhauer Felix Dr.
HEXIS AG
Zum Park 5
8404 Winterthur
SWITZERLAND
+41 52 262 6326
felix.fleischhauer@hexis.com

Foit Severin
IEK-9
Forschungszentrum Jülich
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
+4916098437138
s.foit@fz-juelich.de

Forrer Kora Aglaja
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND
k.forrer@efcf.com

Frandsen Henrik Lund Dr.
Department of Energy Conversion and Storage
Technical University of Denmark
Frederiksborgvej 399
4000 Roskilde
DENMARK
+45 46775668
hlfr@dtu.dk

Frank Matthias
IEK-3: Electrochemical Process Engineering
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
+492461614394
ma.frank@fz-juelich.de

Freund Thomas
ARBOR Fluidtec AG
Loonstrasse 10
5443 Niederrohrdorf
SWITZERLAND
t.freund@arborag.ch

Friedrich Andreas Prof.
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
andreas.friedrich@dlr.de

Friedrich Thomas
Plansee SE
Metallwerk Plansee-Strasse 71
6600 Reutte
AUSTRIA
thomas.friedrich@plansee.com

Fuchs Franz-Martin
Kerafol - Keramische Folien GmbH
Koppe-Platz 1
92676 Eschenbach
GERMANY
franz-martin-fuchs@kerafol.com

Geis Michael
Lehrstuhl für Energiesysteme
Technische Universität München
Boltzmannstr 15
85748 Garching
GERMANY
+498928916355
michael.geis@tum.de

Geisler Helge Dipl.-Ing.
Institut für Angewandte Materialien - Werkstoffe der Elektrotechnik (IAM-WET)
Karlsruher Institut für Technologie (KIT)
Adenauerring 20b
76131 Karlsruhe
GERMANY
+49 721 608-41732
helge.geisler@kit.edu

Geisser Gabriela
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND
g.geisseri@efcf.com

Ghasemi Zahra
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND

Gipp Daniel
FuelCon AG
Steinfeldstr. 1
39179 Magdeburg-Barleben
GERMANY
sales@fuelcon.com

Göbel Claudia
Energy and Materials
Chalmers University of Technology
Kemivägen 4
41296 Göteborg
SWEDEN
+46 31 772 2867
goebel@chalmers.se

Goettler Richard
LG Fuel Cell Systems
6065 Strip Avenue NW
44720 North Canton
UNITED STATES
+1 330 491 4821
richard.goettler@lgfcs.com

Gore Colin Dr.
Redox Power Systems
4467 Technology Drive
20742 College Park
UNITED STATES
+14847040168
colin@redoxpowersystems.com

Greco Fabio
Fuelmat Group
EPFL
Rue de l'industrie 17
CH-1951 Sion
SWITZERLAND
+412 16 958301
fabio.greco@epfl.ch

Guk Erdogan
Aeronautical and Automotive Engineering
LE113TU Leicestershire
UNITED KINGDOM
+44 7761321429
E.Guk@lboro.ac.uk

Gupta Mohit Dr.
University West
Gustava Melins gata 2
46151 Trollhättan
SWEDEN
+46 520 22 3282
mohit-kumar.gupta@hv.se

Hagen Anke Prof.
DTU Energy
Technical University of Denmark
Frederiksborgvej 399
4000 Roskilde
DENMARK
+4546775884
anke@dtu.dk

Hamada Tomoko
Daiichi Kigenso Kagaku Kogyo Co., Ltd.
4-4-7 Imabashi, Chuo-ku
541-0042 Osaka
JAPAN
hamada-t@zr.dkkk.co.jp

Hansen John Bøgild
Haldor Topsøe A/S
Nymøllevej 55
2800 Kgs. Lyngby
DENMARK
+45 22754072
jbh@topsoe.dk

Hart David Prof.
E4tech
Avenue Juste-Olivier 2
1006 Lausanne
SWITZERLAND
+41 21 331 1570
hart@e4tech.com

Hartmann Mathias
Fraunhofer IKTS
Winterbergstrasse 28
01277 Dresden
GERMANY
mathias.hartmann@ikts.fraunhofer.de

Hartvigsen Joseph
SOFC & Synfuels
Ceramatec, Inc.
2425 S 900 W
84119 Salt Lake City
UNITED STATES
+1 801 978 2163
jjh@ceramatec.com

Hauth Martin Dr.
AVL List GmbH
Hans-List-Platz 1
8020 Graz
AUSTRIA
+433167872770
martin.hauth@avl.com

Heddrich Marc Dr.
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 68628184
marc.heddrich@dlr.de

Henke Moritz Dr.
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 6862795
moritz.henke@dlr.de

Hernández Elba
Advanced Materials for Energy
Catalonia Institute for Energy Research (IREC)
Jardins de les Dones de Negre 1, 2ª pl.
08930 Barcelona
SPAIN
+034 93 3562615
ehernandez@irec.cat

Herrmann Stephan
Energy Systems
Technical University of Munich
Boltzmannstr. 15
85748 Garching
GERMANY
+498928916279
stephan.herrmann@tum.de

Herzhof Werner
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
w.herzhof@fz-juelich.de

Hibino Tomohiko
FCO Power Inc.
2-22-8 Chikusa Chikusa-ku
464-0858 Nagoya
JAPAN
+81 90 4768 3587
t_hibino@ecobyfco.com

Himanen Olli Dr.
VTT TEchnical Research Centre of Finland
Biologinkuja 5
02044 VTT
FINLAND
+358207225346
olli.himanen@vtt.fi

Hodjati-Pugh Oujen
School of Chemical Engineering
University of Birmingham
Edgbaston
B15 2TT Birmingham
UNITED KINGDOM

Hoffmann Alex Christian Prof.
Dept. of Physics and Technology
University of Bergen Norway
Allegaten 55
5007 Bergen
NORWAY
+4790832490
nfyah@uib.no

Höh Steffen
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
s.hoeh@fz-juelich.de

Hong Jae-Woon
Chonnam National University
77 Yongbong-ro, Buk-gu
61186 Gwangju
KOREA, REPUBLIC OF
+82 10 6790 9283
hjw01067909283@gmail.com

Hong Jongsup Dr.
High-temperature Energy Materials Research Center
Korea Institute of Science and Technology
5, Hwarang-ro 14-gil
02792 Seoul
KOREA, REPUBLIC OF
+82 02 958 5431
jhong@kist.re.kr

Hong Jong-Eun
School of Chemical Engineering
University of Birmingham
Edgbaston
B15 2TT Birmingham
UNITED KINGDOM

Horita Teruhisa Dr.
Research Institute for Energy Conservation
AIST
AIST Central 5
3058565 Tsukuba
JAPAN
+81 29 861 9362
t.horita@aist.go.jp

Hörlein Michael
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 6862279
michael.hoerlein@dlr.de

Hornes Aitor Dr.
Department of Materials for Energy
IREC
Jardins de les Dones de Negre 1, 2º
08930 Sant Adrià de Besòs
SPAIN
+34 933562615
ahornes@irec.cat

Horstmann Peter Dr.
CR/AEB1
Robert Bosch GmbH
Robert-Bosch-Campus 1
71272 Renningen
GERMANY
+4971181142806
peter.horstmann2@de.bosch.com

Ihringer Raphaël
Fiaxell Sarl
Aloyse-Fauquez 31
1018 Lausanne
SWITZERLAND
info@fiaxell.com

Ikeda Hiroya
DOWA HD Europe GmbH
Ostendstrasse 196
90482 Nuremberg
GERMANY
hiroya.ikeda@dowa-europe.com

Im Hani Dr.
Chonnam National University, 77 Yongbong-ro, Buk-gu
61186 Gwangju
KOREA, REPUBLIC OF
+820625301713
endzz0220@gmail.com

Irvine John Prof.
School of Chemistry
University of St Andrews
Purdie Building
KY16 9ST St Andrews
UNITED KINGDOM
+4401334463817
jtsi@st-andrews.ac.uk

Ivers-Tiffée Ellen Prof.
Institut für Angewandte Materialien - Werkstoffe der Elektrotechnik (IAM-WET)
Karlsruher Institut für Technologie (KIT)
Adenauerring 20b
76131 Karlsruhe
GERMANY
+49 721 608-47491
ellen.ivers@kit.edu

James Sean
Microsoft
One Microsoft Way
98052 Redmond
UNITED STATES
+001 425 722 4050
sean.james@microsoft.com

Jan Erik Svensson Prof.
Chemistry and Chemical Engineering
Chalmers University of Technology
Kemivägen 10
41296 Gothenburg
SWEDEN
+46730794212
jes@chalmers.se

Jang Hansaem
Gwangju Institute of Science and Technology
61005 Gwangju
KOREA, REPUBLIC OF
+82 10 4444 2749
luxuriest@gist.ac.kr

Janssens Jean-Paul
BOSAL ECI
Kamerling Onnesweg 5
4131 PK Vianen
NETHERLANDS
dr.janssens@eur.bosal.com

Jean Claude
CEATECH-LITEN
Rue des Martyrs 17
38054 Grenoble
FRANCE
claude.jean@cea.fr

Jeanmonod Guillaume
Fuelmat Group
EPFL
Rue de l'industrie 17
1951 Sion
SWITZERLAND
+41216958273
chantal.donaghey@epfl.ch

Joud Jean-Charles Prof.
Grenoble INP
38054 Grenoble
FRANCE

Kaida Taku
Department of Hydrogen Energy System
Kyushu University
Motooka 744
819-0395 Fukuoka
JAPAN
+81 92 802 3058
2TE15417N@s.kyushu-u.ac.jp

Karas Filip
Department of Inorganic Technology
UCT Prague
Technická 5
16628 Praha 6
CZECH REPUBLIC
+420720508387
karasf@vscht.cz

Kareh Kristina
Earth Science and Engineering
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
kristina.kareh05@imperial.ac.uk

Kawamura Kimito Dr.
Assistant to Director in charge of Corporate Social Responsibillity
Asahi Group Holdings, ltd.
1-23-1, Azumabashi
130-8602 Tokyo
JAPAN
+81 3 5608 5218
kimito.kawamura@asahigroup-holdings.com

Kawauchi Makoto
CAP CO.,LTD
3415-42 Shinyoshidacho Kohoku-ku
223-0056 Yokohama
JAPAN
k-sato@cap-co.jp

Khan Ieeba
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND

Kilner John Professor
Materials
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
j.kilner@imperial.ac.uk

Kim Jung-Sik Dr.
Aeronautical and Automotive Engineering, loughborough
LE11 3TU Leicestershire
UNITED KINGDOM
+44 1509 227 219
j.kim@lboro.ac.uk

Kim In-Ho
Engineering college 6-212, Chonnam National University, 77 Yongbong-ro, Buk-gu
61186 Gwangju
KOREA, REPUBLIC OF
+82 62 530 1713
wwwdlsgh@gmail.com

Kim jongwook Dr.
KIER
152,Gajeong-ro, Yuseong-gu
34129 Daejeon
KOREA, REPUBLIC OF
+82 10 2460 3170
jongwkim@kier.re.kr

Kishimoto Masashi Dr.
Kyoto University
Nishikyo-ku, Kyoto
6158540 Kyoto
JAPAN
+81753833652
kishimoto.masashi.3m@kyoto-u.ac.jp

Kitai Makoto
Daiichi Kigenso Kagaku Kogyo Co., Ltd.
4-4-7 Imabashi, Chuo-ku
541-0042 Osaka
JAPAN
hamada-t@zr.dkkk.co.jp

Kiviaho Jari Dr.
VTT
Biologinkuja 5
02044 Espoo
FINLAND
+358505116778
jari.kiviaho@vtt.fi

Knobel Stefan
G.Bopp & Co. AG
Bachmannweg 21
8046 Zürich
SWITZERLAND
sknobel@bopp.ch

Konysheva Elena Dr.
Chemistry
Xi'an Jiaotong-Liverpool University
111 Ren'ai Road
215123 Suzhou
CHINA
+86 512 88161435
elena.konysheva@xjtlu.edu.cn

Kotisaari Mikko
Fuel Cells
VTT Technical Research Centre of Finland Ltd
Biologinkuja 5
FI-02150 Espoo
FINLAND
+358404837715
mikko.kotisaari@vtt.fi

Kramer Daniel Prof.
University of Dayton
Kettering Laboratories - 165
45469 Dayton
UNITED STATES
+19372291038
daniel.kramer@udri.udayton.edu

Kroemer Joachim Dr.
Borit NV
Lammerdries 18e
2440 Geel
BELGIUM
+4981713650039
joachim.kroemer@borit.be

Kumari Neetu
Chemical Engineering
Currently persuing PhD from IIT Delhi
Indian Institute of Technology, Delhi,
110016 New Delhi
INDIA
+918802872891
neetusingh.kumari@gmail.com

Lang Michael Dr.
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 6862605
michael.lang@dlr.de

Larring Yngve Dr.
Sustainable Energy
SINTEF Materials and Chemistry
Forskningsveien 1
0314 Oslo
NORWAY
+4798283956
Yngve.Larring@sintef.no

Lattimer Alex
Flexitallic Ltd
Hunsworth Lane Cleckheaton
BD19 4LN West Yorkshire
UNITED KINGDOM
alattimer@flexitallic.eu

Lee Rueyyi Dr.
No. 1000 Wenhua Road, Longtan District
32546 Taoyuan
TAIWAN
+88634711400
rylee@iner.gov.tw

Lee Crystal
KCeraCell Co., Ltd.
465-9, Dabok-ro, Boksu-myeon
312923 Chungcheongnam-do
KOREA
kceracell@gmail.com

Lee Haeweon Dr.
High-temperature Energy Materials Research Center
Korea Institute of Science and Technology
5, Hwarang-ro 14-gil
02792 Seoul
KOREA, REPUBLIC OF
+82 02 958 5523
hwlee@kist.re.kr

Lee Jin Goo Dr.
Chemical and Bio-molecular Engineering
Yonsei University
134 Shinchon-dong, Seodaemun-gu
120749 Seoul
KOREA, REPUBLIC OF
+821051970542
ljk0542@nate.com

Lefebvre-Joud Florence Dr.
CEA LITEN
17 avenue des martyrs
38054 Grenoble
FRANCE
+33 4 38784040
florence.lefebvre-joud@cea.fr

Leites Keno
Research and Development
thyssenkrupp Marine Systems GmbH
Hermann-Blohm-Str. 3
20457 Hamburg
GERMANY
+494317001466
keno.leites@thyssenkrupp.com

Li Tao
Chemical Engineering
Imperial College
Imperial College
SW7 2AZ London
UNITED KINGDOM
+447926374460
tao.li10@imperial.ac.uk

Li Kang Prof.
Chemical Engineering
Imperial College
Imperial College
SW7 2AZ London
UNITED KINGDOM
+44(0)2075945676
kang.li@imperial.ac.uk

Liang Jun
CHAOZHOU THREE-CIRCLE(GROUP)CO.,LTD
Sanhuan Industrial district, fengtang
515646 Chaozhou
CHINA
+867686859255
jennifer@cctc.cc

Liebaert Philippe Dr.
Research&developpement
DCX Chrome
68 rue Jean Jaures
59770 Marly
FRANCE
+33 03 27200786
pliebaert@delachaux.fr

Lim Tak-Hyoung Dr.
152, Gajeong-ro, Yuseong-gu, Daejeon, 34129, Korea
34129 Daejeon
KOREA, REPUBLIC OF
+82 10 7556 7971
ddak@kier.re.kr

Lim Kevin
Nanyang Technological University
Nanyang Technological University
639798 50 Nanyang Avenue
SINGAPORE
+6593201654
kevi0016@e.ntu.edu.sg

Lin Chih-Kuang Prof.
Mechanical Engineering
National Central University
300 Jhong-Da Rd.
32001 Tao-Yuan City
TAIWAN
+886 3 4267340
t330014@cc.ncu.edu.tw

Lippelt Erik Dr.
Busch Dienste GmbH
Schauinslandstrasse 1
79689 Maulburg
GERMANY
+497622681220
erik.lippelt@busch.de

Littwin René Dipl.-Ing.
EBZ GmbH
Marschnerstraße 26
01307 Dresden
GERMANY
rene.littwin@ebz-dresden.de

Lo Faro Massimiliano Dr.
ITAE
CNr
Via salita S. Lucia sopra Contesse 5
98128 Messina
ITALY
+39 090 624243
lofaro@itae.cnr.it

Long Tran Dang
Hydrogen Energy Systems
Kyushu University
Motooka 744, Nishiku, Fukuoka, 819-0395
81 Fukuoka
JAPAN
+848064726448
longtrandang@yahoo.com

Lupetin Piero Dr.
Corporate Sector Research and Advance Engineering
Robert Bosch GmbH
Robert-Bosch-Campus 1
71272 Renningen
GERMANY
+497118117388
piero.lupetin@de.bosch.com

Madi Hossein
Fuelmat Group
EPFL
Rue de l'industrie 17
1951 Sion
SWITZERLAND
+41216958273
hossein.madi@epfl.ch

Mai Andreas Dr.
HEXIS AG
Zum Park 5
8404 Winterthur
SWITZERLAND
+41 52 262 6312
andreas.mai@hexis.com

Maier Nicolas Dr.
Corporate Sector Research and Advance Engineering - Functional Materials & Coating - Ceramics
Robert Bosch GmbH
Renningen
70465 Stuttgart
GERMANY
+49 711 811 26141
nicolas.maier@de.bosch.com

Majerus Samuel
Fuelmat Group
EPFL
Rue de l'industrie 17
1951 Sion
SWITZERLAND
+41216958273
samuel.majerus@epfl.ch

Majewski Artur
School of Chemical Engineering
University of Birmingham
Edgbaston
B15 2TT Birmingham
UNITED KINGDOM

Malzbender Jürgen Dr.
IEK-2
Forschungszentrum Jülich GmbH
Leo-Brandt-Strasse
52425 Jülich
GERMANY
+492461616964
j.malzbender@fz-juelich.de

Margaritis Nikolaos
ZEA-1
Forschungszentrum Jülich
Forschungszentrum Jülich GmbH
52425 Jülich
GERMANY
+4902461619587
n.margaritis@fz-juelich.de

Marinha Daniel Dr.
Saint-Gobain CREE
550, avenue Alphonse
84306 Cavaillon
FRANCE
+33679024193
danielmarinha@gmail.com

Masini Alessia
Brittle Fracture Group
Institute of Physics of Materials
Zizkova, 22
616 62 Brno
CZECH REPUBLIC
+420774982727
masini@ipm.cz

Matencio Tulio Prof.
Chemistry
UFMG
Rua Dom José Pereira Lara 366/101
30535520 Belo Horizonte
BRAZIL
+5531988598006
tmatencio@ufmg.br

Mathe Jörg
AVL LIST GmbH
Hans-List Platz 1
8020 Graz
AUSTRIA
Doris.Schoenwetter@avl.com

Matte Eric
Functional Materials and Coating Technologies
Robert Bosch GmbH
Postfach 1625
39006 Magdeburg
GERMANY
+4971181111381
eric.matte@de.bosch.com

Megel Stefan
Fraunhofer IKTS
Winterbergstrasse 28
01277 Dresden
GERMANY
Stefan.Megel@ikts.fraunhofer.de

Menzler Norbert Dr.
IEK-1
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Str.
52425 Jülich
GERMANY
+49 2461 613059
n.h.menzler@fz-juelich.de

Mermelstein Joshua Dr.
Boeing
5301 Bolsa Ave
92647 Huntington Beach
UNITED STATES
+1 714 896 6110
joshua.m.mermelstein@boeing.com

Micoli Luca Dr.
Department of Chemical, Materials and Production Engineering
University of Naples
P.le Tecchio n 80
80125 Naples
ITALY
+393393351328
luca.micoli@unina.it

Millner Lois
School of Chemical Engineering
University of Birmingham
Edgbaston
B15 2TT Birmingham
UNITED KINGDOM

Miranda Paulo Prof.
COPPE
UFRJ
AV. HORACIO MACEDO 2030 - I-146
21941-598 Rio de JANEIRO
BRAZIL
+552139388791
pmiranda@labh2.coppe.ufrj.br

Miyamae Takuma
Nisikyo-ku Kyoto
6158540 Kyoto
JAPAN
+81753833652
miyamae.takuma.22a@st.kyoto-u.ac.jp

Miyamoto Takayuki
New Energy Materials Business Unit
Nippon Shokubai Co., Ltd.
Kogin Bldg., 4-1-1
541-0043 Osaka
JAPAN
+81 90 5120 8754
takayuki_miyamoto@shokubai.co.jp

Mizutani Yasunobu Dr.
Inorganic Functional Materials Research Institute
National Institute of Advanced Industrial Science and Technology (AIST)
2266-98 Anagahora Shimo-shidami Moriyama-ku
463-8560 Nagoya city
JAPAN
+81 52 736 7157
yas-mizutani@aist.go.jp

Mogensen Mogens B. Prof.
DTU Enery
Technical University of Denmark
Frederiksborgvej 399
DK 4000 Roskilde
DENMARK
+45 21326622
momo@dtu.dk

Moore Fiona
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND
+41 77 210 2365
f.moore@efcf.com

Morales Miguel Dr.
Advanced Materials for Energy
Catalonia Institute for Energy Research
Jardins de les Dones de Negre 1, 2ª pl.
08930 BARCELONA
SPAIN
+34 93 3562615
mmorales@irec.cat

Mougin Julie
CEATECH-LITEN
Rue des Martyrs 17
38054 Grenoble
FRANCE
julie.mougin@ce.fr

Muggli Felix
G.Bopp & Co. AG
Bachmannweg 21
8046 Zürich
SWITZERLAND
fmuggli@bopp.ch

Mukerjee Subhasish Dr.
Fuel Cell & Stack Development
Ceres Power
Viking House
RH13 5PX Horsham
UNITED KINGDOM
+441403273463
subhasish.mukerjee@cerespower.com

Nagano Hiroki
CAP CO.,LTD
3415-42 Shinyoshidacho Kohoku-ku
223-0056 Yokohama
JAPAN
k-sato@cap-co.jp

Nagato Keisuke Dr.
Department of Mechanical Engineering
The University of Tokyo
71D4, 2nd Bldg -Eng., 7-3-1 Hongo
113-8656 Bunkyo-ku
JAPAN
+81358416361
nagato@hnl.t.u-tokyo.ac.jp

Nagatomi Akira
DOWA Electronics Materials Co., Ltd.
Akihabara UDX Building
Sotokanda 4-14-1 Tokyo
JAPAN
hiroya.ikeda@dowa-europe.com

Nakajima Hironori Dr.
Department of Mechanical Engineering
Kyushu University
744 Motooka, Nishi-ku
819-0395 Fukuoka
JAPAN
+81 92 802 3161
nakajima@mech.kyushu-u.ac.jp

Nakajo Arata Dr.
Fuelmat Group
EPFL
Rue de l'industrie 17
1951 Sion
SWITZERLAND
+41216958273
arata.nakajo@epfl.ch

Näke Ralf
Fraunhofer Institut für Keramische Technologien und Systeme
Winterbergstr. 28
01277 Dresden
GERMANY
+4935125537663
ralf.naeke@ikts.fraunhofer.de

Neeser Samuel
Bronkhorst (Schweiz) AG
Nenzlingerweg 5
4153 Reinach
SWITZERLAND
s.neeser@bronkhorst.ch

Ni Na
Materials
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
n.ni@imperial.ac.uk

Nikumaa Maria
Chemistry and Chemical Engineering
Chalmers University of Technology
Kemivägen 10
SE-41296 Göteborg
SWEDEN
+46 31 772 2748
maria.nikumaa@gmail.com

Nor Arifin Anisa
School of Chemical Engineering
University of Birmingham
Edgbaston
B15 2TT Birmingham
UNITED KINGDOM

Norby Truls Prof.
Department of Chemistry
University of Oslo
FERMiO
NO-0349 Oslo
NORWAY
+4799257611
truls.norby@kjemi.uio.no

Ohara Hiroaki
Chemical Engineering Department
IHI Corporation
1 Shin-Nakahara, Isogo
235-8501 Kanagawa
JAPAN
+81 45 759 2798
hiroaki_ohara@ihi.co.jp

Oostra Hendrikus
Haikutech Europe BV
Spoorweglaan
6221 BS Maastricht
NETHERLANDS
hoostra@haikutech.com

Oum Melissa
School of Chemical Engineering
University of Birmingham
Edgbaston
B15 2TT Birmingham
UNITED KINGDOM

Ouyang Mengzheng
Earth Science and Engineering
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
m.outang15@imperial.ac.uk

Packbier Ute
IEK-3
Forschungszentrum Jülich
Wilhelm Johnen Str
52428 Jülich
GERMANY
+492461615170
u.packbier@fz-juelich.de

Park JinSung
KCeraCell Co., Ltd.
465-9, Dabok-ro, Boksu-myeon
312923 Chungcheongnam-do
KOREA
kceracell@gmail.com

Park Jun-Young Prof.
Nanotechnology and Advanced Materaisl Engineering
Sejong University
379 Gwangjin-gu, Gunja-dong
143-747 Seoul
KOREA, REPUBLIC OF
+82234083848
jyoung@sejong.ac.kr

Peters Roland
IEK-3
Forschungszentrum Jülich GmbH
Leo-Brandt-Strasse
52428 Jülich
GERMANY
+492461614664
ro.petetrs@fz-juelich.de

Pianko-Oprych Paulina Dr.
Faculty of Chemical Engineering and Technology
West Pomeranian University of Technology, Szczecin
Al. Piastów 42
71-065 Szczecin
POLAND
+0048914494731
paulina.pianko@zut.edu.pl

Pillarisetti Praneeth
3450 Sandstone Cir
47201 Columbus
UNITED STATES
+13524430719
pran2eth@gmail.com

Ploner Alexandra
Frederiksborgvej 399
4000 Roskilde
DENMARK
+4593511509
aplo@dtu.dk

Poitel Stéphane
Fuelmat Group
EPFL
Rue de l'industrie 17
1951 Sion
SWITZERLAND
+41216958273
stephane.poitel@epfl.ch

Pöpke Hendrik
Kerafol - Keramische Folien GmbH
Koppe-Platz 1
92676 Eschenbach
GERMANY
hendrik-poepke@kerafol.com

Posdziech Oliver Dr.
Sunfire GmbH
Gasanstalt 2
01237 Dresden
GERMANY
oliver.posdziech@sunfire.de

Price Robert
JTSI Group, School of Chemistry,
University of St Andrews
University of St Andrews,
KY16 9ST St Andrews,
UNITED KINGDOM
+441334463814
rp63@st-andrews.ac.uk

Rachau Mathias
FuelCon AG
Steinfeldstr. 1
39179 Magdeburg-Barleben
GERMANY
sales@fuelcon.com

Ranaweera Manoj
Aeronautical and Automotive Engineering
loughborough university
LE113TU Leicestershire
UNITED KINGDOM
+44 1509 227 219
R.A.M.P.Ranaweera@lboro.ac.uk

Rass-Hansen Jeppe Dr.
New Business R&D
Haldor Topsøe A/S
Haldor Topsøes Allé 1
DK-2800 Kgs. Lyngby
DENMARK
+4522754283
JERH@topsoe.dk

Rautanen Markus Dr.
Fuel Cells
VTT Technical Research Centre of Finland
Biologinkuja 5
02044 Espoo
FINLAND
+358 405387552
markus.rautanen@vtt.fi

Recalde Mayra
Leeghwaterstraat 39
2628 CA Delft
NETHERLANDS
+31684543578
mayra.recalde@tudelft.nl

Rechberger Jürgen
AVL LIST GmbH
Hans-List Platz 1
8020 Graz
AUSTRIA
Doris.Schoenwetter@avl.com

Reiter Bernd
AVL LIST GmbH
Hans-List Platz 1
8020 Graz
AUSTRIA
Doris.Schoenwetter@avl.com

Richter Andreas
CerPoTech AS
Kvenildmyra 6
7093 Tiller
NORWAY
+46763059892
andreas.richter@cerpotech.com

Riedel Marc
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 68628205
marc.riedel@dlr.de

Riegraf Matthias
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 68628027
matthias.riegraf@dlr.de

Rinaldi Giorgio
Fuelmat Group
EPFL
Rue de l'industrie 17
1951 Sion
SWITZERLAND
+41216958273
giorgio.rinaldi@epfl.ch

Roehrens Daniel Dr.
IEK-1
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Straße
52425 Jülich
GERMANY
+49 2461 61 96650
d.roehrens@fz-juelich.de

Rolland Mélanie
Department of Industrial Engineering
University of Trento
Via Sommarive 9
38127 Trento
ITALY
+393497036701
melanie.rolland@unitn.it

Rothman Rachael Dr.
Chemical and Biological Engineering
University of Sheffield
Mappin St
S1 3JD Sheffield
UNITED KINGDOM
+44 114 2227574
r.rothman@sheffield.ac.uk

Roux Guilhem
CEATECH-LITEN
Rue des Martyrs 17
38054 Grenoble
FRANCE
guilhem.roux@cea.fr

Ruhland Sandro Dr.-Ing.
EBZ GmbH
Marschnerstraße 26
01307 Dresden
GERMANY
sandro.ruhland@ebz-dresden.de

Ruiz-Trejo Enrique
Earth Science and Engineering
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
eruiztre@imperial.ac.uk

Russner Niklas Dipl.-Ing.
Institut für Angewandte Materialien - Werkstoffe der Elektrotechnik (IAM-WET)
Karlsruher Institut für Technologie (KIT)
Adenauerring 20b
76131 Karlsruhe
GERMANY
+49 721 608-47980
niklas.russner@kit.edu

Sammes Nigel Dr.
Low Emissions Research Corp
17 State Street
10004 New York
UNITED STATES
+16469527023
nsammes@lercorp.com

Santhanam Srikanth
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 6862755
santhanam.srikanth@dlr.de

Santin Maria
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND
m.santin@efcf.com

Sarruf Bernardo
School of Chemical Engineering
University of Birmingham
Edgbaston
B15 2TT Birmingham
UNITED KINGDOM

SASAKI Kazunari Prof.
Kyushu University
744 Motooka
819-0395 Fukuoka
JAPAN
+81 92 802 3143
sasaki@mech.kyushu-u.ac.jp

Sato Koki
Fundamental Technology Dept.
TOKYO GAS CO., LTD.
A-5F, 3-13-1
116-0003 TOKYO
JAPAN
+81 3 5604 8285
k-sato1218@tokyo-gas.co.jp

Sato Kimihiko
CAP CO.,LTD
3415-42 Shinyoshidacho Kohoku-ku
223-0056 Yokohama
JAPAN
k-sato@cap-co.jp

Sato Atsuko
CAP CO.,LTD
3415-42 Shinyoshidacho Kohoku-ku
223-0056 Yokohama
JAPAN
k-sato@cap-co.jp

Schaefer Lawrence
8143 McCamidge Dr.
13039 Cicero, NY
UNITED STATES
+001 3154848490
larry@schaefer-city.net

Schafbauer Wolfgang Dr.
ISWB
Plansee SE
Metallwerk-Plansee-Str. 71
6600 Reutte
AUSTRIA
+43 5672 600 2439
wolfgang.schafbauer@plansee.com

Schäppi Kathrin
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND

Scharrer Michael Dr.
CeramTec AG
CeramTec-Platz 1-9
73207 Plochingen
GERMANY
M.Scharrer@Ceramtec.de

Schauperl Richard
AVL LIST GmbH
Hans-List Platz 1
8020 Graz
AUSTRIA
Doris.Schoenwetter@avl.com

Schauperl Richard
Research and Technology Powertrain Engineering
AVL List GmbH
Hans-List Platz 1
8020 Graz
AUSTRIA
+433167872168
richard.schauperl@avl.com

Scherer Günther G. Dr.
TUM Create
1 CREATE Way #10-02, CREATE Tower
138602 Singapore
SINGAPORE
guenther.scherer@tum-create.edu.sg

Schiemann Kevin
IEK-9
Forschungszentrum Jülich
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
+491776778892
k.schiemann@fz-juelich.de

Schiller Günter Dr.
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 6862635
guenter.schiller@dlr.de

Schilm Jochen Dr.
Fraunhofer Institut für Keramische Technologien und Systeme
Winterbergstr. 28
01277 Dresden
GERMANY
+4935125537824
jochen.schilm@ikts.fraunhofer.de

Schimanke Danilo
Sunfire GmbH
Gasanstalt 2
01237 Dresden
GERMANY
danilo.schimanke@sunfire.de

Schipke Mandy
NOVUM engineerING GmbH
Schnorrstrasse 70
01069 Dresden
GERMANY
+49 351 323 27003
m.schipke@novum-engineering.biz

Schluckner Christoph
Institute of Thermal Engineering
Graz University of Technology
Inffeldgasse 25/B
8010 Graz
AUSTRIA
+433168737811
christoph.schluckner@tugraz.at

Schrödl Nina
Chair of Physical Chemistry
Montanuniversität Leoben
Franz-Josef-Straße 18
8700 Leoben
AUSTRIA
+43 3842 4024809
nina.schroedl@unileoben.ac.at

Schröter Falk
NOVUM engineerING GmbH
Schnorrstrasse 70
01069 Dresden
GERMANY
f.schroeter@novum-engineering.biz

Schuler J. Andreas Dr.
HEXIS AG
Zum Park 5
8404 Winterthur
SWITZERLAND
+41 52 262 6318
andreas.schuler@hexis.com

Schuler Alexander Dr.
HEXIS AG
Zum Park 5
8404 Winterthur
SWITZERLAND
+41 52 262 8297
alexander.schuler@hexis.com

Selby Mark Dr.
Technology
Ceres Power
Viking House
RH13 5PX Horsham
UNITED KINGDOM
+441403273463
mark.selby@cerespower.com

Shen Zonghao
Materials
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
zonghao.shen12@imperial.ac.uk

Shimura Takaaki Dr.
Institute of industrial science, the university of Tokyo
4-6-1 Komaba Meguro-ku
153-8505 Tokyo
JAPAN
+81 3 5452 6777
tshimura@iis.u-tokyo.ac.jp

Shin Hyeong Cheol
KCeraCell Co., Ltd.
465-9, Dabok-ro, Boksu-myeon
312923 Chungcheongnam-do
KOREA
shhych@naver.com

shinkai masahiro
Planning Dvivision
TDK corp.
3-9-1 shibaura
1080023 Tokyo
JAPAN
+81 3 6852 7214
mshinkai@jp.tdk.com

Shul Yong Gun Prof.
Department of Chemical and Biomolecular Engineering
Yonsei Univercity
50, Yonsei-ro,Seodaemun-gu
03722 Seoul
KOREA, REPUBLIC OF
+82 10 4726 2758
shulyg@yonsei.ac.kr

Singh Prabhakar Dr.
Ceter for Clean Energy Engineering
University of Connecticut
44 Weaver Road
06269 Storrs Mansfield
UNITED STATES
+1 860 4868379
prabhakar.singh@uconn.edu

Sitte Werner Prof.
Physikalische Chemie
Montanuniversität Leoben
Franz-Josef-Strasse 18
A-8700 Leoben
AUSTRIA
+43 3842 402 4800
sitte@unileoben.ac.at

Skafte Theis
Haldor Topsøe A/S
Haldor Topsøes Allé 1
2800 Kgs. Lyngby
DENMARK
+4525529534
tlsk@topsoe.dk

Skinner Stephen Professor
Materials
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
02075946782
s.skinner@imperial.ac.uk

Skrabs Stefan
Plansee SE
Metallwerk Plansee-Strasse 71
6600 Reutte
AUSTRIA
stefan.skrabs@plansee.com

Song Bowen
Earth Science and Engineering
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
b.song15@imperial.ac.uk

Song Shin Ae Song Dr.
Micro/Nano Scale Manufacturing R&D Group
Korea Institute of Industrial Technology
KITECH D-318 143 Hanggaulro, Sangnok-gu
15588 Ansan-si, Gyeonggi-do
KOREA, REPUBLIC OF
+82 31 8040 6827
sasong@kitech.re.kr

Spirig Michael Dr.
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND
m.spirig@efcf.com

Spirig Leandra
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND
l.spirig@efcf.com

Standke Timothy
IMPCO Technologies, Inc.
7100 East 15 Mile Rd
48312 Sterling Heights
UNITED STATES
+1 7146046883
tstandke@impcotechnologies.com

Steffen Michael
European Fuel Cell Forum AG
Obgardihalde 2
6043 Adligenswil
SWITZERLAND
m.steffen@efcf.com

Stehlík Karin Dr.
Hydrogen Technologies
Centrum Výzkumu Rez
Hlavní 130
25068 Husinec-Rez
CZECH REPUBLIC
+420266172045
karin.stehlik@cvrez.cz

Steinberger-Wilckens Robert
School of Chemical Engineering
University of Birmingham
Edgbaston
B15 2TT Birmingham
UNITED KINGDOM
R.SteinbergerWilckens@bham.ac.uk

Stelter Michael Prof.
Fraunhofer IKTS
Fraunhofer IKTS
07629 Hermsdorf
GERMANY
+493660193013902
michael.stelter@ikts.fraunhofer.de

Stevenson Graham
Earth Science and Engineering
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
g.stevenson15@imperial.ac.uk

Su Pei-Chen Prof.
School of Mechanical and Aerospace Engineering
Nanyang Technological University
50 Nanyang Avenue
639798 Singapore
SINGAPORE
+6567905033
peichensu@ntu.edu.sg

Subotic Vanja
Institute of Thermal Engineering
Graz University of Technology
Inffeldgasse 25b/4
8010 Graz
AUSTRIA
+433168737319
vanja.subotic@tugraz.at

Sudireddy Bhaskar Reddy Dr.
Department of Energy Conversion and Storage
Technical University of Denmark
Frederiksborgvej 399
4000 Roskilde
DENMARK
+45 4677 5640
bhsu@dtu.dk

Sumi Hirofumi Dr.
Inorganic Functional Materials Research Institute
National Institute of Advanced Industrial Science and Technology (AIST)
2266-98, Anagahora, Shimo-shidami, Moriyama-ku
463-8560 Nagoya
JAPAN
+81 52 736 7592
h-sumi@aist.go.jp

Szabo Patric
Institute of Engineering Thermodynamics
DLR
Pfaffenwaldring 38-40
70569 Stuttgart
GERMANY
+49 711 6862494
patric.szabo@dlr.de

Szász Julian Dipl.-Ing.
Institut für Angewandte Materialien - Werkstoffe der Elektrotechnik (IAM-WET)
Karlsruher Institut für Technologie (KIT)
Adenauerring 20b
76131 Karlsruhe
GERMANY
+49 721 608-48796
julian.szasz@kit.edu

Takagi Yuto
Conductive Ceramics
Saint-Gobain
9 Goddard road
01532 Northboro, MA
UNITED STATES
+1 508 414 2298
yuto.takagi@saint-gobain.com

Tallgren Johan
Fuel Cells
VTT Technical Research Centre of Finland Ltd
Biologinkuja 5
02150 Espoo
FINLAND
+358406840646
johan.tallgren@vtt.fi

Tamazaki Fuminori
Daiichi Kigenso Kagaku Kogyo Co., Ltd.
4-4-7 Imabashi, Chuo-ku
541-0042 Osaka
JAPAN
hamada-t@zr.dkkk.co.jp

Tarancon Albert Dr.
IREC
C/Jardí de les Dones de Negre, 1, Planta 2
E-08930 Sant Adrià del Besòs (Barcelona)
SPAIN
+34933562615
atarancon@irec.cat

Tariq Farid
Earth Science and Engineering
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
farid.tariq02@imperial.ac.uk

Torrell Marc Dr.
NI-SOFC
IREC
Jardins dones de Negre 1
08930 St. Adrià de Besos
SPAIN
+34651993841
mtorrell@irec.cat

Turnbull Rob
10 Collington Road
EH10 5DT Edinburgh
UNITED KINGDOM
+447765002888
R.Turnbull@napier.ac.uk

van Biert Lindert
M&TT, P&E
Delft University of Technology
Mekelweg 2
2628CA Delft
NETHERLANDS
+31152788249
l.vanbiert@tudelft.nl

Van herle Jan Dr.
Fuelmat Group
EPFL
Rue de l'industrie 17
1951 Sion
SWITZERLAND
+41216958273
jan.vanherle@epfl.ch

Vesovic Toni
Fuelmat Group
EPFL
Rue de l'industrie 17
1951 Sion
SWITZERLAND
+41216958273
chantal.donaghey@epfl.ch

Vidal Karmele Dr.
Mineralogy and Petrology
University of Basque Country (UPV/EHU)
Barrio sarriena s/n
48940 Leioa
SPAIN
+34946015984
karmele.vidal@ehu.es

Vogt Ulrich Prof.
EMPA
Überlandstrasse 129
8600 Dübendorf
SWITZERLAND

Wain Aritza
Mineralogy and Petrology
University of the Basque Country
Facultad de Ciencia y Tecnología, Edificio F3 (sótanos -1 y -2)
48940 Leioa
SPAIN
+34 601 5984
aritza.wain@ehu.eus

Walter Christian Dr.
Sunfire GmbH
Gasanstalt 2
01237 Dresden
GERMANY
christian.walter@sunfire.de

Wankmüller Florian Dipl.-Ing.
Institut für Angewandte Materialien - Werkstoffe der Elektrotechnik (IAM-WET)
Karlsruher Institut für Technologie (KIT)
Adenauerring 20b
76131 Karlsruhe
GERMANY
+49 721 608-48794
florian.wankmueller@kit.edu

Weber André Dr.-Ing.
Institut für Angewandte Materialien - Werkstoffe der Elektrotechnik (IAM-WET)
Karlsruher Institut für Technologie (KIT)
Adenauerring 20b
76131 Karlsruhe
GERMANY
+49 721 608-47572
andre.weber@kit.edu

Wei Jianping
IEK-2
Forschungszentrum Jülich
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
+49 2461 61 9399
j.wei@fz-juelich.de

Wezenbeek Stef
BOSAL ECI
Kamerling Onnesweg 5
4131 PK Vianen
NETHERLANDS
Robert.vanDorst@eur.bosal.com

Wong Chi Ho
Materials
Imperial College
Prince Consort Road
SW7 2AZ London
UNITED KINGDOM
c.wong13@imperial.ac.uk

Wood Anthony
Materials R&D
Versa Power Systems
4852 52nd Street SE
T2B3R2 Calgary
CANADA
+14032046134
twood@fce.com

Xie Shuo Min
CHAOZHOU THREE-CIRCLE(GROUP)CO.,LTD
Sanhuan Industrial district, fengtang
515646 Chaozhou
CHINA
+867686859255
jennifer@cctc.cc

Yamamoto Tohru Dr.
Energy Engineering Research Laboratory
Central Research Institute of Electric Power Industry
Nagasaka 2-6-1
2400196 Yokosuka
JAPAN
+81468562121
tohru-y@criepi.denken.or.jp

Yamamoto Takuya
Daiichi Kigenso Kagaku Kogyo Co., Ltd.
4-4-7 Imabashi, Chuo-ku
541-0042 Osaka
JAPAN
hamada-t@zr.dkkk.co.jp

Yan Yulin
IEK-3: Elektrochemische Verfahrenstechnik
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Straße
52425 Jülich
GERMANY
+49 24 61 61 5487
y.yan@fz-juelich.de

Yashiro Keiji Prof.
Tohoku University
6-6-01 Aramakiaoba, Aoba-ku
9808579 Sendai
JAPAN
+81 22 795 6976
yashiro@ee.mech.tohoku.ac.jp

Yildiz Saffet
IEK-9
Forschungszentrum Jülich
Wilhelm-Johnen Straße
52425 Jülich
GERMANY
+49 2461 61 8841
s.yildiz@fz-juelich.de

Yin Xiaoyan
IEK-2
Forschungszentrum Jülich GmbH
Wilhelm-Johnen-Straße
52428 Jülich
GERMANY
+49 2461 61 5896
x.yin@fz-juelich.de

Yokokawa Harumi Prof.
Institute of Industrial Science
The University of Tokyo
4-6-1 Komaba, Meguro-tu
153-8505 Tokyo
JAPAN
+81 3 5452 6780
yokokawa@iis.u-tokyo.ac.jp

Z. Domingues Rosana Prof.
Chemistry
UFMG
Rua Percio Babo de Rezende 144
31310560 Belo Horizonte
BRAZIL
+5531999036738
rosanazd@yahoo.com.br

Zähringer Thomas
HEXIS AG
Zum Park 5
8404 Winterthur
SWITZERLAND
+41 58 934 71 68
thomas.zaehringer@hexis.com

Ziegler Cora
CeramTec AG
CeramTec-Platz 1-9
73207 Plochingen
GERMANY
C.Ziegler@Ceramtec.de

Zinko Tomasz
Institute of Chemical Engineering and Environmental Protection Processes
West Pomeranian University of Technology, Szczecin
al. Piastów 17
70-310 Szczecin
POLAND
+48 511788807
tomasz.zinko@zut.edu.pl

List of Institutions

Related to Participants Registered until 16 June 2016

12th EUROPEAN SOFC & SOE FORUM 2016

5 - 8 July 2016

Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

3mE, Delft University of Technology
Delft/The Netherlands

AB Sandvik Materials Technology
Sandviken/Sweden

Abengoa Hidrogeno, Energía Solar nº1
Seville/Spain

Adelan
Birmingham/United Kingdom

Advanced Materials Laboratory, Department of Mechanical Engineering, University of Chile
Santiago/Chile

Advanced Research Centre for Electric Energy StorageKyushu University
Fukuoka/Japan

AGH University of Science and Technology
Krakow/Poland

Alantum
Sangdaewon/Seongnam/Korea

ALMUS AG
Oberrohrdorf/Switzerland

Alternative Energy Lab., Boğaziçi University, Department of Chemistry
Istanbul/Turkey

AMES Carrer de Laureà Miró
Barcelona/Spain

Anan Kasei Co., Ltd.
Anan/Tokushima /Japan

AVL List GmbH
Graz/Austria

Boeing
Huntington Beach/USA

Bosal ECS NV
Lummen/Belgium

Cambridge Centre for Analysis, University of Cambridge
Cambridge/United Kingdom

Catalonia Institute for Energy Research (IREC)
Barcelona/Spain

Catalonia Institute for Energy Research (IREC), Department of Advanced Materials for Energy
Barcelona/Spain

CEA
Grenoble/France

CEA/-Le Ripault DMAT
Monts/France

CEA-Grenoble, LITEN
Grenoble/France

Center for Clean Energy Engineering, Materials Science and Engineering, University of Connecticut
Storrs/USA

Center for Co-Evolutional Social Systems (CESS), Kyushu University
Fukuoka/Japan

Center for Thorium Molten Salt Reactor System, Shanghai Institute of Applied Physics, Chinese Academy of Sciences
Shangha/China

Central Institute of Engineering, Electronics and Analytics - Forschungszentrum Jülich GmbH
Jülich/Germany

Central Research Institute of Electric Power Industry (CRIEPI)
Yokosuka/Kanagawa/Japan

Centre for Fuel Cell and Hydrogen Research, School of Chemical Engineering, University of Birmingham
Birmingham/England

Ceraco Ceramic Coating GmbH
Ismaning/Germany

Ceramatec, Inc.
Salt Lake City/USA

Ceramic Powder Technology AS
Tiller/Norway

Ceramics Laboratory, Ecole Polytechnique Fédérale de Lausanne (EPFL)
Lausanne/Switzerland

CeramTec GmbH
Marktredwitz/Germany

Ceres Power Ltd.
Horsham/United Kingdom

CerPoTech AS
Tiller/Norway

Chair of Physical Chemistry, Montanuniversitaet Leoben
Leoben/Austria

Chalmers University of Technology, Energy and Materials
Göteborg/Sweden

Chemical Engineering Department, Faculty of Engineering, University of Malaya
Kuala Lumpur/Malaysia

Chemical Engineering, University of Waterloo
Ontario/Canada

China Steel Corporation
Kaohsiung/Taiwan

Chonnam National University, Ionics Laboratory, School of Materials Science and Engineering
Gwang-Ju/Republic of Korea

Christian Doppler Laboratory for Interfaces in Metal-Supported Electrochemical Energy Converters
Jülich/Germany

CICECO, Department of Materials and Ceramic Engineering, University of Aveiro
Aveiro/Portugal

CIEMAT
Madrid/Spain

Clausthaler Umwelttechnik-Institut GmbH
Clausthal-Zellerfeld/Germany

CNR-ITAE
Messina/Italy

CNRS, ICMCB
Pessac/France

CNRS, Laboratoire d'Electrochimie et de Physico-Chimie des Matériaux et des Interfaces
Grenoble/France

College of Engineering, Peking University
Beijing/China

Convion Ltd
Espoo/Finland

CoorsTek Membrane Sciences Norway
Oslo/Norway

CSIR-Central Glass and Ceramic Research Institute, Fuel Cell & Battery Division
Kolkata/India

Czech Hydrogen Technology Platform
Prague/Czech Republic

DAFNE, University of Tuscia
Viterbo/Italy

Dassault Systemes
Bangalore/India

Department of Advanced Energy Technology, University of Science and Technology
Daejeon/Republic of Korea

Department of Aeronautical & Automotive Engineering Department, Loughborough University
Loughborough/United Kingdom

Department of Aeronautics and Astronautics, Kyoto University
Nishikyo-ku/Kyoto/Japan

Department of Applied Physics, Aalto University
Aalto/Finland

Department of Chemical and Bio-molecular Engineering, Yonsei University
Seoul/Republic of Korea

Department of chemical and process engineering, Faculty of Integrated Technology, University Brunei Darussalam
Gadong/Brunei Darussalam

Department of Chemical Engineering, Chungbuk National University
Seowon-gu Cheong-ju/Chungbuk/Korea

Department of Chemical Engineering, Imperial College London
London/United Kingdom

Department of Chemical Engineering, Indian Institute of Technology
New Delhi/India

Department of Chemistry and Chemical Engineering, Chalmers University of Technology
Gothenburg/Sweden

Department of Chemistry, Belarusian State University
Minsk/Belarus

Department of Chemistry, University of Calgary
Calgary, Alberta/Canada

Department of Chemistry, Xi'an Jiaotong-Liverpool University
Suzhou/China

Department of Civil and Industrial Engineering, University of Pisa
Pisa/Italy

Department of Civil, Chemical and Environmental Engineering, University of Genoa
Genoa/Italy

Department of Earth Science & Engineering, Imperial College London
London/United Kingdom

Department of Energy Conversion and Storage, Technical University of Denmark (DTU)
Roskilde/Denmark

Department of Energy, Politecnico di Milano
Milano/Italy

Department of Graduate Program in New Energy and Battery Engineering, Yonsei University
Seoul/Republic of Korea

Department of Hydrogen Energy Systems, Graduate School of Engineering, Kyushu University
Fukuoka/Japan

Department of Materials & Metallurgical Engineering, Colorado School of Mines
Golden/USA

Department of Materials and Environmental Chemistry, Stockholm University
Stockholm/Sweden

Department of Materials Science and Engineering, Gebze Technical University
Kocaeli/Turkey

Department of Materials Science and Engineering, Norwegian University of Science and Technology
Trondheim/Norway

Department of Materials Science and Engineering, University of Alabama at Birmingham
Birmingham/Alabama/USA

Department of Materials Science and Engineering, Yonsei University
Seoul/Republic of Korea

Department of Materials, Royal School of Mines, Imperial College
London/United Kingdom

Department of Mathematics, South Kensington Campus, Imperial College London
London/United Kingdom

Department of Mechanical and Industrial Engineering, Università di Brescia
Brescia/Italy

Department of Mechanical Engineering and Energy Processes, Southern Illinois University Carbondale
Carbondale/USA

Department of Mechanical Engineering, Babol University of Technology
Babol/Iran

Department of Mechanical Engineering, Graduate School of Engineering
Tokyo/Japan

Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology
Daejeon/Republic of Korea

Department of Mechanical Engineering, Korea University
Seoul/South Korea

Department of Mechanical Engineering, Kyushu University
Fukuoka/Japan

Department of Mechanical Engineering, National Central University
Jhong-Li/Taiwan

Department of Mechanical Engineering, University of Connecticut
Storrs/USA

Department of Mechanical Science and Engineering, Hiroshima University,
Hiroshima/Japan

Department of Nanotechnology and Advanced Materials Engineering, Sejong University
Seoul/Korea

Department of Physics, University of Rome Tor Vergata
Roma/Italy

Department of Science and Technology, Parthenope University
Naples/Italy

Department of systems engineering, Faculty of Integrated Technology, University Brunei Darussalam
Gadong/Brunei Darussalam

Dept. of Civil, Chemical and Environmental Engineering, University of Genoa
Genoa/Italy

Dept. of Energy
Beer Sheva/Israel

Dept. of Mechanical Engineering
Beer Sheva/Israel

Dipartimento di Ingegneria Industriale e Scienze Matematiche, Università Politecnica delle Marche
Ancona/Italy

DLR e.V.
Stuttgart/Germany

Drexel University
Philadelphia/USA

DTE-PCU-SPCT, ENEA C.R. Casaccia
Rome/Italy

DTU
Roskilde/Denmark

DTU Chemical Engineering
Kgs. Lyngby/Denmark

E4Tech
Lausanne/Switzerland

Earth Science and Engineering Department, Imperial College London
London/United Kingdom

École polytechnique fédérale de Lausanne Valais/Wallis
Sion/Switzerland

Edinburgh Napier University
Edinburgh/Scotland/United Kingdom

EIFER
Karlsruhe/Germany

Elcogen AS
Tallinn/Estonia

Elcogen Oy
Vantaa/Finland

Electric Energy Express
ChuBei, Hsinchu 302/Taiwan

Electrochemical Innovation Lab, Department of Chemical Engineering, University College London
London/United Kingdom

Electrochemical Reaction and Technology Laboratory, School of Environmental Science and Engineering, Gwangju Institute of Science and Technology (GIST)
Gwangju/South Korea

ElringKlinger AG
Dettingen/Germany

ENEA CR Casaccia
Rome/Italy

Energy and Materials, Chalmers University of Technology
Gothenburg/Sweden

Energy Department, CIEMAT
Madrid/Spain

Energy Department, Politecnico di Milano
Milan/Italy

Energy Department, Politecnico di Torino
Torino/Italy

Energy Policy Research Team, Korea Institute of Energy Research
Daejeon/Republic of Korea

Energy Research Institute at NTU (ERIAN), Nanyang Technological University
Singapore/Singapore

Ertl Center for Electrochemistry and Catalysis, Research Institute for Solar and Sustainable Energies
Gwangju/South Korea

European Fuel Cell Forum
Luzern/Switzerland

European Institute for Energy Research (EIFER)
Karlsruhe/Germany

Faculty of Chemical Technology and Engineering, Institute of Chemical Engineering and Environmental Protection Processes, West Pomeranian University of Technology
Szczecin/Poland

Faculty of Civil Engineering, Universiti Teknologi MARA Pahang
Pahang/Malaysia

Faculty of Engineering (Hydrogen Energy Systems)
Fukuoka/Japan

Faculty of Engineering, Kyushu University
Fukuoka/Japan

Faculty of Integrated Technologies, Universiti Brunei Darussalam
Gadong/Brunei Darussalam

Faculty of Materials and Energy, Southwest University
Chong Qing/China

Faculty of Physics and Technology
Bergen/Norway

FAE
L'Hospitalet de Llobregat/Spain

FCH JU
Busssles/Belgium

Federal University of Minas Gerais: Faculty of Chemistry, Faculty of Economics
Minas Gerais/Brazil

Federal University of Minas Gerais-Departamento de Química
Minas Gerais/Brazil

Federal University of São João del Rei
Sete Lagoas/Minas Gerais/Brazil

Fiaxell Sàrl
Lausanne/Switzerland

Fine Chemical and Material Technical Institute
Ulsan/Republic of Korea

Forschungszentrum Jülich GmbH , Institute of Energy and Climate Research
Jülich/Germany

Forschungszentrum Jülich GmbH, Central Institute for Engineering, Electronics and Analytics (ZEA)
Jülich/Germany

Forschungszentrum Jülich GmbH, IEK-2
Jülich/Germany

Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research – Materials Synthesis and Processing (IEK-1)
Jülich/Germany

Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK)
Jülich/Germany

Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK-1)
Jülich/Germany

Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research, Fundamental Electrochemistry (IEK-9)
Jülich/Germany

Forschungszentrum Jülich, Central Institute of Engineering, Electronics and Analytics (ZEA) - Engineering and Technology (ZEA-1)
Jülich/Germany

Fraunhofer IKTS
Dresden/Germany

Fuel Cell Research Laboratory, Korea Institute of Energy Research (KIER)
Yuseong-gu/Daejeon/Korea

FuelCell Energy, Inc.
Danbury/USA

FUELMAT group, École Polytechnique Fédérale de Lausanne (EPFL)
Sion/Switzerland

FUELMAT Group, EPFL Valais
Sion/Switzerland

FUELMAT Group, Faculty of Engineering Sciences (STI), Ecole Polytechnique Fédérale de Lausanne (EPFL)
Lausanne/Switzerland

Fuelmat Group, Faculty of Engineering Sciences and Technology STI, Ecole Polytechnique Fédérale de Lausanne
Lausanne/Switzerland

FUELMAT Group, Inst. Mech. Eng., Ecole Polytechnique Fédérale de Lausanne Valais (EPFL Valais)
Sion/Switzerland

FUELMAT Group, Institute of Mechanical Engineering, Faculty of Engineering Sciences and Technology, EPFL
Sion/Switzerland

Fundamental Technology Department, Tokyo Gas Co. Ltd.
Yokohama City/Kanagawa/Japan

Fusion Energy Group, Future Technology Research Lab., Korea Electric Power Research Institute (KEPRI), Korea Electric Power Corporation (KEPCO)
Munji-Ro/Yuseong-Gu/Daejeon/Republic of Korea

Gaia Energy Research Institute
Arlington/VA/USA

German Aerospace Center (DLR)
Stuttgart/Germany

German Aerospace Center (DLR), Institute for Engineering Thermodynamics
Stuttgart/Germany

German Aerospace Center (DLR), Institute for Technical Thermodynamics
Stuttgart/Germany

Graduate School of Engineering, The University of Tokyo
Tokyo/Japan

Graduate School of Environmental Studies, Tohoku University
Sendai/Japan

Gurion University of the Negev: Faculty of Engineering
Beer Sheva/Israel

Haldor Topsoe A/S
Kgs. Lyngby/Denmark

Hexis AG
Winterthur/Switzerland

High-temperature Energy Materials Research Center, Korea Institute of Science and Technology (KIST)
Seoul/South Korea

HTceramix SA
Yverdon-les-Bains/Switzerland

Hydrogen Laboratory COPPE, Metallurgical and Materials Engineering, Federal University of Rio de Janeiro
Rio de Janeiro/Brazil

ICE Strömungsforschung GmbH
Leoben/Austria

ICP – Institute for Computational Physics, ZHAW – Zurich University of Applied Sciences
Winterthur/Switzerland

IMPE - Institute for Materials and Process Engineering
Winterthur/Switzerland

Imperial College London, Department of Materials, Royal School of Mines
London/United Kingdom

Indian Institute of Technology, Delhi
New Delhi/India

Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT)
Karlsruhe/Germany

Institute for Electron Microscopy and Nanoanalysis (FELMI), Graz University of Technology & Graz Center for Electron Microscopy (ZFE), Austrian Cooperative Research (ACR)
Graz/Austria

Institute for Electron Microscopy and Nanoanalysis of the TU Graz (FELMI), Graz University of Technology
Graz/Austria

Institute for Energy Systems, Technische Universität München
Garching/Germany

Institute of Chemical Technologies and Analytics, Technical University Vienna
Vienna/Austria

Institute of Energy and Climate Research (IEK-1), Forschungszentrum Jülich GmbH
Jülich/Germany

Institute of Energy and Climate Research IEK-9, Forschungszentrum Jülich GmbH
Jülich/Germany

Institute of Industrial Science, The University of Tokyo
Tokyo/Japan

Institute of Nuclear Energy Research
Taoyuan City/Taiwan

Institute of Physics of Materials (IPM)
Brno/Czech Republic

Institute of Thermal Engineering, Graz University of Technology
Graz/Austria

Institute of Thermodynamics, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture FESB
Split/Croatia

Instituto de Ciencia de Materiales de Aragón (ICMA), CSIC-Universidad de Zaragoza
Zaragoza/Spain

Interdisciplinary Centre for Electron Microscopy (CIME), Ecole Polytechnique Fédérale de Lausanne (EPFL)
Lausanne/Switzerland

International Institute for Carbon-Neutral Energy Research (WPI-I2CNER)
Fukuoka/Japan

International Institute for Carbon-Neutral Energy Research (WPI-I2CNER) Kyushu University
Fukuoka/Japan

International Research Center for Hydrogen Energy, Kyushu University
Fukuoka/Japan

Ionics Lab, School of Materials Science and Engineering, Chonnam National University
Buk-gu/Gwang-Ju/Republic of Korea

IQM Elements Ltd, Quantitative Imaging Division
London/United Kingdom

IREC, Catalonia Institute for Energy Research, Dept of Advanced Materials for Energy Applications
Barcelona/Spain

ITQ UPV-CSIC
Valencia/Spain

JST CREST
Saitama/Japan

JST PRESTO
Saitama/Japan

Juelich Research Center IEK-3: Electrochemical Process Engineering
Jülich/Germany

Jülich Aachen Research Alliance: JARA-Energy
Aachen/Germany

Karlsruhe Institute of Technology (KIT)
Karlsruhe/Germany

Karlsruhe Institute of Technology, Engler-Bunte-Institute
Karlsruhe/Germany

KCeraCell Co., Ltd.
Geumsan-gun/Chungcheongnam-do/Republic of Korea

Kerafol GmbH
Eschenbach i. d. Opf./Germany

Korea Advanced Institute of Science and Technology (KAIST)
Daehak-ro/Yuseong-gu/Daejeon

Korea Institute of Energy Research (KIER)
Daejeon/Republic of Korea

Korea Institute of Industrial Technology
Ansan/South Korea

Korea Institute of Machinery and Materials (KIMM)
Daejeon/Republic of Korea

Korea Institute of Science and Technology (KIST)
Seoul/Korea

Kumoh National Institute of Technology
Gumi/Gyeongbuk/Korea

Kyoto University
Kyoto/Japan

Kyushu University
Fukuoka/Japan

Laboratoire Réactions et Génie des Procédés, CNRS-Univ. Lorraine
Nancy/France

Laboratory for Electron Microscopy (LEM), Karlsruhe Institute of Technology (KIT)
Karlsruhe/Germany

Laboratory of Heterogeneous Mixtures and Combustion Systems, Thermal Engineering Section, School of Mechanical Engineering, National Technical University of Athens
Athens/Greece

Laboratory of Metallurgy and Materials, DCCI, University of Genoa
Genoa/Italy

Lancaster University Engineering Dept.
Lancaster/United Kingdom

Lawrence Berkeley National Laboratory
Berkeley/USA

Lehrstuhl für Energiesysteme, Technische Universität München
Garching/Germany

Los Alamos National Laboratory
Los Alamos/USA

EringKlinger AG
Dettingen/Erms/Germany

Max Planck Institute for Plasma Physics
Garching/Germany

Microsoft Infrastructure & Operations
USA

Montanuniversitaet Leoben, Chair of Physical Chemistry
Leoben/Austria

National Fuel Cell Research Center (NFCRC)
Yuseong-Gu/Daejeon/KoreaYuseong-Gu
Daejeon/Republic of Korea

National Institute of Advanced Industrial Science and Technology (AIST)
Moriyama-ku/Nagoya/Japan

National Institute of Advanced Industrial Science and Technology
Tsukuba
Ibaraki/Japan

New Energy Technology Institute
Ulsan/Republic of Korea

Next-Generation Fuel Cell Research Center (NEXT-FC), Kyushu University
Fukuoka/Japan

NGK Insulators Ltd.
Tokyo/Japan

NGK Spark Plug CO. Ltd
Nagoya/Japan

Nissan Technical Center
Michigan/USA

NRCN
Beer Sheva/Israel

NTU
Singapore/Singapore

Nuclear Fuels and Materials Division, Institute of Nuclear Energy Research
Lung-Tan/Taiwan

Paul Scherrer Institut, General Energy Research Department, Bioenergy and Catalysis Laboratory
Villigen/Switzerland

Plansee SE
Reutte/Austria

Process and Energy Department, Delft University of Technology
CA Delft/The Netherlands

Prototech AS
Bergen/Norway

Research Center Rez
Prague/Czech Republic

Research Institute for Energy Conservation, National Institute of Advanced Industrial Science and Technology
Tsukuba/Ibaraki/Japan

RIST
Gyeongbuk/Korea

Robert Bosch GmbH
Renningen/Germany

RWTH Aachen University Lehrstuhl für Brennstoffzellen, Fakultät für Maschinenwesen
Aachen/Germany

School of Chemical Engineering, College of Engineering and Physical Sciences University of Birmingham
Birmingham/England

School of Chemical Engineering, University of Birmingham
Edgbaston/United Kingdom

School of Chemistry, University of St Andrews
St Andrews/United Kingdom

School of Energy and Chemical Engineering, UNIST
Ulsan/Republic of Korea

School of Materials Science and Engineering, Changwon National University
Gyeongnam/South Korea

School of Mechanical and Aerospace Engineering, Nanyang Technological University
Singapore/Singapore

School of Mechanical Engineering, College of Engineering, University of Tehran
Tehran/Iran

School of Metallurgy and Material, University of Birmingham
Edgbaston/Birmingham/United Kingdom

School of Metallurgy and Materials Eng. College of Engineering, University of Tehran
Tehran/Iran

SCI-STI-JVH FUELMAT Group, Faculty of Engineering Sciences (STI), Ecole Polytechnique Fédérale de Lausanne (EPFL)
Sion/Switzerland

Shanghai Branch, Chinese Academy of Sciences
Shanghai/P. R. China

Shanghai Institute of Applied Physics, Chinese Academy of Sciences
Shanghai/P. R. China

Singapore-Peking University Research Centre, Campus for Research Excellence & Technological Enterprise (CREATE)
Singapore/Singapore

SINTEF Materials and Chemistry
Oslo/Norway

SOLIDpower S.p.a.
Mezzolombardo/Italy

Sunfire GmbH
Dresden/Germany

Sustainable Gas Institute, Imperial College
London/United Kingdom

Swiss Federal Office of Energy
Bern/Switzerland

Sylfen
Grenoble/France

Technical University of Denmark, Department of Energy Conversion and Storage
Roskilde/Denmark

Technion, Israel Institute of Technology
Haifa/Israel

Teer Coatings Ltd, Miba Coating Group
Droitwich/United Kingdom

The Hydrogen Laboratory-Coppe – Department of Metallurgy and Materials Engineering, Federal University of Rio de Janeiro
Rio de Janeiro/Brazil

The Johns Hopkins University, Whiting School of Engineering
Baltimore/USA

The University of Tokyo
Tokyo/Japan

thyssenkrupp Marine Systems GmbH
Hamburg/Germany

Tokyo Gas Co., Ltd., Fundamental Technology Dept.
Yokohama/Japan

Transportation Sustainability Research Center
California/USA

Turbocoating S.p.a.
Rubbiano di Solignano/Italy

ÚJV Rez
Prague/Czech Republic

Univ. Grenoble Alpes, LEPMI
Grenoble/France

Univ. Grenoble Alpes, LMGP
Grenoble/France

Universidad del País Vasco/ Euskal Herriko Unibertsitatea (UPV/EHU), Facultad de Ciencia y Tecnología
Bilbao/Spain

Universidade Federal de Minas Gerais: Faculty of Chemistry
Pampulha/Belo Horizonte/Brazil

Università di Perugia - Dipartimento di Ingegneria
Perugia/Italia

Université Grenoble Alpes, Laboratoire d'Electrochimie et de Physico-Chimie des Matériaux et des Interfaces
Grenoble/France

University of California Berkeley
Etcheverry Hall/USA

University of Chemistry and Technology Prague, Department of Inorganic Technology
Praha/Czech Republic

University of Connecticut
Storrs/USA

University of Genoa: Department of Civil, Chemical and Environmental Engineering (DICCA)
Genoa/Italy

University of Oslo
Oslo/Norway

University of Science and Technology (UST)
Yuseong-Gu/Daejeon/Republic of Korea

University of Trento, Department of Industrial Engineering
Trento/Italy

University West
Trollhättan/Sweden

USP-IQSC
São Carlos/Brasil

Versa Power Systems, Ltd.
Calgary/Alberta/Canada

VTT Technical Research Centre of Finland Ltd, Fuel Cells
Helsinki/Finland

West Pomeranian University of Technology,Institute of Chemical Engineering and Environmental Protection Processes
Szczecin/Poland

Zentrum für BrennstoffzellenTechnik GmbH
Duisburg/Germany

Integrated IT-tool & services for technology status evaluation **Applied for Hydrogen and Fuel Cells**

TEMONAS

Technology Monitoring + Analysis System

info@fomenta.ch

Fomenta AG
Fomenting Energy & Technology

List of Exhibitors

Registered by 16 June 2016

12th EUROPEAN SOFC & SOE FORUM 2016

5 - 8 July 2016

	Company	Exhibits
A10	**Almus AG** Morgenacherstr. 2F 5453 Oberrohrdorf **Switzerlandhg** www.almus-ag.ch	UBOCELL SOFC Module SOFC Demo-Kit portable SOFC systems
A11	**AVL List GmbH** Hans-List Platz 1 8020 Graz **Austria** www.avl.com	SOFC APU
B15	**Bosal Energy Conversion Industry** Kamerling Onnesweg 5 4130 PK Vianen The Netherlands www.eci.bosal.com	SOFC / SOEC heat exchangers
B10	**Bronkhorst (Schweiz) AG** Nenzlingerweg 5 4153 Reinach Switzerland www.bronkhorst.com	Massflowmeter and controler for gas and liquid, pressure meter and controller, controlled evaporater
A08	**CAP CO., Ltd.** 3415-42 Shinyoshidacho, Kohoku-ku 223-0056 Yokohama, Japan www.cap-co.jp	Anode gas recycle blower
A12	**CEATECH - LITEN** 17, rue des Martyrs 38058 Grenoble France www.liten.cea.fr	R&D for SOFC and SOE

B11 + B12	**CeramTec - The Ceramic Experts** Ceram Tec-Platz 1-9 73207 Plochingen Germany **www.ceramtec.com/ceramcell**	Ceramic SOFC components
B01	**Daiichi Kigenso Kagaku Kogyo Co., Ltd.** 4-4-7 Imabashi, Chuo-ku 541-0042 Osaka **Japan** **www.dkkk.co.jp**	Scandium stabilized zirconia powders
A14 + A15	**DOWA HD Europe GmbH** Ostendstrasse 196 90482 Nürnberg Germany **www.dowa-electronics.co.jp**	Perovskite-type complex oxide powder (SOFC) Various oxides that can be used as the materials for electrodes and electrolytes.
B13	**EBZ GmbH** Marschnerstraße 26 01307 Dresden Germany **www.ebz-dresden.de**	SOFC Stack- & Cell Test Rigs, SOFC Components

B20	**Fiaxell Sarl** Aloyse-Fauquez 31 1018 Lausanne Switzerland **www.fiaxell.com**	Test setup and components for fuelcell
A06	**FLEXITALLIC Ltd** Hunsworth Lane Cleckheaton BD19 4LN West Yorkshire United Kingdom **www.flexitallicsofc.com**	Gasket & sealing products - Thermiculite 866
B03	**Fomenta AG / Temonas*** Schufelistrasse 3a 8863 Buttikon Switzerland **www.fomenta.ch**	FCH Services and Technology Monitoring and Assessment
B07 + B08	**Forschungszentrum Jülich GmbH** Wilhelm-Johnen-Strasse 52428 Jülich Germany **www.fz-juelich.de**	R&D for SOFC, SOE and ROB

B21	**Fraunhofer IKTS** Winterbergstrasse 28 01277 Dresden Germany www.ikts.fraunhofer.de	CFY stacks, eneramic fuel cell system, cerenergy high-temperature battery
B09	**fuelcellmaterials** 404 Enterprise Drive 43035 Lewis Center **United States** www.fuelcellmaterials.com	SOFC materials, components, testing equipment, and interconnect coatings
B19	**FuelCon AG** Steinfeldstrasse 1 39179 Magdeburg-Barleben Germany www.fuelcon.com	Testing assembling & diagnostic systems for fuel cells & batteries
B02	**G. Bopp & Co. AG** Bachmannweg 21 8046 Zürich **Switzerland** www.bopp.ch	High precision woven wire cloth for SOFC anodes made of AISI 304 / AISI 316 / Nickel / Crofer / Inconel etc.

B03	**Greenlight Innovation*** 104A – 3430 Brighton Av. Burnaby, BC V5A 3H4 **Canada** www.greenlightinnovation.com	SOFC & SOEC cell and stack test stations. Fuel cell diagnostics and testing software. Automated fuel cell manufacturing equipment.
B14	**Haikutech Europe BV** Spoorweglaan 16 6221 BS Maastricht **The Netherlands** www.haikutech.com	Equipment for SOFC manufacturing, tape casers, screenprinters
A09	**KCeraCell Co., Ltd.** 465-9, Dabok-ro, Boksu-myeon, Chungcheongnam-do, 312923 32702 Geumsan-gun Republic of Korea www.kceracell.com	Electrolyte, cathode, anode and interconnect materials /various SOFC cells
B06	**KERAFOL GmbH** Stegenthumbach 4-6 92676 Eschenbach i.d.Opf. Germany www.kerafol.com	Electrolyte substrates, ceramic fuel cells

B09	**Nexceris, LLC** 404 Enterprise Drive 43035 Lewis Center **United States** **www.nexceris.com**	SOFC materials, components, testing equipment, and interconnect coatings
A07	**NOVUM engineerING GmbH** Schnorrstrasse 70 01069 Dresden Germany **www.novum-engineering.biz**	Real time monitoring fuel cell inverter
B18	**PLANSEE SE** Metallwerk Plansee Str. 71 6600 Reutte Austria **www.plansee.com**	SOFC stack components
B17	**Praxair Surface Technologies, Inc.** 16130 Wood-Red Road Suite 7 98072 Woodinville, WA USA **www.praxair.com/specialtyceramics**	Manufacturer of multi-component oxide powders and shapes specializing in cathode, anode, interconnects, electrolytes and barrier layers for SOFC's and SOE's

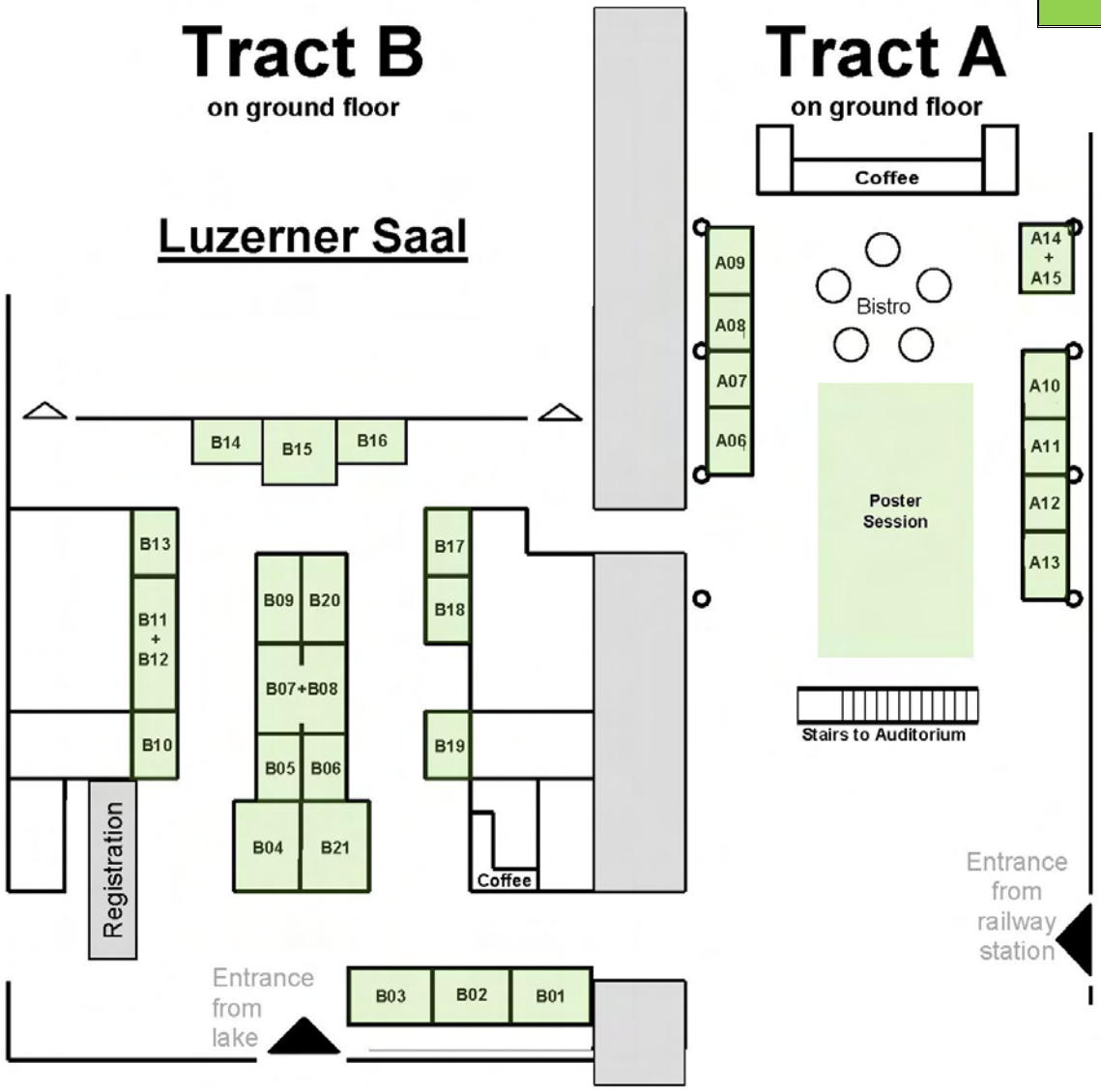
B03	**SOLIDpower S.p.A.*** Viale Trento, 115/117 C/O BIC 38017 Mezzolombardo (TN) Italy **www.solidpower.com**	BlueGen uCHP system, SOFC&SOE Stacks
B05	**Sunfire GmbH** Gasanstalt 2 01237 Dresden Germany **www.sunfire.de**	SOFC
B04	**Swagelok Switzerland** **c/o ARBOR Fluidtec AG** Loonstrasse 10 5443 Niederrohrdorf Switzerland **www.arbor.swagelok.com**	Fluid & gas system components and services
A13	**SYLFEN** MINATEC, BHT bâtiment 52 7 Parvis Louis Néel 38040 Grenoble Cedex 9 France **www.sylfen.com**	Sylfen Energy Hub based on reversible fuel cell technology

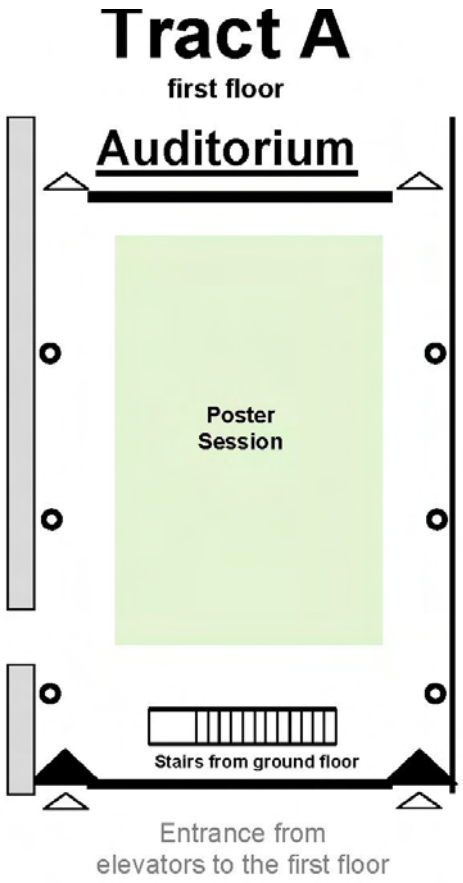
Florplan

Exhibition - Poster - Registration

B16	**Werner Mathis AG** Rütisbergstrasse 3 8156 Oberhasli Switzerland www.mathisag.com	Coating, calandering, relaxing machine

*Sponsor Exhibitors





List of Booths

Registered by 16 June 2016

12th EUROPEAN SOFC & SOE FORUM 2016

5 - 8 July 2016 KKL Lucerne/Switzerland

*Sponsor Exhibitors

Booth	Exhibitor	Country	Website
A06	FLEXITALLIC Ltd	United Kingdom	www.flexitallicsofc.com
A07	NOVUM engineerING GmbH	Germany	www.novum-engineering.biz
A08	CAP CO., Ltd.	Japan	www.cap-co.jp
A09	KCeraCell Co., Ltd.	Republic of Korea	www.kceracell.com
A10	Almus AG	Switzerland	www.almus-ag.ch
A11	AVL List GmbH	Austria	www.avl.com
A12	CEATECH - LITEN	France	liten.cea.fr
A13	SYLFEN	France	sylfen.com
A14/15	DOWA HD Europe GmbH	Germany	www.dowa-electronics.co.jp
B01	Daiichi Kigenso Kagaku Kogyo Co., Ltd.	Japan	www.dkkk.co.jp
B02	G. Bopp & Co. AG	Switzerland	www.bopp.ch
	Fomenta AG / Temonas*	Switzerland	www.fomenta.ch
B03	Greenlight Innovation*	Canada	www.greenlightinnovation.com
	SOLIDpower S.p.A.*	Italy	www.solidpower.com

B04	**Swagelok Switzerland c/o ARBOR Fluidtec AG**	Switzerland	arbor.swagelok.com
B05	**Sunfire GmbH**	Germany	www.sunfire.de
B06	**KERAFOL GmbH**	Germany	www.kerafol.com
B07/08	**Forschungszentrum Jülich GmbH**	Germany	www.fz-juelich.de
B09	**Fuelcellmaterials**	United States	www.fuelcellmaterials.com
	Nexceris, LLC	United States	www.nexceris.com
B10	**Bronkhorst (Schweiz) AG**	Switzerland	www.bronkhorst.com
B11/12	**CeramTec -The Ceramic Experts**	Germany	www.ceramtec.com/ceramcell
B13	**EBZ GmbH**	Germany	www.ebz-dresden.de
B14	**Haikutech Europe BV**	The Netherlands	www.haikutech.com
B15	**Bosal Energy Conversion Industry**	The Netherlands	www.eci.bosal.com
B16	**Werner Mathis AG**	Switzerland	www.mathisag.com
B17	**Praxair Surface Technologies, Inc.**	United States	www.praxair.com/specialtyceramics
B18	**PLANSEE SE**	Austria	www.plansee.com
B19	**FuelCon AG**	Germany	www.fuelcon.com
B20	**Fiaxell Sarl**	Switzerland	www.fiaxell.com
B21	**Fraunhofer IKTS**	Germany	www.ikts.fraunhofer.de

Outlook 2017

In this moment of preparation, we are excited to see all the valuable contributions and efforts of so many authors, scientific committee and advisors, exhibitors and staff materialising in this 12th EUROPEAN SOFC & SOE FORUM 2016. However, looking a short glance beyond these intensive days, we see another important event emerging at a not too far horizon in 2017:

Science, Facts and Figures

at the

6th European PEFC & Electrolyser Forum

4 to 7 July 2017, in the KKL of Lucerne, Switzerland

HYDROGEN FUEL CELLS PEFC, HTPEM, AFC, PAFC
DIRECT ALCOHOL FUEL CELLS DMFC
ELECTROLYSERS PEM, Alkaline, SOE

Electrochemical Science and Engineering,
Manufacturing, Design, Integration, Standardization, Operation
Applications, Combinations, Market Issues

Already now, many stakeholder have expressed their strong interest to participate and contribute to this event as presenters or exhibitors. The 6th European PEFC & Electrolyser Forum will be a major European gathering place for fuel cell and electrolyser scientists, experts, engineers, and increasingly business developers and managers. Responding to the wishes of many stakeholders, the event will focus around hydrogen fuel cells, including direct alcohol fuel cells, and all electrolysers. On specific request, there will also be space to compare directly AFC and PEM electrolysers with SO electrolysers.

Dr. Isotta Cerri
Toyota Motor Europe Belgium

Dr. Isotta Cerri worked as scientific researcher on catalytic processes at Politecnico di Torino after receiving a PhD in Chemical Engineering on catalytic combustions. She has been actively working in the field of fuel cell technologies for Toyota as from 2004 in the advanced technology department where currently she is leading the fuel cell, battery and robotics teams. In the area of fuel cells she has been developing innovative electrode membrane assemblies based on newly developed material, structures and manufacturing processes. For Toyota she has been involved in several bilateral cooperations in order to develop improved materials and production processes of the different components of the automotive fuel cell stack and high pressure hydrogen tanks to enable the commercialization of reliable and affordable fuel cell vehicles. She is the author of several publications and inventor of patents.

Prof. Dr. Angelika Heinzel
ZBT GmbH, Universität Duisburg-Essen Germany

Prof. Dr. Angelika Heinzel received her PhD in Chemistry at Carl-von-Ossietzky University, Oldenburg. The next 15 years, she joined the Fraunhofer-Institute for Solar Energy Systems ISE in Freiburg, first as coworker later on as head of the department "Energy Technology" with research focus on PEM fuel cells, fuel processing, electrolysers and Cr-Fe redox-flow batteries. In 2001, she accepted the offer of a chair in Energy Technology at University of Duisburg-Essen. The second offer for this position was the founding of ZBT, a center for fuel cell research in Duisburg, funded by the State of North-Rhine Westfalia. ZBT has meanwhile grown to an internationally well known center with about 100 coworkers.

Professor Heinzel acts as an expert for the EU and the AiF. She is chairperson at Dechema for electrochemical processes, applied electrochemistry and VDI member of fuel cell group as well as of the steering committee of the Grove Fuel Cell Symposium. Numerous scientific publications on the topic of fuel cells have been published in the recent years.

The European Fuel Cell Forum's focus is on Science, Facts and Figures, covering approaches and solutions for electrochemistry, catalysis, materials, processes and components. We expect increasingly manufacturing, design, integration, standardization and operation, from electrochemistry to the drive-train and demonstration projects to be featured. A growing number of series products will be presented in alignment with the FCV launch of the car manufactures like Toyota, Hyundai, Daimler, BMW, Audi. Topics like reforming and

hydrogen refuelling are not core part of the EFCF and will be treated in a coordinated manner at the following event of the IAHE: WHTC 2017 in Prague.

The forum comprises a scientific conference, an exhibition and a tutorial. Beside this, the public and commercial Energy-Moblity-Show "Green-Salon" is planned again. Contributions are very welcome.

In its traditional manner, the meeting aims at a fruitful dialogue between researchers, engineers and manufacturers, hardware developers and users, academia and industry. Business opportunities will be identified for manufacturers, commerce, consultants, public authorities and investors. Although a Europe-bound event, participation is invited from all continents. About 400 participants and 30 exhibitors are expected from more than 30 nations.

For everybody interested in **Hydrogen Fuel Cells** and **Electrolysis**, please take note in your agenda of the next opportunity to enjoy Lucerne as a scientific and technical exchange platform.
The 6th European PEFC & Electrolyser FORUM will take place from 4 - 7 July 2017, in the KKL of Lucerne, Switzerland.

We look forward to welcoming you again in Lucerne.

The organisers
Olivier Bucheli & Michael Spirig

Outlook 2018

The elected Chair will be announced.
Call for Paper is in Sept 2017.

13th European SOFC & SOE Forum

3 - 6 July 2018

forum@efcf.com / www.EFCF.com/**2018**

Your event in Lucerne

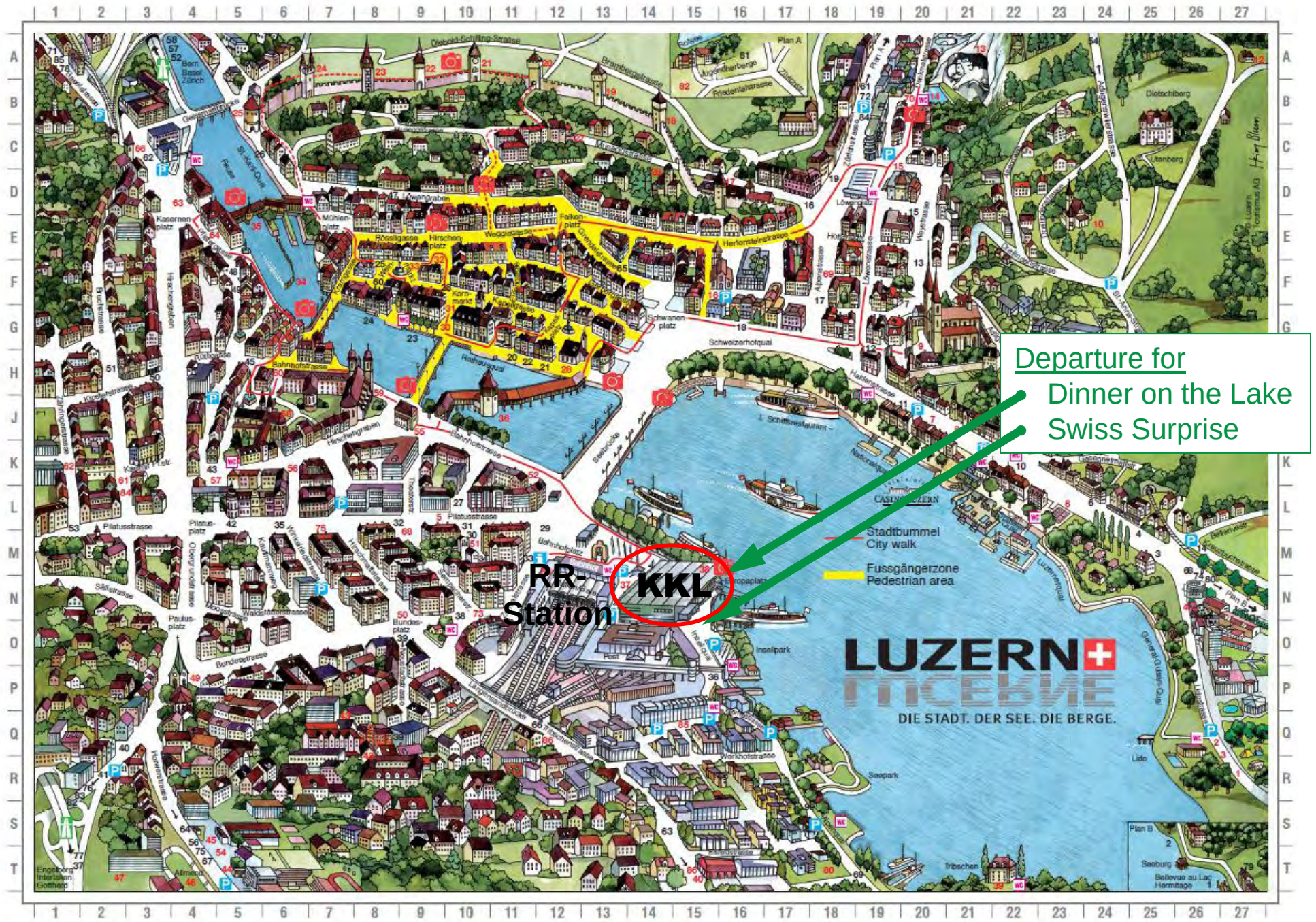
Imagine holding your business event where people like to come for their holidays. Lucerne, at the heart of Switzerland. With domestic and international connections second-to-none and a professionally run conferencing infrastructure, we aim to see your business event reap the rewards of success.

Lucerne Tourism Ltd.
Lucerne Convention Bureau
Bahnhofstrasse 3, CH-6002 Lucerne
Phone +41 (0)41 227 17 07
Fax +41 (0)41 227 17 18
convention-bureau@luzern.com
www.luzern.com/business

Business Development Lucerne
Alpenquai 30, CH-6005 Lucerne
Phone +41 (0)41 367 44 00
Fax +41 (0)41 367 44 01
info@luzern-business.ch
www.luzern-business.ch

LUZERN
THE CITY. THE LAKE. THE MOUNTAINS.

LUZERN
BUSINESS DEVELOPMENT


Departure for
Dinner on the Lake
Swiss Surprise
RR-Station
KKL
LUZERN
DIE STADT. DER SEE. DIE BERGE.
Stadtbummel
City walk
Fussgängerzone
Pedestrian area

International Conference on SOLID OXIDE FUEL CELL and ELECTROLYSER

12th EUROPEAN SOFC & SOE FORUM

5 - 8 July 2016

Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

Schedule of Events

Tuesday	**5 July 2016**	11:00 - 16:00	Exhibition set-up
		09:30 - 10:00	Tutorial Registration at KKL on the 2nd floor in the club rooms above the Auditorium
		10:00 - 17:00	Tutorial held by Dr. Günther G. Scherer & Dr. Jan Van herle
		16:00 - 18:00	Poster pin-up / Official opening of the exhibition
		16:00 - 18:00	On-site Registration open, continued on the following days
		18:00 - 19:00	Welcome gathering on the terrace of the KKL above the registration area
		from 19:00	Thank You Dinner with special invitation only
Wednesday	**6 July 2016**	08:00 - 16:00	On-site Registration open, continued on the following days
		08:00 - 09:00	Speakers' Breakfast in the Auditorium Foyer on the 1st floor of the KKL above sector A of the exhibition
		09:00 - 18:00	Conference Sessions 1–6, plenary presentations on «Fuel Cell Market - Korean Industry - European Projects & Activities, companies & major groups development status, technical highlights, extended poster session, networking & exhibition
		09:00 - 18:00	Poster area and exhibition open
		12:30	Press Conference (by invitation only)
		18:30 - 23:00	This year special 20th EFCF Jubilee Swiss Surprise Night (separate registration 50 places, first-come-first-served)
Thursday	**7 July 2016**	08:00 - 16:00	On-site registration open, continued on the following days
		08:00 - 9:00	Speakers' Breakfast in the Auditorium Foyer like on Wednesday
		09:00 – 18:00	Poster area and exhibition open
		09:00 - 18:00	Conference sessions 7–12, key note «FC innovations by Microsoft», extended poster session, networking & exhibition
		19:30 - 23:30	Great Dinner on the Lake
Friday	**8 July 2016**	08:00 - 10:00	On-site registration and Speakers' Breakfast like on Wednesday
		09:00 - 16:15	Conference sessions 13–16, key note of gold medal of honour winner 2016, poster presentation, networking & exhibition, 09:00 - 12:00 Poster area and exhibition open; 12:00-14:00 Poster removal
		15:00 - 16:15	Closing and Award Ceremony: Best Poster, best scientific contribution & outstanding lifetime work; Keynote «New Materials, structures & concepts for Solid Oxide Cells» John TS Irvine, Uni St. Andrews/UK
		16:30 - 17:00	Goodbye coffee and travel refreshment in front of the Luzerner Saal

Motto 2016 **Solid Oxide Fuel Cells, Electrolysers and Reactors: From development to delivery.**