

Conference Agenda



15th highly valued conference series of the European Fuel Cell Forum in Lucerne

European Fuel Cell Forum 2011

28 June – 1 July 2011 Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

Chairman: Prof. Dr. K. Andreas Friedrich German Aerospace Center DLR



International Conference on FUEL CELL and HYDROGEN including Tutorial, Exhibition and Demonstration Area

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

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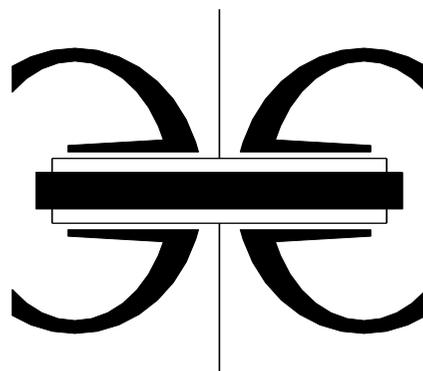
International conference on FUEL CELL and HYDROGEN
EUROPEAN FUEL CELL FORUM 2011

28 June – 1 July 2011

Kultur- und Kongresszentrum Luzern (KKL) Lucerne / Switzerland

Chairman: Prof. Dr. Andreas Friedrich

German Aerospace Center DLR



Tutorial

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

Exhibition and Demonstration Area

Event organized by European Fuel Cell Forum
Olivier Bucheli & Michael Spirig
Obgardihalde 2, 6043 Luzern-Adligenswil, Switzerland
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EUROPEAN FUEL CELL FORUM 2011

Table of content

■ Welcome by the Organisers	I - 4
■ The Chairman's Welcome to the European Fuel Cell Forum 2011	I - 5
■ Conference Session <u>Overview</u>	I - 6
■ <u>Conference Schedule and Program</u>	I - 7
■ <u>Abstracts</u> of the Oral and Poster Presentations	I - 29
■ List of Authors	II - 1
■ List of Participants	II - 7
■ List of Institutions	II - 14
■ List of Exhibitors and Demonstrators	II - 17
■ Outlook to the 10 th European SOFC Forum 2012	II - 19

Official Carrier



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Welcome by the Organisers

Olivier Bucheli & Michael Spirig

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

Welcome to the EUROPEAN FUEL CELL FORUM 2011. As from the year 2000, this 15th event of a successful series of conferences in Fuel Cell and Hydrogen Technologies takes place in the beautiful and impressive KKL, the Culture and Congress Center of Lucerne. Competent staff, smooth technical services and excellent food allow the participants to focus on science and technology in a creative and productive work atmosphere.

After 17 years of valued commitment by Dr. Ulf Bossel, this year's event is organised for the first time by a new management team. While we adapt some details to evolving needs of the scientific community, we want to keep one thing constant: The focus on facts and physics. This is granted by the independency of the organisation that does not depend on public or private sources, but is fully financed by the participants and exhibitors. Your participation has made possible this event, please take those following days as your personal reward!

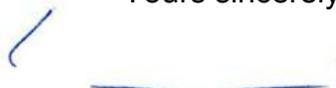
The recent events around the globe have raised the awareness of the whole society about the importance of energy. Renewables, reduced dependency on fossil and nuclear, and efficiency start to be part of the daily vocabulary of politicians. Fuel cells and Hydrogen have an important contribution in answering this global challenge. This conference will state where the technology is on this long path, what progress has been achieved, what it can do today, but also where the remaining challenges lie.

In this respect, we would like to thank the conference chair Prof. Dr. K. Andreas Friedrich from the German Aerospace Center DLR, the DLR team, the Scientific Organising Committee and the Scientific Advisory Committee. Based on more than 180 submitted scientific contributions, they have composed a sound scientific program picturing the recent progress in fuel cell and hydrogen from more than 25 countries and 5 continents – we look forward to seeing this exciting program of the EUROPEAN FUEL CELL FORUM 2011. We also hope that the charming and inspirational atmosphere of Lucerne allows many strong experts to initiate or confirm partnerships that result in true products and solutions for society, and will allow adding 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 provider of demonstration objects, the media, the KKL staff and Lucerne Incoming for the registration services. Finally, we thank all of you for your coming. May we all have a wonderful week in Lucerne with fruitful technical debates and personal exchanges!

The next chance to enjoy Lucerne as scientific and technical exchange platform will come in 2012. The 10th EUROPEAN SOFC FORUM will take place from 26 to 29 June 2012, chaired by Dr. Florence Lefebvre-Joud from CEA, France, in the KKL of Lucerne.

Yours sincerely


Olivier Bucheli

&


Michael Spirig

Chairman's Welcome to European Fuel Cell Forum 2011

K. Andreas Friedrich

German Aerospace Center DLR
Pfaffenwaldring 38-40
70569 Stuttgart / Germany

Dear participant,

I am very pleased to welcome you to the EUROPEAN FUEL CELL FORUM 2011 in Lucerne. The conference encompasses fuel cell and hydrogen technology, ranging from material and cell development, system design, applications to large scale demonstration. During the three-day program more than 170 papers will be presented in 20 oral sessions and two poster sessions. The program offers scientific lectures, program overviews, demonstrations projects, product demonstrations and exhibits.

Concerns about price and security of energy supply, safety of power generation, climate change, air pollution, and water use are driving the world's nations to transform their energy systems, i.e., the network of energy flows and technologies that link energy sources through energy carriers to energy services. The most common worldwide trend is the further accelerated implementation of renewable energies with considerable challenges concerning grid stability, transmission line expansion, and cost competitiveness.

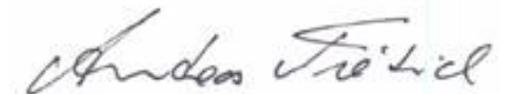
In this context, fuel cell technology as well as the related electrolysis technology provides many essential features since it can be implemented as a clean energy conversion system with high electrical efficiency. Additional benefits are the relative quietness, low to nonexistent toxic emissions, and the high flexibility regarding

the integration in many applications. The automotive power train application is one main driver with anticipated commercialisation in 2015. However, stationary power generation for cogeneration is already seeing commercial distribution in some areas. Fuel cells will be an economic growth area in the coming decades securing high quality employment for many thousands of people. Public interest is also pronounced leading to significant public-private initiatives worldwide which will also be presented in this year's European Fuel Cell Forum.

Nevertheless, production volume of fuel cells is still low and costs are too high. Therefore, continuous research and development is of paramount importance for further improvements in cost effectiveness, reliability and durability as well as optimised system design with high efficiency. In this respect, the European Fuel Cell Forum is a premier event in Europe which is the forum to present progress in material research, cell development, system integration, and novel applications. Due to the increasing effort in field testing and large scale demonstration projects in Europe, America and Asia, the presentation of these developments is of high importance for the conference. In addition, hydrogen generation for energy storage is gaining momentum. As a result, hydrogen storage and generation is an evolving field with prominence at EFCF 2011. As chairman of the conference I wish you all a successful scientific interaction at this beautiful venue and many inspirations for your further scientific and technical work.

Many thanks go to the Scientific Advisory and Organising Committee for the help in evaluating contributions, to the DLR team, especially my assistant Monika Baumann and Nancy Thamke for organisational support, as well as the local organisers Michel Spirig and Olivier Bucheli for their assistance. I am indebted to Ulf Bossel for his continuous support and advice.

Yours sincerely


K. Andreas Friedrich





Conference Session Overview

Session	Auditorium (1 st floor)	Session	Club Rooms 5-6 (2 nd floor)
A01	Opening Session Worldwide Fuel Cell & Hydrogen Programs 1		
A02	Worldwide Fuel Cell & Hydrogen Programs 2		
A03	in Club Rooms 3-4 (2nd floor)	<u>Poster Session I</u> concerning Sessions A04, A05, A07, A09 A10, A12, A14	
A04	PEMFC Applications	B04	SOFC Development and Durability
A05	Fuel Cell Applications I	B05	Intermediate Temperature SOFC
A06	Fuel Cell Demonstration -Transportation		
A07	PEMFC Components - Electrodes	B07	Fuel Cell Applications II
A08	in Club Rooms 3-4 (2nd floor)	<u>Poster Session II</u> concerning Sessions B04, B05, B07, B09, B10, B12, A13, B13, B14	
A09	Direct Methanol Fuel Cell Components	B09	High Temperature Fuel Cell characterisation
A10	PEMFC Components Characterisation and Improvements	B10	SOFC Components Characterisation and Improvements
A11	Fuel Cell Demonstration - Stationary		
A12	Fuel Processing Integration and Durability	B12	Fuel Cell Diagnostics
A13	Fuel Cell Modelling	B13	Development of Fuel Processing
A14	Control Strategies and Modelling	B14	Hydrogen Production and Storage
A15	Closing Ceremony		

Conference Schedule and Program

Wednesday, June 29, 2011

Morning

Auditorium (1st floor)

Morning

09:00		Opening Session Fuel Cell & Hydrogen Programs 1		A01	
<i>Chair: K. A. Friedrich, Organizers</i>					
		Welcome by the Organisers Michael Spirig, Olivier Bucheli European Fuel Cell Forum, Luzern/Switzerland		A0101	
		Welcome by the Chairman Andreas Friedrich German Aerospace Center (DLR), Stuttgart/Germany		A0102	
		Welcome to Lucerne the Inspiring Meeting Point Marcel Perren Luzern Tourismus, Luzern/Switzerland		A0103	
		Welcome to Switzerland the Smart Research Place Stefan Oberholzer Swiss Federal Office of Energy, Bern/Switzerland		A0104	
09:30		Europe's Fuel Cells and Hydrogen Joint Undertaking Jean-Luc Delplancke Fuel Cells and Hydrogen Joint Undertaking, Brussels/European Commission		A0105	
10:00		Overview of DOE Hydrogen and Fuel Cell Activities Dimitrios Papageorgopoulos U.S. Department of Energy, Washington/USA		A0106	
10:30	Intermittence → Refreshments served on Ground Floor in the Exhibition				

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- Prof. Constantinos Vayenas (University of Patras / Greece)
- Prof. Martin Winter (Uni Münster / Germany)
- Dr. Christian Wunderlich (Staxera / Germany)



Wednesday, June 29, 2011

Morning

Auditorium (1st floor)

Morning

11:00	Fuel Cell & Hydrogen Programs 2 <i>Chair: K. A. Friedrich / W. Ling</i>	A02	
11:00	Strategies for Development of Fuel Cells and Hydrogen Stations in Japan Akira Izumi New Energy and Industrial Technology Development Organization, Paris or Tokyo/Japan	A0201	
11:30	Overview of Fuel Cell and Hydrogen Activities in China Jianxi Ma Tongji University, Shanghai/China	A0202	
12:00	Fuel Cell Research Programme and Activities in South Korea Jaeyoung Lee Ertl Center for Electrochemistry & Catalysis, Gwangju/South Korea	A0203	
12:30	Lunch Break → <u>Lunch</u> served on 2 nd Floor - Terrace → <u>Coffee</u> served on 2 nd Floor in the Poster Session & Ground Floor in the Exhibition		

Afternoon

Club Rooms 3-4 (2nd floor)

Afternoon

13:30	Poster Session I <i>Chair: K.A. Friedrich / N. Wagner / M. S. Kim</i>	A03
concerning Sessions A04, A05, A07, A09 A10, A12, A14 (see page I-24 – I-28)		

Wednesday, June 29, 2011

Afternoon	Auditorium (1st floor)	A04	Club Rooms 5-6 (2nd floor)	Afternoon
14:30	PEMFC Applications <i>Chair: C. Cremers / L. Jörissen</i>	A04	SOFC Development and Durability <i>Chair: R. Steinberger-Wilckens / A. Arico</i>	B04
14:30	Improvement of PEMFC Stack Components for Commercializing Residential CHP Systems Haruhiko Adachi Tokyo Institute of Technology, Tokyo/Japan	A0401	Fabrication of Low-Profile and Large Size Solid Oxide Fuel Cell Combined with Strength Reinforcement Layer and Shrinkage Control Layer Hongyoul Bae, Junghoon Song, Youngmin Park, Jinsoo Ahn Research Institute of Industrial Science & Technology (RIST), Pohang/Korea	B0401
14:45	H₂/O₂ Fuel Cell System for Automotive Application Jérôme Bernard (1), Marcel Hofer (1), Uwe Hannesen (2), Felix N. Büchi (1) (1) Paul Scherrer Institut, Villigen/Switzerland (2) Belenos Clean Power Holding, Biel/Switzerland	A0402	Sol-Gel Process to Prepare an Anode Supported SOFC Emilie Courtin, Philippe Boy, Nathalie Poirot, Christel Laberty-Robert CEA-DAM, Monts/France	B0402
15:00	Preliminary results from the EcoMotion Demonstration Project – Reformed Methanol Fuel Cells in Niche Transport Applications Jesper Lebak, Morten Holst Johansen, Johan Hardang Vium Danish Technological Institute, Aarhus/Denmark	A0403	SOFC Degradation Quantification Using Image Analysis Robert Steinberger-Wilckens, Maxim Ananyev, Alexander Gavriluk Forschungszentrum Jülich GmbH, Jülich/Germany	B0403
15:15	PEMFCs compared to other technologies for air independent energy supply Thomas Nietsch, Olivier Verdu HELION, Aix-en-Provence/France	A0404	Direct Methanol Solid Oxide Fuel Cell: a resistant anode towards carbon deposition Maurizio Minutoli, Massimiliano Lo Faro, Vincenzo Antonucci, Antonino Salvatore Aricò CNR-ITAE, Messina/Italy	B0404
15:30	Uninterruptible Power Supply with PEM FC Technology Ulrike Trachte, Beat Wellig Lucerne School of Engineering and Architecture, Horw/Switzerland	A0405	Influence of artificial wood gas with alkali salt vapors on the Solid Oxide Fuel Cell Ni-cermet anode Gunnar Nurk, Artur Braun, Peter Holtappels, Thomas Graule EMPA Swiss Federal Laboratories for Materials Science and Technology, Dübendorf/Switzerland	B0405





15:45	Auto-Stack Implementing a European Automotive Fuel Cell Stack Cluster André Martin, Ludwig Jörissen Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), Ulm/Germany	A0406	Fabrication and cell performance of anode-supported SOFC made of in-house produced NiO-YSZ nano-composite powder Hanna Tikkanen (1), Crina Suciu (2), Ivar Wærnhus (2), Alex C. Hoffmann (1) (1) University of Bergen, Bergen/Norway (2) Prototech AS, Bergen/Norway	B0406
16:00	Intermittence → Refreshments served on Ground Floor in the Exhibition & on 2 nd Floor in the Poster Session			
Afternoon	Auditorium (1st floor)		Club Rooms 5-6 (2nd floor)	Afternoon

Wednesday, June 29, 2011

Afternoon	Auditorium (1st floor)		Club Rooms 5-6 (2nd floor)	Afternoon
16:30	Fuel Cell Applications I <i>Chair: U. Vogt / W. Huber</i>	A05	Intermediate Temperature SOFC <i>Chair: J. Van Herle / F. Lefebvre-Joud</i>	B05
16:30	Regenerative Fuel Cell System as alternative energy storage device Willigert Raatschen, Joachim Lucas, Walter Jehle, Sebastian Markgraf Astrium GmbH, Friedrichshafen/Germany	A0501	Low Temperature Preparation and Characterization of LSGMC based LT-SOFC cell by Aerosol Deposition Jong-Jin Choi, Joon-Hwan Choi, Dong-Soo Park Korea Institute of Material Science, Gyeongnam/Korea	B0501
16:45	PEM Electrolysis for Decentralized Energy Uwe Kueter, Claus Wuerfel h-tec Wasserstoff-Energie-Systeme GmbH, Lübeck/Germany	A0502	Discussion on the feasibility of SOFC anodes based on CeO₂-ZrO₂ mixed oxides. Marta Boaro, Chiara Abate, Matteo Ferluga, Alfonsina Pappacena, Alessandro Trovarelli Università di Udine, Udine/Italy	B0502
17:00	Design and characterisation of a portable high temperature PEM fuel cell module Timo Kurz, Julian Keller Fraunhofer Institute for Solar Energy Systems ISE, Freiburg/Germany	A0503	Nd-Nickelate Based Solid Oxide Fuel Cell Cathodes Sensitivity to Cr-, Si-Contamination J. Andreas Schuler, Henning Lübbe, Aïcha Hessler-Wyser, Jan Van Herle Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne/Switzerland	B0503

17:15	Recent developments of micro DMFC and FC/battery hybrid power supply system in ITRI Welkin Ling, Li-Duan Tsai, Yin-Wen Tsai, Ku-Yen Kang ITRI Industrial Technology Research Institute, Chutung/Taiwan ROC	A0504	Preparation of SOFC materials via co-precipitation Giovanni Dotelli, Cinzia Cristiani, Renato Pelosato, Luca Zampori Politecnico di Milano, Milano/Italy	B0504
17:30	Development of alkaline direct alcohol fuel cells Carsten Cremers, Florina Jung, André Niedergesäß, Jens Tübke Fraunhofer Institute for Chemical Technology ICT, Pfinztal/Germany	A0505	Functional Layers Design between Multiple Doped Electrolyte and Perovskite Electrodes Horng-Yi Chang, Shing-Hoa Wang, Chia-Ming Chang, Chien-Wei Lai National Taiwan Ocean University, Keelung/Taiwan ROC	B0505
17:45	High efficient solar hydrogen generation using a HyCon® system Sebastian Rau, Aurelien Yanwouo, Gerhard Peharz, Tom Smolinka Fraunhofer Institute for Solar Energy Systems ISE, Freiburg/Germany	A0506	Correlation of electronic structure and electronic transport in LaSrFeNi-oxide – a potential IT-SOFC cathode material Artur Braun, S. Erat, L. J. Gauckler, T. Graule EMPA Swiss Federal Laboratories for Materials Science and Technology, Dübendorf/Switzerland	B0506
18:00	End of Sessions			
18:30	Swiss Surprise → Extra registered participants meet in front of the KKL for the <u>Lucerne focused evening program</u>			

Afternoon

Auditorium (1st floor)

Club Rooms 5-6 (2nd floor)

Afternoon

Wednesday, June 29, 2011





Thursday, June 30, 2011

Morning

Auditorium (1st floor)

Morning

Morning		Auditorium (1st floor)	Morning	
09:00	Fuel Cell Demonstration – Transportation <i>Chair: J. Lee / L. Jörisen</i>	A06		
09:00	Fuel Cell Buses in Transit Use Update on Canada and London Geoffrey Budd Ballard Power, Burnaby/Canada	A0601	Scientific Advisory Committee <ul style="list-style-type: none"> • Prof. Dr. K. Andreas Friedrich, DLR, Stuttgart / Germany (Chair) • Prof. Nicolas Alonso-Vante, U. de Poitiers, Poitiers / France • Dr. Antonio S. Aricò, CNR ITAE, Messina / Italy • Dr. Sylvie Escribano, CEA, Grenoble / France • Prof. Hubert Gasteiger, TU Munich, Munich / Germany • Dr. Peter Holtappels, Risø / DTU, Roskilde / Denmark • Dr. Deborah Jones, Université CNRS, Montpellier / France • Dr. Ludwig Jörisen, ZSW, Ulm / Germany • Prof. Anthony Kucernak, Imperial College London, London / UK • Prof. Göran Lindbergh, KTH, Stockholm / Sweden • Prof. Adélio Mendes, Universidade do Porto, Porto / Portugal • Dr.-Ing. Angelo Moreno, ENEA – CR Casaccia, Rome / Italy • Ing. Bert Rietveld, ECN, Petten / The Netherlands • Prof. Elena Savinova, U. de Strasbourg, Strasbourg / France • Prof. Detlef Stolten, FZ Jülich, Jülich / Germany • Prof. Kai Sundmacher, MPI and U. Magdebur / Germany • Dr. Georgios Tsotridis, JRC, Petten / The Netherlands • Prof. Daria Vladikova, Bulgarian Acad. of Sci., Sofia / Bulgaria 	
09:15	CHIC – Clean Hydrogen in European cities Monika Kentzler, Ulrich Piotrowski Daimler EvoBus GmbH, Kirchheim/Germany	A0602		
09:30	Hydrogen pathways in France: Results of the Hyfrance3 project Le Duigou Alain, Marie-Marguerite Quéméré, Pierre Marion, Philippe Menanteau, Sandrine Decarre, Laure Sinegre, Lionel Nadau, Aline Rastetter, Aude Cuni, Philippe Mulard, Loïc Antoine, T. Alleau CEA Saclay, Gif-Sur-Yvette/France	A0603		
09:45	Fuel Cells for Green Corridors Walter Huber IIT (Institut für Innovative Technologien), Bozen/Italy	A0604		
10:00	Intermittence → Refreshments served on Ground Floor in the Exhibition			

Thursday, June 30, 2011

Morning	Auditorium (1st floor)		Club Rooms 5-6 (2nd floor)	Morning
10:30	PEMFC Components - Electrodes <i>Chair: N. Alonso-Vante / R. Hiesgen</i>	A07	Fuel Cell Applications II <i>Chair: M. Kentzler / U. Krewer</i>	B07
10:30	Surface properties of Pt and PtCo electro-catalysts and their influence on the performance and degradation of high temperature polymer electrolyte fuel cells Antonino Salvatore Arico, Alessandro Stassi, Enza Passalacqua, Irene Gatto CNR-ITAE, Messina/Italy	A0701	Advanced Electrolysers for Hydrogen Production with Renewable Energy Sources Olivier Bucheli (1), Florence Lefebvre-Joud (2), Annabelle Brisse (3), Martin Roeb (4), Manuel Romero (1) HTceramix SA, Yverdon-les-Bains/Switzerland (2) CEA/DEHT/Liten, Grenoble/France (3) European Institut for Energy Research EIFER, Karlsruhe/Germany (4) German Aerospace Center (DLR Köln), Köln/Germany IMDEA, Madrd/Spain	B0701
10:45	Towards stable catalyst supports Isotta Cerri ^a , Tetsuo Nagami ^b , Jon Davies ^c , C. Mormiche ^c , A. Vecoven ^c and Brian Hayden ^c ^a Toyota Motor Europe, Hoge Wei 33, 1930 Zaventem / Belgium ^b Advanced Material Engineering Division, Toyota Motor Corporation, 1, Toyota-cho, Toyota, Aichi, 471-8571 Japan ^c Illika Technologies plc, Kenneth Dibben House, Enterprise Road, University of Southampton Science Park, Chilworth, Southampton SO16 7NS, United Kingdom	A0702	Status of the RelHy project on innovative Solid Oxide Electrolyser Stacks for Efficient and Reliable Hydrogen production Florence Lefebvre-Joud (1), Marie Petitjean (1), Bert Rietveld (2), Jacob Bowen (3), Nigel Brandon (4), T. , Thomas Nietsch (5), Annabelle Brisse (6), Jens Ulrik Nielsen (7) (1) CEA/DEHT/Liten, Grenoble/France (2) ERC NL, Petten/The Netherlands (3) Risoe National Laboratory Danish Tech. Uni, Frederiksborgvej/Denmark (4) Imperial College of London, London/United Kindom (5) HELION, Aix-en-Provence/France (6) European Institut for Energy Research EIFER, Karlsruhe/Germany (7) Topsoe FuelCell, Lyngby/Denmark	B0702
11:00	Continuous preparation of highly active Pt/CNT catalysts Alicja Schlange, Antonio Santos, Thomas Turek, Ulrich Kunz Clausthal University of Technology, Clausthal-Zellerfeld/Germany	A0703	Coupling an SOFC System with a High-Performing Metal Hydride Storage Robert Steinberger-Wilckens, Arvin Mossadegh pour, Klaus Taube, Jose Belosta von Colbe Forschungszentrum Jülich GmbH, Jülich/Germany	B0703





11:15	Ultrasonic Spraying of PEM-FC Electrodes Casey J. Hoffman, Daniel F. Walczyk, Christopher Cichetti Rensselaer Polytechnic Institute, Troy/USA-NY	A0704	Catalytic Hydrogen Combustion on Porous SiC Ceramics Ulrich F. Vogt, Victor Siong, Benjamin Fumey, Michael Biemann, Andreas Züttel EMPA Swiss Federal Laboratories for Materials Science and Technology, Dübendorf/Switzerland	B0704
11:30	PEM systems with Pt-free cathodes using FlowCath® Technology Andrew M Creeth, Andrew R Potter, Kathryn J Knuckey, Brian Clarkson ACAL Energy Ltd, Runcorn/United Kingdom	A0705	SOFC Module for Rapid Start-Ups and Many applications Ulf Bossel ALMUS AG, Oberrohrdorf/Switzerland	B0705
11:45	Effect of oxide formation on the oxygen reduction kinetics on Pt and PtCo PEMFC cathodes Max Cimenti, Robert Kehoe, Jürgen Stumper Automotive Fuel Cell Cooperation Corporation, Burnaby/Canada	A0706	Development of Anode Supported Tubular Solid Oxide Fuel Cells with Low Cost and High Performance Hong Ryul Lee, Han UI Yoo, Jae Hyuk Jang Corporate R&D Institute, Samsung Electro-Mechanics Co. Ltd, Suwon City/Korea	B0706
12:00	Integrated Electrodes with Pt Nanowires in Direct Methanol Fuel Cells Shangfeng Du, Benjamin Millington, Bruno G. Pollet University of Birmingham, Birmingham/United Kingdom	A0707	Composite materials for molten carbonate fuel cell anodes Fabio Zaza, Hary Devianto, Claudia Paoletti, Elisabetta Simonetti ENEA, Rome/Italy	B0707
12:15	Lunch Break → <u>Lunch</u> served on 2 nd Floor - Terrace → <u>Coffee</u> served on 2 nd Floor in the Poster Session & Ground Floor in the Exhibition			

Morning

Auditorium (1st floor)

Club Rooms 5-6 (2nd floor)

Morning

Thursday, June 30, 2011

Afternoon

Club Rooms 3-4 (2nd floor)

Afternoon

Poster Session II

A08

 13:30 *Chair: K.A. Friedrich / N. Wagner / J. Lee*

concerning Sessions B04, B05, B07, B09, B10, B12, A13, B13, B14 (see page I-24 – I-28)

Thursday, June 30, 2011

Afternoon

Auditorium (1st floor)

Club Rooms 5-6 (2nd floor)

Afternoon

Direct Methanol Fuel Cell Components <i>Chair: J. Kerres / S. Escibano</i>		A09	High Temperature Fuel Cell characterization <i>Chair: U. Bossel / F. Zaza</i>		B09
14:30	RuSe cluster-like as cathode catalyst in a formic acid laminar flow fuel cell N. Alonso-Vante, A. S. Gago, L. Timperman University of Poitiers, Poitiers/France	A0901	Performance of SOFC stacks under partial internal reforming of methane Stefan Diethelm, Rolando Rodas, Emanuele Facchinetti, Jan Van herle Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne/Switzerland	B0901	
14:45	Oxygen reduction reaction (ORR) on Ir, Rh, and Ru selenides M Neergat, R. K. Singh Indian Institute of Technology Bombay (IITB), Mumbai/India	A0902	Control of a Solid Oxide Fuel Cell System with Biased Gas Temperature Measurements Leonidas Tsikonis, Joel Albrektsson, Jan Herle, Daniel Favrat Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne/Switzerland	B0902	
15:00	Methanol Electro-oxidation by Carbon Supported Cobalt and Nickel based Nanocomposites Eithne Dempsey, Baljit Singh Centre for Research in Electroanalytical Technologies (CREATE), Dublin/Ireland	A0903	Single Layer or Electrolyte-free Fuel Cell Bin Zhu, Rizwan Raza, Haiying Qin, Liangdong Fan KTH Stockholm, Stockholm/Sweden	B0903	
15:15	Effect of the hydrophobicity of the electrocatalyst support on HT-PEMFC and vapour-fed DMFC performances Lúcia Brandão, Nadine Grandjean, Paula Oliveira, Alfredo Tanaka, Adélio Mendes LEPAE – Laboratório de Engenharia de Processos, Ambiente e Energia, Porto/Portugal	A0904	Estimating of the SOFC electrolyte/electrode contact area by impedance spectroscopy Jacqueline Amanda Figueiredo dos Santos, Tulio Matencio and Rosana Zacarias Domingues Universidade Federal de Minas Gerais, Minas Gerais/Brazil	B0904	





15:30	Preparation of core shell structured Pt@Au/C electro-catalysts for oxygen reduction reaction Rui Lin, Jianxin Ma, Haiyan Zhang, Chunhui Cao Tongji University, Shanghai/China	A0905	Parametric comparative analysis of lifetime energy demand and CO₂-eq savings of a SOFC μ-CHP unit D. Giannopoulos, M. A. Founti National Technical University of Athens, Athen/Greece	B0905
15:45	Promising Non-Ru Methanol Electro-Oxidation Catalysts for Direct Methanol Fuel Cell Application Syed Javaid Zaidi, Mukhtar Bello, Sleem-Ur Rahman, Shakeel Ahmed King Fahd University of Petroleum & Minerals, Dhahran/Saudi Arabia	A0906	Role of Sn Catalyst Mixture for Electrochemical Oxidation of Solid Carbon in Direct Carbon Fuel Cell Jaeyoung Lee, HyungKuk Ju, Sunghyun Uhm, Jin Won Kim Gwangju Institute of Science and Technology (GIST), Gwangju/Korea	B0906
16:00	Intermittence → Refreshments served on Ground Floor in the Exhibition & on 2 nd Floor in the Poster Session			
Afternoon	Auditorium (1st floor)		Club Rooms 5-6 (2nd floor)	Afternoon

Thursday, June 30, 2011

Afternoon	Auditorium (1st floor)		Club Rooms 5-6 (2nd floor)	Afternoon
16:30	PEMFC Components - Characterisation & Improvements <i>Chair: A. Mendes / B. Pollet</i>	A10	SOFC Components - Characterisation & Improvements <i>Chair: P. Piccardo / A. Esposito</i>	B10
16:30	PEMFC ageing: effect of operating conditions on performance and MEA components degradation Sylvie Escribano (1), M. Holber (2), L. Merlo (3), M. Schulze (4), G. Tsotridis (5) (1) CEA/DEHT/Liten, Grenoble/France (2) Volvo Technology Corporation, Göteborg/Sweden (3) Solvay-Solexis, Bollate/Italy (4) German Aerospace Center (DLR), Stuttgart/Germany (5) JRC, Petten/European Commission	A1001	GDC Buffer Layer Coating by Aerosol Deposition Byeong-Geun Seong, Hong-Youl Bae, Jong-Jin Choi, Dong-Soo Park Research Institute of Industrial Science & Technology (RIST), Pohang/Korea	B1001

16:45	<p>Degradation of Fuel Cell Materials Investigated by Atomic Force Microscopy Renate Hiesgen (1), Ines Wehl (2), Stefan Helmly (2), Andrea Haug (3), Mathias Schulze (3), Alexander Bauder (3), K. Andreas Friedrich (3), Haijiang Wang (4), Xiao-Zi Yuan (4) (1) University of Applied Sciences Esslingen, Esslingen/Germany (2) Universität Stuttgart, Stuttgart/Germany (3) German Aerospace Center (DLR), Stuttgart/Germany (4) National Research Council Canada, Ottawa/Canada</p>	A1002	<p>Synthesis, Electrical and Electrochemical Properties of $\text{Sr}_{0.6}\text{Ba}_{0.4}\text{Co}_{0.3}\text{Mn}_{0.7}\text{O}_{3-\delta}$ Cathode for Low-Temperature Solid Oxide Fuel Cells Ghazanfar Abbas (1), Rizwan Raza (2), M. Ashraf Chaudhary (3), Bin Zhu (4) (1) Bahauddin Zakaria University (BZU), Multan/Pakistan (2) COMSATS Institute of Information Technology, Islamabad/Pakistan (3) Bahauddin Zakaria University (BZU), Multan/Pakistan (4) KTH Stockholm, Stockholm/Sweden</p>	B1002
17:00	<p>New Aryl Monomers, Polymers and Membranes for PEMFC and DMFC Jochen Kerres Universität Stuttgart, Stuttgart/Germany</p>	A1003	<p>Testing of mechanical performance of reactive-air brazed (RAB) metal / ceramic joints for SOFC applications Jörg Brandenburg, Bernd Kuhn, Tilmann Beck Forschungszentrum Jülich GmbH, Jülich/Germany</p>	B1003
17:15	<p>Influence of different Micro Porous Layers on electrochemical performance of PEFCs Paola Gallo Stampino, Saverio Latorata, Cinzia Cristiani, Giovanni Dotelli Politecnico di Milano, Milano/Italy</p>	A1004	<p>Synthesis and Electrical Properties of Strontium Titanate-Based Materials for Solid Oxide Fuel Cells Jong-Won Lee, Beom-Kyeong Park, Rak-Hyun Song Korea Institute of Energy Research, Daejeon/Korea</p>	B1004
17:30	<p>Study of the TiO₂ content as filler in PBI-based membranes for high temperature PEM fuel cells. F. Javier Pinar, Justo Lobato, Pablo Cañizares, Manuel A. Rodrigo, Diego Úbeda University of Castilla-La Mancha, Ciudad Real/Spain</p>	A1005	<p>Testing metallic Interconnects for SOFC with working "real life" parameters at 600°C Paolo Piccardo (1), Sebastien Fontana (2), Roberta Amendola (3), Massimo Viviani (4), Zeynep Ilhan (5), Kazimierz Przybylski (6) (1) University of Genoa, Genoa/Italy (2) Université Nancy, Nancy/France (3) CNR-IENI, Milano/Italy (4) CNR-IENI, Milano/Italy (5) German Aerospace Center (DLR), Stuttgart/Germany (6) AGH, Kraków/Poland</p>	B1005
Afternoon	Auditorium (1st floor)		Club Rooms 5-6 (2nd floor)	Afternoon

Thursday, June 30, 2011



Thursday, June 30, 2011

Afternoon	Auditorium (1st floor)		Club Rooms 5-6 (2nd floor)	Afternoon
17:45	Determination of “good” or “bad” protic ionic liquids or molten salts for high temperature PEMFC electrolytes Jiangshui Luo, Ivo F. J. Vankelecom, Carsten Agert, Olaf Conrad Next Energy · EWE Research Center for Energy Technology, Oldenburg/Germany	A1006	Electrochemical recycling of cobalt from cathodes of spent lithium-ion batteries for application in interconnects of solid oxide fuel cells Eric Marsalha Garcia, Tulio Matencio, Rosana Zacarias Domingues Universidade Federal de Minas Gerais, Minas Gerais/Brazil	B1006
18:00	End of Sessions			
19:30	Dinner on the Lake 19.20 Boarding - Lake side of KKL peer 5/6 - Back in Lucerne 23.30 (short stop in Brunnen ca. 21.45 for earlier return by train)			



Friday, July 1, 2011

Morning

Auditorium (1st floor)

Morning

09:00	Fuel Cell Demonstration - Stationary <i>Chair: P. Scott / T. Nietsch</i>	A11	
09:00	Status and Accomplishments of Worldwide SOFC Demonstration Robert Steinberger-Wilckens, Ludger Blum Forschungszentrum Jülich GmbH, Jülich/Germany	A1101	
09:20	Fuel Cells for Commercial Buildings Whitney G. Colella, Mike Rinker, Jamie Holladay, Carl Baker Pacific Northwest National Laboratory (PNNL), Richland/USA-WA	A1102	
09:40	How close to the market? The Fuel cell heating appliance Galileo 1000 N Volker Nerlich, Thomas Doerk, Andreas Mai, Alexander Schuler Hexis AG, Winterthur/Switzerland	A1103	
10:00	Intermittence → Refreshments served on Ground Floor in the Exhibition		

Morning

Auditorium (1st floor)

Club Rooms 5-6 (2nd floor)

Morning

10:30	Fuel Processing Integration and Durability <i>Chair: T. Aicher / R. Szolak</i>	A12	Fuel Cell Diagnostics <i>Chair: V. Nerlich / M. Neergat</i>	B12
10:30	Bio-Ethanol Reformer with HT-PEM Fuel Cell for Residential Combined Heat and Power Generation Lisbeth Rochlitz, Wolfgang Koch, Thomas Aicher Fraunhofer Institute for Solar Energy Systems ISE, Freiburg/Germany	A1201	Spatially resolved analysis of water transport mechanisms Dietmar Gerteisen, Andreas Spadinger, Maximilian Schwager, Walter Mérida, Christopher Hebling Fraunhofer Institute for Solar Energy Systems ISE, Freiburg/Germany	B1201
10:45	Integrated fuel cell APU based on a diesel steam reformer and a PEM fuel cell Philip Engelhardt, Frank Beckmann, Martin Brenner, Sascha Toelle OWI Oel-Waerme-Institut GmbH, Aachen/Germany	A1202	An in operando and time resolved x-ray absorption spectroscopy study of the ethanol oxidation reaction Julia Melke ^{1,2} , Alexander Schoekel ¹ , Frank Ettingshausen ¹ , Ditty Dixon ¹ , Dietmar Gerteisen ² ¹ Fraunhofer-Institute for Solar Energy Systems ISE, Freiburg, Germany ² Institute for Materials Science, Technische Universität Darmstadt, DE	B1202





Friday, July 1, 2011

Morning	Auditorium (1st floor)	Club Rooms 5-6 (2nd floor)	Morning	
11:00	An overview of current micro-structured fuel processing activities from fundamental studies to early markets application Martin O'Connell, Martin Wichert, David Tiermann, Gunther Kolb Institut für Mikrotechnik Mainz GmbH, Mainz/Germany	A1203	On-line Gas Measurements within PEM Fuel Cell Flow Fields by Electric Arc Emission Spectroscopy and Raman Spectroscopy Hans Bettermann, Peter Fischer, Martin Labus Heinrich-Heine-University of Duesseldorf, Düsseldorf/Germany	B1203
11:15	Hydrogen Quality for LT-PEM Fuel Cells - Commercial an operational aspects of Selective Methanation Hans-Peter Schmid, Lutz Schilling WS Reformer GmbH, Renningen/Germany	A1204	Microbial fuel cells: Electron transfer from the outer cell membrane to the anode Ana Ferreira da Costa, Christèle Bastian, Manuel Happe and Fabian Fischer University of Applied Sciences Western Switzerland, Sion/Switzerland	B1204
11:30	Design and evaluation of a cyclic fixed bed reactor for hydrogen purification Christoph Hertel, Peter Heidebrecht, Kai Sundmacher Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg/Germany	A1205	Electrochemical Impedance Spectroscopy – a Tool for SOFCs Studies Daria Vladikova, Zdravko Stoynov, Anthony Chesnaud, Gergana Raikova Institute of Electrochemistry and Energy Systems - BAS, Sofia/Bulgaria	B1205
11:45	Characterization of a 500We PEMFC Stack during ageing Philippe Moçotéguy, Bastian Ludwig, Guillaume Gehier European Institut for Energy Research EIFER, Karlsruhe/Germany	A1206	Multiscale and element specific microstructure characterization of SOFC assemblies with resonant ultra small angle x-ray scattering Artur Braun EMPA Swiss Federal Laboratories for Materials Science and Technology, Dübendorf/Switzerland	B1206
12:00	Surface characterization of Ni-based anode after poisoning with low concentration of H₂S in MCFC Hary Devianto, Fabio Zaza, Claudia Paoletti, Elisabetta Simonetti ENEA, Rome/Italy	A1207	Investigation of the Transport Properties on the Strained Ceramic Proton Conductors under Pressure Qianli Chen, Artur Braun, Nikolai Bagdassarov, Thomas Graule EMPA Swiss Federal Laboratories for Materials Science and Technology, Dübendorf/Switzerland	B1207
12:15	Lunch Break → <u>Lunch</u> served on 2 nd Floor - Terrace → <u>Coffee</u> served on 2 nd Floor - Terrace & Ground Floor in the Exhibition			

Friday, July 1, 2011

Afternoon	Auditorium (1st floor)		Club Rooms 5-6 (2nd floor)	Afternoon
13:30	Fuel Cell Modelling <i>Chair: A. Braun / D. Vladikova</i>	A13	Development of Fuel Processing <i>Chair: M. O'Connell / H.P. Schmidt</i>	B13
13:30	Understanding Water Removal from Fuel-Cell Gas-Diffusion Layers Adam Z. Weber, Prodip Das, Haluna P. Gunterman Lawrence Berkeley National Laboratory, Berkeley/Canada	A1301	The review of on-board hydrogen production and CO purification for transportation PEM Fuel Cells Athanasios Tsolakis, J. J. Chong, W. C. Tsolakis University of Birmingham, Birmingham/United Kindom	B1301
13:45	Two phase Pore Network Model of the cathode catalyst layer of the PEMFC Mohamed El Hannach, Joël Pauchet, Marc Prat CEA/DEHT/Liten, Grenoble/France	A1302	An experimental approach to the capability of metering units for future fuels Thomas Rolland, Axel Müller, Horst Kappler Thomas Magnete GmbH, Herdorf/Germany	B1302
14:00	A Numerical Model Predicting Liquid Water Saturation within the Cathode Electrode of a Proton Exchange Membrane Fuel Cell Naveed Akhtar, Piet J.A.M. Kerkhof Technical University, Eindhoven, Eindhoven/The Netherlands	A1303	Combined dry and steam reforming of biogas for generation of H₂ and CO rich fuel gas for SOFC Carsten Spieker, Christian Spitta, M. Steffen, A. Heinzl Zentrum für BrennstoffzellenTechnik ZBT GmbH, Duisburg/Germany	B1303
14:15	Aging mechanisms in Lithium-Ion-Battery and PEM-Fuel Cell and their influence on Hybrid-Systems Frieder Herb, Kavin Trivedi, Martin Wöhr, Stefan Reiff Daimler AG, Kirchheim/Germany	A1304	Pre-reforming of liquid hydrocarbons at atmospheric pressure Nils Kleinohl, Ansgar Bauschulte, Klaus Lucka OWI Oel-Waerme-Institut GmbH, Aachen/Germany	B1304
14:30	Numerical study on the water distribution in GDL and channels of PEMFC applying microchannel bipolar plate Yongchan Kim, Bosung Kim, Ahyoung Woo, Yongtaek Lee Korea University, Seoul/Korea	A1305	Pyrolysis, a Low Cost Multi-fuel Processor for Fuel Cells Robert Szolak, Thomas Aicher Fraunhofer Institute for Solar Energy Systems ISE, Freiburg/Germany	B1305
14:45	Influence of nature and concentration of iron ions on the degradation of PEMFCs: a modeling study Romain Coulon (1), Alejandro A. Franco (1), Wolfgang G. Bessler (2) (1) CEA/DRT/Liten/DTH, Grenoble/France (2) German Aerospace Center (DLR), Stuttgart/Germany	A1306	Further development of a microchannel steam reformer for diesel fuel Marius Maximini, Melanie Grote, Martin Brenner, Sascha Tölle OWI Oel-Waerme-Institut GmbH, Aachen/Germany	B1306
15:00	Intermittence → Refreshments served on 1 st Floor in front of Auditorium & on 2 nd Floor in front of the Club Rooms			





Friday, July 1, 2011

Afternoon	Auditorium (1st floor)		Club Rooms 5-6 (2nd floor)	Afternoon
15:30	Control Strategies and Modelling <i>Chair: D. Gerteisen / A. Weber</i>	A14	Hydrogen Production and Storage <i>Chair: T. Kurz / M. Maximini</i>	B14
15:30	Using Electrochemical Impedance Spectroscopy for fuel cell control Stefan Keller, Abdellatif Zaghoul, Quirin Meder Fraunhofer Institute for Solar Energy Systems ISE, Freiburg/Germany	A1401	Thermo-chemical H₂ production: Thermo-economic modeling and process integration Laurence Tock, François Maréchal Ecole Polytechnique Fédérale de Lausanne, Lausanne/Switzerland	B1401
15:45	Numerical Study of PEMFC Water Management for Control and Diagnosis Strategies Design Cesare Pianese, Angelo Esposito, Pierpaolo Polverino University of Salerno, Salerno/Italy	A1402	Optimised hydrogen storage and operating pressure of electrolyzers Thomas Nietsch, Anaïs Konieczny HELION, Aix-en-Provence/France	B1402
16:00	Application of Proton Exchange Membrane Fuel Cell for Lift Trucks Elham Hosseinzadeh, Masoud Rokni Technical University of Denmark, Lyngby/Denmark	A1403	Solid Ammonia as Energy Carrier: Possibilities and Technology Development Debasish Chakraborty, Henrik Nybo Petersen, Tue Johannessen Amminex A/S, Soeborg/Denmark	B1403
16:15	Nonlinear operating behaviour of PEM fuel cells Richard Hanke-Rauschenbach, Michael Mangold, Kai Sundmacher Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg/Germany	A1404	Modeling of heat and mass transfer in metal hydride matrix during hydrogen adsorption-desorption cycle Akanji Olaitan, Andrei Kolesnikov Tshwane University of Technology, Pretoria/South Africa	B1404
16:30	Model-based analysis of the environmental operating range of direct methanol fuel cell systems Ulrike Krewer, Federico Zenith Otto-von-Guericke-University, Magdeburg/Germany	A1405	Functionalized metal oxide nanoparticulate films for solar photo-electrochemical hydrogen generation Artur Braun, D. K. Bora, E. C. Constable, T. Graule EMPA Swiss Federal Laboratories for Materials Science and Technology, Dübendorf/Switzerland	B1405
16:45	Thermal Management of Fuel Cell Air Independent Propulsion System Sangseok Yu, Young Duk Lee, Chan Ho Song, Seok Yeon Im Chungnam National University, Daejeon/South Korea	A1406	Towards Solving Fundamental Issues For Alkaline Exchange Membrane Fuel Cells Andrew M. Herring, James Horan, Mei-Chen Kuo, Jerri D. Jessop Colorado School of Mines, Golden/USA-CO	B1406
17:00	Transfer time → Quick change to Auditorium on 1 st floor			

Friday, July 1, 2011

Afternoon

Auditorium (1st floor)

Afternoon

17:00	Closing Ceremony <i>Chair: K.A. Friedrich, Organizers</i>	A15	
	Summary by the Chairman K. Andreas Friedrich German Aerospace Center (DLR), Stuttgart/Germany	A1501	
	Information on Next EFCF in 2012 Olivier Bucheli (1), Florence Lefebvre-Joud (2), Michael Spirig (1) (1) European Fuel Cell Forum, Winterthur/Switzerland (2) CEA/DEHT/Liten, Grenoble/France	A1502	
	Hermann Göhr Award for the Best Paper Norbert Wagner (DLR) ZAHNER-Elektrik GmbH & Co.KG, Kronach/Germany	A1503	
	Friedrich Schönbein Awards for the Most Impressive Results, Best Poster, Best Presentation K. Andreas Friedrich (1), Ulf Bossel (2) (1) German Aerospace Center (DLR), Stuttgart/Germany (2) European Fuel Cell Forum, Luzern/Switzerland	A1504	
	Thank you and Closing by the Organizers Michael Spirig, Olivier Bucheli European Fuel Cell Forum, Luzern/Switzerland	A1505	
18:00	End of Sessions		
End of Conference – Welcome You again on 25 June - 29 June 2012			



Afternoon

13:30

Afternoon

13:30

Wednesday, June 29, 2011

14:30

Thursday, June 30, 2011

14:30

Poster Session I		Poster Session II		
Poster Session	PEMFC Applications	A04	SOFC Development and Durability	B04
	Distributed characteristics of PEMFC operated in dead-end mode with gas recirculation Adélio Mendes, Luis C. Pérez, José M. Sousa, Adélio Mendes LEPAE – Laboratório de Engenharia de Processos, Ambiente e Energia, Porto/Portugal	A0407	Effect of Sr contents of (Ba,Sr)(Co,Fe)O_{3-δ} Cathodes on Chromium Poisoning Phenomena Yu-Mi Kim, Xinbing Chen, San Ping Jiang, Joongmyeon Bae KAIST, Daejeon/Korea	B0407
	A Smart Grid-Connected Ethanol Powered PEMFC System José Geraldo de Melo Furtado, Gisele Ezechiello da Silva, Roberto Furtado, Eduardo Torres Serra Electric Power Research Center – Eletrobras Cepel, Rio de Janeiro/Brazil	A0408	Development of Anode-supported Flat-tube SOFC Stack having a New IC Design Seung-Bok Lee, Seok-Joo Park, Rak-Hyun Song Korea Institute of Energy Research, Daejeon/Korea	B0408
	Fuel Cell Applications I	A05	Intermediate Temperature SOFC	B05
	Design Optimization of the 1kW Residential Power Generator with PEMFC Minjin Kim, Young-Jun Sohn, Won-Yong Lee Korea Institute of Energy Research, Daejeon/Korea	A0508	Composite Cathodes Assisted Low Temperature Micro-SOFCs Yan Yan, Yan Yan, Janine Conde, Paul Muralt Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne/Switzerland	B0507
	Study on purge performance improvement of fuel cells with a pulsating flow Min Soo Kim, Ji Yong Jang, Sung Il Kim Seoul National University, Seoul/Korea	A0509	Fuel Cell Applications II	B07
	The influence of CO on the current density distribution of high temperature polymer electrolyte membrane fuel cells Marta Boaventura (1), Heinz Sander (2), Andreas Friedrich (2), Adélio Mendes (3) (1) Faculdade de Engenharia - Universidade do Porto, Porto/Portugal (2) German Aerospace Center (DLR), Stuttgart/Germany (3) Faculdade de Engenharia - Universidade do Porto, Porto/Portugal	A0510	BZ-BattExt – DMFC as Battery-Extender in solar-boat application Johannes Schirmer (1), Regine Reißner (1), Jochen Zabold (2), Katica Krajinovic (3), Thomas Häring (4), Stefan Nettesheim (5), Joachin Kopf (6), Klaus Steinhart (7) (1) German Aerospace Center (DLR), Stuttgart/Germany; (2) Freudenberg FCCT KG, Weinheim/Germany; (3) Universität Stuttgart, Stuttgart/Germany; (4) Between Lizenz GmbH, Stuttgart/Germany; (5) Staxon Consulting GbR, Berlin/Germany; (6) Kopf Solarschiff GmbH, Sulz-Kastell/Germany; (7) Ulmer Brennstoffzellen Manufaktur GmbH, Ulm/Germany	B0708
		Optimization of MCFC Hybrid Plant Design for CO₂	B0709	

Water Droplet Dynamics in a Micro-Tubular, Proton Exchange Membrane Fuel Cell Naveed Akhtar Technical University, Eindhoven, Eindhoven/The Netherlands	A0511	Recovery Meeyoung Park, Won-Joon Choi, Ahrim Yoo, Jong Kyun You, Gi pung Lee, Kil ho Moon, Tae won Lee Doosan Heavy Industries & Construction Co., Ltd, Daejeon/Korea	
PEMFC Components - Electrodes	A07	A Quantitative Comparison on SOFC Power Cycles Young Duk Lee, Byungjun Kim, Sang Min Lee, Kook Young Ahn Korea Institute of Machinery and Materials, Daejeon/Korea	B0710
Pt based thin films deposited by magnetron sputtering for PEMFC and DMFC fuel cells Aboubakr Ennajdaoui, Matthieu Vogt, Marjorie Cavarroc Made In Dreux Innovation, Vernouillet/France	A0709	High Temperature Fuel Cell characterisation	B09
Development of Membrane Electrode Assemblies for PEFC based on Aromatic Membranes Sebastian Altmann, Erich Gülzow, K. Andreas Friedrich German Aerospace Center (DLR), Stuttgart/Germany	A0710	Synthesis and Characterization of LaSr₂Fe_{3-y}CryO_{9-δ} Cathode for IT -SOFC Bok-Hee Kim, Eun-Sil Choi, Min Chen Chonbuk National University, Jeonju/Korea	B0907
CNTs grown on Carbon paper as a cathode for PEMFCF Yong-Gun Shul, Jinhee Ok, Altalsukh Dorjgotov, Junki Rhee, Sangsun Park Yonsei University, Seoul/South Korea	A0712	Development and Characterization of Biomass-derived Fuels Powered SOFC José Geraldo de Melo Furtado, Taisa Eva Gutierrez, Roberto Furtado, Eduardo Torres Serra Electric Power Research Center – Eletrobras Cepel, Rio de Janeiro/Brazil	B0908
Direct Methanol Fuel Cell Components	A09	Oxide Scale Formation in Different Metallic Interconnects for Solid Oxide Fuel Cells (SOFCs) V. Miguel-Pérez, Ana Martínez-Amesti, K. Vidal, A. Larrañaga, M. L. Nó, M. I. Arriortua Universidad del País Vasco/Euskal Herriko Unibertsitatea (UPV/EHU), Leioa/Spain	B0909
Methanol tolerance of Pt-Co catalysts F.G.S. Wasim (1), B. P. Ladewig (2), M. Neergat (1) (1) Indian Institute of Technology Bombay (IITB), Mumbai/India (2) Monash University, Melburn/Australia	A0907	Electrochemical and Structural Properties of Li/K Carbonate Electrolyte in Matrix for MCFCs Suk-Youn Jang, Mi-Youn Shin, Bo-Hyun Ryu, Tae-Won Lee Doosan Heavy Industries & Construction Co., Ltd, Daejeon/Korea	B0910
Studies of the Synergetic Effects of Sb₂O₄ on Pt Electrocatalyst for Intermediate Temperature DMFC Application Jin Hu, Jiangshui Luo, Peter Wagner, Carsten Agert EWE-Forschungszentrum für Energietechnologie e. V., Oldenburg/Germany	A0910	A Direct Carbon Fuel Cell Operating with De-ashed Coal Chung Hwan Jeon, Jong Pil Kim, Ju Hun Song, Young June Chang Pusan National University, Busan/Korea	B0911



PEMFC Components - Characterisation and Improvements	A10	SOFC Components - Characterisation and Improvements	B10
Development of High Performance and Durable Fuel Cell Membranes Based on Radiation Grafting Lorenz Gubler, Hicham Ben Youcef, Sandro Lüscher, Jürg Thut, Lukas Bonorand, Günther G. Scherer Paul Scherrer Institut, Villigen/Switzerland	A1008	Obtaining and characterization of 3YSZ+8YSZ mixtures for SOFC electrolyte Crina Suciulea, Hanna Tikkanen, Eugen Dorolti, Catalin G. Ilea Prototech AS, Bergen/Norway	B1007
High-Temperature Polymer Electrolyte Membrane Fuel Cells: The Effect of Compression Anja Diedrichs, Peter Wagner, Olaf Conrad Next Energy · EWE Research Center for Energy Technology, Oldenburg/Germany	A1009	Thin-film solid oxide fuel cells using proton conductor Suk Won Cha, Ikwhang Chang, Yoonho Lee, Seungbum Ha Seoul National University, Seoul/Korea	B1008
Stability of Suspensions and Manufacturing of Electrolyte Films Hosane Aparecida Taroco, Rosana Zacarias Domingues, Tulio Matencio Universidade Federal de Minas Gerais, Minas Gerais/Brazil	A1010	Ceramic and glass composite interconnects for Solid Oxide Fuel Cells Seung-Bok Lee, Seuk-Hoon Pi, Rak-Hyun Song Korea Institute of Energy Research, Daejeon/Korea	B1009
Preparation and characterization of new sulfonated partially fluorinated polyarylenethioether and their blends with a polybenzimidazole Corina Seyb, Jochen Kerres Universität Stuttgart, Stuttgart/Germany	A1011	New Laser-Based Glass Sealant Applications For Fuel Cell Stack Manufacturing Dietrich Faidel, Wilfried Behr, Uwe Reisinger Forschungszentrum Jülich GmbH, Jülich/Germany	B1011
New High Performance Proton Conducting Membranes for Hotter, Drier Operation of Polymer Electrolyte Fuel Cells Andrew M. Herring, James L. Horan, Mei-Chen Kuo, Gregory J. Schlichting Colorado School of Mines, Golden/USA-CO	A1012	Fuel Cell Diagnostics	B12
Thermally stabilized PVA-g-PAA substituted benzimidazolium group membranes for Fuel cell applications Pratima Gajbhiye, Anil Kumar, J. K. Singh Indian Institute of Technology Kanpur (IITK), Kanpur/India	A1014	Local measurement of electrical potential in a PEMFC stack using wire instrumentation technique Samir Rachidi, Ludovic Rouillon, Sébastien Rosini, Sergueï Martemianov CEA/DEHT/Liten, Grenoble/France	B1209
		Analysis of the ethanol oxidation in alkaline media Carsten Cremers, Domnik Bayer, Birgit Kintzel, Jens Tübke Fraunhofer Institute for Chemical Technology ICT, Pfinztal/Germany	B1210

<p>Development of covalently cross-linked sulfonated PEEK/heteropoly acid composite membranes for PEMFC Yong-Gun Shul, Heesoo Na, Hyungkwon Hwang, Chanmin Lee Yonsei University, Seoul/South Korea</p>	A1015	<p>Development of Fuel Processing Preferential CO Oxidation over Ru/α-Al₂O₃ Catalyst Prepared by Deposition-Precipitation Wang Lai Yoon, Kee Young Koo, U. H.Un Ho Jung Korea Institute of Energy Research, Daejeon/Korea</p>	<p>B13 B1308</p>
<p>Characterization of anion exchange membranes for use in alkaline anion exchange membrane fuel cells Carolina Nunes Kirchner, Peter Wagner, Olaf Conrad Next Energy · EWE Research Center for Energy Technology, Oldenburg/Germany</p>	A1016	<p>Fuel Cell Modelling Numerical Simulation of Solid Oxide Fuel Cell for Impedance Analysis Rafat Mohammadi, Majid Ghassemi, Y. Mollayi Barzi, M.Hosseini Hamedi K.N. Toosi University of Technology, Tehran/Iran</p>	<p>A13 A1307</p>
<p>Novel ultrathin composite membranes of Nafion/PVA for PEMFCs Vicente Compañ, Sergio Mollá, Enrique Gimenez, Alberto Blazquez Universidad Politécnica de Valencia, Valencia/Spain</p>	A1017	<p>Kinetic Monte Carlo Simulation of Ion Conduction in Ydoped Barium Zirconate Rojana Pornprasertsuk, Onthida Kosasang, Kittichai Somroop, Friedrich B. Prinz Chulalongkorn University, Bangkok/Thailand</p>	A1309
<p>Fuel Processing Integration and Durability</p>	A12	<p>A Parameter Estimation Method for Fuel Cell Diagnostics Leonidas Tsikonis, Arata Nakajo, Jan Herle, Daniel Favrat Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne/Switzerland</p>	A1310
<p>Highly integrated micro fuel cell system based on a methanol steam reformer and a HT-PEM fuel cell Philip Engelhardt, Daniel Wichmann, Thomas Huck, Klaus Lucka OWI Oel-Waerme-Institut GmbH, Aachen/Germany</p>	A1208	<p>Multiphysics Model of the Anode of a Direct Methanol Fuel Cell Pablo A. García-Salaberri, Marcos Vera, Immaculada Iglesias, Ramón Zaera Universidad Carlos III de Madrid, Leganés/Spain</p>	A1311
<p>Influence of Gas Composition on the Polymer Membrane Fuel Cell (PEFC) Performance Norbert Wagner, Günter Schiller German Aerospace Center (DLR), Stuttgart/Germany</p>	A1209		



Poster Session	Control Strategies and Modelling	A14	Hydrogen Production and Storage	B14
	The characteristics study on thermal management of the proton exchange membrane fuel cell system for the unmanned aerial vehicle Sanggyu Kang, Byungjun Kim, Hanseok Kim, Sangmin Lee Korea Institute of Machinery and Materials, Daejeon/Korea	A1407	Scenarios For The Hydrogen Society Tabea Hirzel SMC University, Zurich-Kloten/Switzerland	B1407
	Matlab/Simulink as design tool of PEM Fuel Cells as electrical generation systems Maria T. Outeiro, Adriano S. Carvalho Faculdade de Engenharia - Universidade do Porto, Porto/Portugal	A1408	Hydrogen Production by Alkaline Electrolysis: Characterization of Porous Diaphragms Jelena Stojadinović, Michal Gorbar, Ulrich Vogt, Andreas Züttel EMPA Swiss Federal Laboratories for Materials Science and Technology, Dübendorf/Switzerland	B1408
	Numerical study on the capillary effect of microchannel in bipolar plate in PEMFC Yongchan Kim, Bosung Kim, Ahyoung Woo, Yongtaek Lee Korea University, Seoul/Korea	A1409	Composite ceramic diaphragms for alkaline electrolysis Michal Gorbar, Daniel Wiedenmann, Benjamin Fumey, Jelena Stojadinovic, Andreas Züttel, Ulrich Vogt EMPA Swiss Federal Laboratories for Materials Science and Technology, Dübendorf/Switzerland	B1409
	Development of a dynamic model and control of a PEM fuel cell Paolo Iora, Jekanthan Thangavelautham Università degli Studi di Brescia, Brescia/Italy	A1410	HT-PEM-Electrolysis Sebastian Stypka, Claudia Schöberl, Corina Seyb, Bernd Oberschachtsiek Zentrum für BrennstoffzellenTechnik ZBT GmbH, Duisburg/Germany	B1410
	Increasing the Efficiency of High Temperature PEM-Fuel-Cells by Using Simulated Optimized Flowfields Volker Wesling, Peter Giese, Thorsten Kandelhardt Clausthal University of Technology, Clausthal-Zellerfeld/Germany	A1411	Protic ionic liquid and ionic melts prepared from imidazole and methanesulfonic acid as non-aqueous electrolytes Jiangshui Luo, Ivo F. J. Vankelecom, Carsten Agert, Olaf Conrad Next Energy · EWE Research Center for Energy Technology, Oldenburg/Germany	B1411
			Sizing of photovoltaic system coupled with hydrogen storage based on the ORIENTE model Christophe Thibault, Christophe Darras, Marc Muselli, Philippe Poggi, J.C. Hoguet, S. Melscoet, E. Pinton Université de Corse, Ajaccio/France HELION, Aix-en-Provence/France CEA/DEHT/Liten, Grenoble/France	B1412

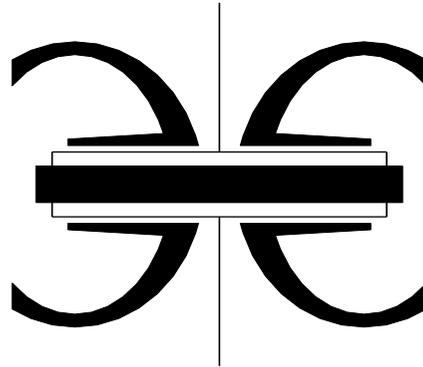
15th highly valued international conference on FUEL CELL and HYDROGEN
EUROPEAN FUEL CELL FORUM 2011

28 June – 1 July 2011

Kultur- und Kongresszentrum Luzern (KKL) Lucerne / Switzerland

Chairman: Prof. Dr. Andreas Friedrich

German Aerospace Center DLR



Abstracts of all Oral and Poster Contributions

Legend:

- The program include three **major thematic blocks**:
 1. Worldwide Fuel Cell & Hydrogen Program (A1, A2);
 2. Relevant European Demonstration Projects (A6, A11);
 3. Technical Sessions - A: Broad Technology Approach; - B: SOFC Technologies, Characterisation & Diagnostics and Hydrogen
- **Abstracts** are identified and sorted by presentation number e.g. A0504, B1205, etc first all A and then all B
 - Oral abstracts contain of numbers where last two digits are 01-06, resp. in session A07, A12 and B07, B12 01-07
 - Poster abstracts are linked to related sessions by letter and first two digits: e.g. A05., B10, ...etc
 - Due to late withdrawals some numbers are missing



A0105

Europe's Fuel Cells and Hydrogen Joint Undertaking

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Abstract

The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) was set up to accelerate the development of fuel cells and hydrogen technologies in Europe towards commercialization from 2015 onwards. To reach this target the FCH JU intends to bring together resources under a cohesive, public-private partnership, to ensure commercial focus, matching RTD activities to industry's needs and expectations and to scale-up and intensify links between Industry and the Research Community

This unique public-private partnership is composed of the European Union, represented by the European Commission, the European Industry Grouping for a Fuel Cell and Hydrogen Joint Technology Initiative¹ and the New European Research Grouping on Fuel Cells and Hydrogen². The latter two are non-profit Associations, open to companies and research institutes respectively within Europe, EEA and Candidate accession countries. All member groups are represented at Board Level and expert advice is provided by *The States Representatives Group*, *The Scientific Committee* and the *Stakeholders General Assembly*.

A predefined budget for the period 2008-2013 of nearly 1 billion Euro contributed jointly by the FCH JU Members is foreseen to support research and demonstration projects and ultimately accelerate the market introduction of these technologies.

A long-term strategy document, the Multi-Annual Implementation Plan, outlines the scope and details of the planning for the programme divided into four main application areas (Transport and refuelling infrastructure; Hydrogen production and distribution; Stationary power generation and combined heat and power and Early markets).

Cross-cutting activities, including regulation, codes and standards, pre-normative research, socio-economic research, life cycle assessments, market support, public awareness and education, have been established as a 5th application area, all of key importance to the commercialisation objective.

Annual Implementation Plans are published annually. They contain work programmes which provide the basis for launching calls for proposals. 3 calls have been executed to date with a fourth in the pipeline this year.

Examples of supported projects will be presented.

¹ <http://www.fchindustry-jti.eu/>; The NEW IG currently has 67 member companies across the EU. It is open to new members at all times.

² <http://www.nerghy.eu/>; N.ERGHY currently has 63 member universities and research institutes across the EU. It is open to new members at all times.

A0106

Overview of DOE Hydrogen and Fuel Cell Activities

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Abstract

This presentation will provide an overview, highlight recent achievements and offer an insight into future prospects of the U.S. Department of Energy's (DOE's) hydrogen and fuel cell research, development, and demonstration efforts. The DOE's Office of Energy Efficiency and Renewable Energy's Fuel Cell Technologies Program represents a comprehensive portfolio of activities that address the full range of technological and non-technological barriers facing the development and deployment of hydrogen and fuel cell technologies.

The Program conducts focused efforts to enable the widespread commercialization of hydrogen and fuel cell technologies in diverse sectors of the economy. The Program addresses challenges facing the development and deployment of hydrogen and fuel cell technologies by integrating basic and applied research, technology development and demonstration, and other supporting activities. These include research and development to address key technological barriers in the areas of fuel cell cost and durability, hydrogen cost, and hydrogen storage capacity, along with demonstration activities to validate technologies under real-world conditions. The Program's efforts to address non-technological barriers include: facilitating the development of safety practices and codes and standards; supporting development of a domestic manufacturing and supplier base; increasing public awareness and acceptance; and investigating options for the development of a hydrogen supply and delivery infrastructure.

Developmental efforts at the DOE are balanced to achieve a comprehensive approach to fuel cells for near-, mid-, and longer-term applications. Early market penetration is targeted through the development of fuel cell technology and systems for portable, auxiliary power, stationary, and specialty vehicle applications. Market penetration will enable lower costs, job creation, and growth in the domestic fuel cell manufacturing and supplier base. As such, funding provided by the American Recovery and Reinvestment Act is supporting the deployment of nearly 1,000 fuel cell systems in emergency backup power, material handling, and combined heat and power applications. In the long term, ongoing efforts in the development of fuel cell technology will also be applicable to light-duty vehicles.

A0201

Strategies for Development of Fuel Cells and Hydrogen Stations in Japan

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Abstract

In Japan, fuel cell and hydrogen technologies are regarded as two of the most promising technologies for reducing CO₂ emissions, particularly in the residential and transport sectors.

NEDO is an incorporated administrative agency under Japan's Ministry of Economy, Trade and Industry (METI). It has promoted innovation in the energy and industrial technology sectors for a number of years by developing comprehensive strategies and working in close cooperation with industry and academia. NEDO's current activities for the practical realization of fuel cell systems and hydrogen stations include technology development, demonstration projects, and providing technological data necessary for amending relevant regulations.

As a result of its efforts, the world's first household fuel cell system was introduced to the commercial market in Japan during 2009. Fuel cell vehicles and hydrogen stations are now under development toward the target year of 2015, which is expected to be the starting point of their commercialization.

A0202

Overview of fuel cell and Hydrogen activities in China

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Abstract

China has put great efforts to develop state and the art technologies of hydrogen and fuel cell in the past decades, and will continue to launch the plan of development and demonstration of fuel cell technologies in order to pave the way for the commercial application of the fuel cell technologies.

At the first year of the 12th Five-year (2011-2015) Economic Development Plan, the ministry of science and technology (MOST) has approved the budget of 738 million RMB for EV R&D, among which 21% is for fuel cell electric vehicles (FCEV). Additionally, MOST has also approved the budget in the area of "advanced energy technology". Among which, the distributed power generation system based on fuel cell has been granted investment.

China carried out a large number of fuel cell vehicles for demonstrations. In 2009, China began the large scale demonstration program of "25 cities-1000 vehicles" in selected cities. It was the first time that new energy vehicles applied in the public transportation system, which promoted the construction of hydrogen refueling facilities. The fuel cell vehicles were also applied in the Exposition in Shanghai 2010. FCEVs demonstration during Shanghai Expo was very successful. About 196 zero emission fuel cell vehicles were applied in the EXPO. During the Asian Games in Guangzhou, 60 fuel cell vehicles were running in Athletes Village and Media Village for demonstration. In August 2011, in the 26th World Universiade in Shenzhen, there will also have the demonstration of clean energy vehicles, including fuel cell vehicles. The demonstration of new energy vehicles will continue after the World Universiade in China.

To help implementation of the Electric Vehicle Initiative (EVI), 2011 International Forum on Electric Vehicles International Pilot City and Industry Development was held in Shanghai. Representatives from governments, pilot cities, industries academia and the financial sectors participated in this forum. Electrical vehicles in the EV-Initiative are including Plug-in Hybrid Electric Vehicle (PHEV), all Electric Vehicles (AEV) and Fuel Cell Vehicles (FCV).

A0203

Fuel Cell Research Programme and Activities in South Korea

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Abstract

In this talk, I shall intend to introduce the activity of Korean government, research institutes, universities and companies in fuel cells research and developments on behalf of a lot of excellent scientists and engineers in South Korea. During last 10 years, we have very much focused on the commercialization of fuel cells in various industrial fields and are showing relevant results from demonstrations of fuel cells. Of late, the national program is also providing the environment for continuous research of basic science to discover breakthrough technologies.

A0401

Improvement of PEMFC Stack Components For Commercializing Residential CHP Systems

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Abstract

In Japan, thirteen thousand of PEMFC CHP systems (ENE-FARM) have been marketed for residential uses by FY2010, but a significant cost reduction is required for the full-fledged commercialization. Manufactures of membranes and systems, fuel suppliers and research institutes joined the ROBUST Project that was funded by New Energy and Industrial Technology Development Organization (NEDO) during FY2005-FY2009. The objectives of this project were to improve reliability and robustness of the PEMFC stack components, which contribute to simplification and cost-reduction of the whole CHP system.

Asahi Kasei E-materials, ENEOS Celltech (Sanyo Electric before FY2007) and Nippon Oil made efforts to improve the reliability of MEAs by using newly developed PFSA membranes. The period to sudden degradation of the membrane was extended 20-fold. The cell voltage decay rate of the improved MEA was reduced to 1.6 μ V/hour under a near-saturated humidification. The initial cell voltage ascended up to 770mV @ 0.2A/cm² under the condition of $T_{cell}=85^{\circ}C$, $T_{da}=60^{\circ}C$, $T_{dc}=75^{\circ}C$. Asahi Glass, Panasonic and Tokyo Gas made efforts to increase the robustness of MEAs by using newly selected PFSA polymers. Under the condition of $T_{cell}=80^{\circ}C$, $T_{da}=T_{dc}=65^{\circ}C$ as well as under the saturated humidification ($T_{cell}=T_{da}=T_{dc}=65^{\circ}C$), the initial cell voltages ascended up to 780mV @ 0.16A/cm². The cell voltage decay caused by start and shutdown cycles was also reduced to 2 μ V/cycle. The operation of a 4-cells stack using newly developed MEAs verified the possibility to obtain recovered hot water of 80-85 $^{\circ}C$ and the cell voltage of 770-780mV. During a WSS (weekly start & shutdown) operation of 2,600 hours that followed a continuous operation of 4,000 hours, it was possible to reduce the cell voltage decay rate to 1.5 μ V/hour. Injection of 0.5ppm SO₂ or 1ppm H₂S into cathode caused a larger and irreversible cell voltage drop especially under higher temperature and lower humidity conditions. Addition of temporary over-humidification ($T_{cell}<T_d$) to every start-sequence reduced the influence of 1ppm SO₂ on the cell. Since FY2008, Sumitomo Chemical has been improving hydrocarbon membranes by using a block copolymer technology, and succeeded to reduce the resistance of the MEA in a lower humidity range, which is close to that of the MEA with NRE-211CS membrane. Toshiba FCP enhanced ability to retain water in the MEAs containing the improved hydrocarbon membranes, and then raised the initial cell voltage over 750mV @ 0.2A/cm² under the condition of $T_{cell}=80^{\circ}C$, $T_{da}=T_{dc}=65^{\circ}C$.

A0402

H2/O2 Fuel Cell System for Automotive Application

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Abstract

Clean and efficient mobility is considered an important contribution for reduction of global warming emissions and decrease of primary energy requirement. These factors have driven the developments of advanced vehicles. Powertrain technology is one of the key factors in these developments. Among the alternative technologies, fuel cell systems have a high potential and received consideration from most major automotive companies. Nevertheless, maturity of fuel cell systems for the automotive application has not been reached yet, and improvements with respect to durability and in particular cost are required.

In collaboration with Belenos Clean Power, Paul Scherrer Institut is developing concepts for fuel cell systems (FCS) for the automotive application. The FCS technology is based on H2/O2 PEFC technology. The use of pure oxygen as the oxidant is not commonly used for powertrain applications where the H2/air fuel cell systems are dominating. A H2/O2 PEFC yet brings several advantages such as a higher specific power, higher efficiency, higher power dynamics, easier water management, lower stress due to the environment (altitude, humidity, air pollution) and lower balance of plant consumption (no air-compressor). The only disadvantage is the need of oxygen on-board storage. This can be partly balanced by the higher efficiencies achieved by such powertrains. In addition to the intrinsic advantages of oxygen FCS, particular efforts were made in the integration of auxiliary components, resulting in a compact system. Finally, because cathode and anode are closed circuits, low operating pressure can be achieved, giving an additional degree of freedom in the system and powertrain management.

A0403

Preliminary results from the EcoMotion Demonstration Project – Reformed Methanol Fuel Cells in Niche Transport Applications

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Abstract

A small fuel cell powered electric utility vehicle has been developed in the joint project EcoMotion. The prototype vehicle features two commercially available 350 Watts reformed methanol high temperature PEM fuel Cell systems. The two systems are installed as battery chargers (APU), in order to supply the lead acid battery pack with energy when the cell voltages are too low. This unique system has been field tested in real life use e.g. as utility truck in a zoo, as gardening utility truck in a cemetery. The preliminary results from these tests are good, showing that the fuel cell systems are capable of operating in real life environments. A pilot series of four vehicles are also developed specifically for four different market areas: Zoo, Cemetery, Municipality and Airports. The four vehicles are all to be field tested in these challenging market areas. During these field tests the vehicle power consumption will be analysed using an advanced data logging system. From the DAQ system several parameters from the vehicle and fuel cell systems can be monitored which enables detailed study of the vehicle performance during the field tests.



The prototype GMR multitruck



A look inside the powertrain of the truck

From the initial data logging of the prototype vehicle it can be seen that the fuel cells are capable of supplying enough energy for the field test conducted. The fuel cell systems generally performed very well, however some instances of premature system shut down have been experienced. However the systems seem to be capable of handling the rough conditions on a vehicle platform without suspension. The users of the truck had to refuel the truck with a 60/40 methanol mixture, although this fuel was new to them, they did not display any discomfort in handling this fuel.

A0404

PEMFCs compared to other technologies for air independent energy supply

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Abstract

This work compares PEMFCs with other technologies suitable for air independent energy storage, potentially usable in manned or unmanned underwater vehicles, satellites and other space application.

In a first round a list of over 30 technologies was drawn up and down selected to a smaller number for a more detailed investigation. Most important down selection criteria are the technology readiness level and operating conditions compatible with the envisaged applications. The down selected technologies were compared in terms of performance, costs and technology readiness as off today and a forecast for the near future is given of wide range of applications or mission profiles.

The considered performance characteristic includes energy per weight (specific energy, kWh/kg), energy per volume (energy density, kWh/l), number of charge / discharge cycles and life time. The gathered economical characteristics are the specific installation costs (€/kW or €/kWh), operating and maintenance costs. These costs might include direct costs for the vehicle as well as indirect costs for infrastructure, etc.

The performance data in this work are not performances related to specific suppliers but to the technology itself and as such generic data. Supplementary volume, weight and costs for the balance of plant, infrastructure and maintenance are added to find the complete systems performance. This was done by using our own experience, results and the companies general experience and database.

By doing this we were able to identify the most suitable technologies of the envisaged application based on today's performance and for most likely expected future performances. These are Li based batteries for high power at lower energy; metal sea water batteries for very low power over very long time (high energy) and PEMFC based systems for reasonable power at high energy.

Parts of the work were carried out under the European Defence Agency (EDA) project "Energy supply for Unmanned Underwater Vehicles (ESUUV) Reference N° 09-R&T-006. The other consortium members were ECA and Nexter.

A0405

Uninterruptible Power Supply with PEM Fuel Cell Technology

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Abstract

Important technical functions such as telecommunication services are protected against grid failures by uninterruptible power supply (UPS) systems. In most cases the emergency power is provided by lead acid batteries. Lead-acid batteries are sensitive with regard to variations in temperature, difficult to control and contain harmful materials.

A more environment-friendly alternative are fuel cells (FC). In this project the lead acid batteries of an UPS system were replaced by a commercial PEM FC System and – to avoid any batteries – the delayed start-up behaviour of the FC was bridged with super capacitor technology.

The aim of the project was to prove the functional, efficient and reliable operation of the FC system under real conditions and over a long-term period. For this reason the system was connected to a real operating base station of a telecommunication service provider near Lucerne from January 2006 until end of 2009. The field test included monthly grid failure simulations of 5x5 minutes and 2x20 minutes as well as several 4 hour simulations. Hydrogen was supplied by two 50 l pressure cylinders which were able to provide a stand-alone operation of the installation for about 6 hours.

Approximately 350 start-ups including two real outages confirmed the functionality and reliability of the system. Under the load of the base station the FC system started with a reliability of 100%. At the end of the tests a decrease of the FC voltage of about 3.3% was observed. An amount of electrical energy of about 470 kWh was provided. The FC system was still fully operational at this time.

The project was realised with two industrial partners and the financial support of the Swiss federal office of energy (SFOE). During the project period of more than three years an increasing number of FC producers and UPS suppliers became aware that the application of FCs as a back-up system responds to critical market demands and developed ready-to-market products. Hence, for the FC UPS application, it is no longer the question of functionality but of a successful market entry.

This early market is now supported by the FC and Hydrogen Joint Undertaking (FCH JU) Program. The Lucerne School of Engineering and Architecture takes part in the EU-project 'Fuel cell field test demonstration of economic and environmental viability for portable generators, backup and UPS power system applications' (FITUP) to demonstrate the application readiness for these back-up systems and to contribute to a widespread acceptance of this new technology.

A0406

Auto-Stack – Implementing a European Automotive Fuel Cell Stack Cluster

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Abstract

The Auto-Stack project combines key European players including automotive OEMs, component suppliers and research organizations in a structured approach to facilitate the development and commercialization of automotive fuel cells in Europe. While the supply base for materials and components in Europe is well advanced, automotive stack integration is lagging behind due to massive investment requirements, fragmented markets and the substantial risks associated with commercialization.

The Auto-Stack consortium is striving to reduce the critical barriers for better collaboration between stakeholders during pre-commercial and early commercial phases by generating a competitive and attractive business case for a European automotive stack industry. The activities include the definition of a common OEM stack platform concept, close interaction between OEMs, supply chain and research organizations, the development of a joint technology roadmap and ultimately the development of a business case by combining volumes and investment while exploring improved economies of scale. In addition, synergies with other vehicle categories such as public transport buses and off-road vehicles as well as vehicular APUs and selected stationary applications will be considered. The presentation will provide an overview of the project, report about the status of activity, address challenges and describe the key milestones towards achieving the project objectives.

A0407

Distributed characteristics of PEMFC operated in dead-end mode with gas recirculation

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Abstract

It is studied a segmented PEMFC (SFC) operated in dead-end mode with gas recirculation. Current density distribution (CDD) measurements and the local electrochemical activity are analyzed for different operating conditions focusing on the effective purge control parameters, the anode operating pressure and the gas recirculation. The anode nitrogen concentration in the purged gas is analyzed.

It is elucidated that the distributed characteristics of PEMFC operated in dead end mode with programmed purging cycles are different to those of PEMFC operated in flow through mode. The gas analysis showed that nitrogen permeates through the membrane, reaching significant concentrations directly related to the purge strategy used. It is also observed that the current generating characteristics of the cell are deeply affected during air supply transients due to increased nitrogen permeation and accumulation inside the anode.

A0408

A Smart Grid-Connected Ethanol Powered PEMFC System

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Abstract

Power systems based on fuel cells have been considered for residential and commercial applications in electrical energy Distributed Generation (DG) and Smart Grid markets. In this work we present an analysis of the main results obtained in a DG power generation system formed by a 2 kW proton exchange membrane fuel cell (PEMFC) and an ethanol fuel processor for local hydrogen production. The performance analysis developed simultaneously the energy and the economic viewpoints, allowing the determination of the best technical and economic conditions of this fuel cell based energy generation power plant, as well as the best operating strategies, enabling the optimization of the overall performance, control and stability of the stationary cogeneration fuel cell system connected to the Smart Grid and show the gains in efficiency, quality and reliability of electric power, as well as environmental gains compared to conventional fossil fuel based generation systems.

This study was made using empirical and theoretical parametric approaches at full load and partial load and the electrical and thermal efficiency analysis were confronted with the results available in literature. It was determined the electrical performance of the cogeneration system in function of the design and operational power plant parameters. Additionally, it was verified the influence of the activation conditions of the fuel cell electro catalytic system and the composition of ethanol reformate fuel on the system performance and durability.

The results indicate that the fuel cell-based power generation system evaluated can operate with potential of 0.60 V per single fuel cell or higher throughout the power range of the system and with fuel cell electrical efficiency peak of 41%. It was examined the criteria of safety and difficulty in regulating the frequency along the load variations, as well as issues relating to the use of intermittent renewable resources and their impacts on the generation and energy storage systems. Additionally, it was estimated the main parameters that characterize the economic operation of the system considered in situations of cogeneration and pure electrical generation, indicating that there is a reduction of around 20% in the cost of the electricity generated in the first case for the second.

A0501

Regenerative Fuel Cell System as alternative energy storage device

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Abstract

There is a strong demand in future space programs to increase the energy density of power storage and supply systems. Currently Li-ion and other types of batteries are in use. While Li-ion batteries e. g. for telecom satellite applications reach 250 Wh/kg on cell level and 150 Wh/kg on system level experts do expect an increase but not a significant one during the next decade.

For space missions with a need for high power and energy (e. g. next generation telecom satellites, lunar rovers, lunar habitats), Regenerative Fuel Cell (RFC) Technology is one candidate to make a big step forward to achieve energy densities of 300 - 350 Wh/kg.

The development focuses on high efficiency and light mass systems with lifetimes of > 15 years and an emphasis on system simplicity.

Taking a closer look at the problems to integrate regenerative energy sources, especially wind and solar power, into the terrestrial grid infrastructure, it will become more and more important to find new technologies to store electrical energy.

Astrium currently evaluates the terrestrial potential of RFC systems. The paper describes the technical approach, the differences between space and terrestrial applications and compares the advantages and disadvantages of alternative technologies.

A0502

PEM-Electrolysis for Decentralized Energy Supply

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Abstract

With the increasing market penetration of local energy supply solutions based on hydrogen, the production of hydrogen locally with renewable energies becomes an ever more important factor. The focus is particularly upon four conceptions:

Stand-alone applications:

Electrical consumers are supplied by wind power or photovoltaics. Any excess electrical power is used for electrolyzers to produce hydrogen to store energy for fuel cells supplying electricity in times without wind or sun.

Back-up systems:

Electrical consumers are usually supplied from the grid. In case of grid breakdown a fuel cell will be the makeshift. When the grid is working again, the hydrogen storage will be replenished via an electrolyser supplied from the grid.

Refilling stations:

Electrolysers supplied either by the grid or by regenerative energies can locally supply hydrogen for any type of vehicles and mobile applications.

Energy storage:

In times of surplus current, the grid can be relieved by supplying several local electrolysers providing hydrogen. In peak times and when there is not enough electricity available, the stored energy can be fed into the grid.

For all these applications PEM electrolysers must be low cost/maintenance, highly efficient, long-life, suitable for grid/regenerative, high pressure. The presentation will give technical details as well as more information regarding the use of PEM electrolysers in the above four conception.

A0503

Design and characterisation of a portable high temperature PEM fuel cell module

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Abstract

A high temperature PEM fuel cell module prototype with a 5-cell stack is presented. It has a nominal output power of 45 W_{el} and a peak power of more than 90 W_{el}. The stack is packed together with essential system components which are fan, heating unit, actors and sensors to obtain a compact stack module.

To reduce weight and volume, the stack is compressed by a string coil instead of threaded bolts. Flow field structure is designed with the aid of CFD calculations to achieve a homogeneous temperature distribution even at high air flow rates. This flow field geometry combines the cooling and cathode air supply, enabling the use of only one fan with low power consumption.

The stack is characterised with polarisation curves and simultaneous electrochemical impedance spectroscopy. Temperature distribution is monitored with 16 thermocouples in the stack. The measurement results show very homogeneous cell behaviour in a wide operating range and high membrane conductivity. This verifies the concept of the stack compression, sealing and flow field design.

A0504

Recent developments of micro DMFC and FC/battery hybrid power supply system in ITRI

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Abstract

New generation "smart electronics", such as iPad and smart phones, have a bigger appetite of electrical energy supply. It has been reported [1] that the energy density need will increase from 500 Wh/L in 2010, to 750~1,000 Wh/L in 2015. With the energy density of the Li-ion battery is approaching limits; various alternative power supplies have been proposed and studied in recent years. Micro fuel cell, such as DMFC (Direct Methanol Fuel Cell), is considered as a potential candidate because methanol possesses much higher energy density, in terms of volume and weight, than all of the popular batteries.

Recent developments about ITRI's Direct Methanol Fuel Cell (DMFC) and FC/battery hybrid will be reported in this presentation, including MEAs and FC/battery hybrid control system. Prototype examples of FC/battery hybrid system in portable electronics applications, e.g. mobile phone electricity-extender, will also be presented to show the potential of them being emerging-market products.

A0505

Development of Alkaline Direct Alcohol Fuel Cells

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Abstract

Direct alcohol fuel cells are very well suited for portable power supply solutions due to their uncomplicated system design and the easy handling of the liquid fuel. However, in proton exchange membrane based fuel cells so far only methanol can be converted completely at platinum based catalyst. Alkaline electrochemistry is more suitable for the oxidation of higher alcohols such as ethanol or ethylene glycol [1, 2]. At the same time it offers the opportunity to avoid the use of platinum based catalysts. New alkaline anion exchange membranes avoid problems with carbonate precipitation and electrolyte leach out.

In this study direct alcohol fuel cells using two types of anion exchange membranes and non platinum metal catalysts by Acta S.p.A. have been tested for operation with ethanol and ethylene glycol as fuel. Results are compared to findings for the electrochemical oxidation at platinum electrodes which have already been published [1, 2]. In agreement with these results the performance of the ethylene glycol cell close to OCV conditions is not as high as that of an ethanol cell. However, at an operation potential of 0.4 to 0.6 V similar performances are achieved if a quaternary amine membrane is used and even higher performance is achieved with ethylene glycol in case a KOH doped PBI membrane is used.

A0506

High efficient solar hydrogen generation Using a HyCon® system

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Abstract

As the world rapidly moves to renewable sources of energy, the need is intensifying to store this energy to match energy availability to energy demand. Hydrogen is ideally suited to be a major energy carrier for the required and inevitable storage of renewable energy. Hence water electrolysis, where electrical energy is used to break water into hydrogen and oxygen, is regarded as an important component in a future energy economy. In particular PEM electrolysis cells have the great ability of a very fast response time in regard to a fluctuating behavior of renewable energy sources and exhibit an excellent part load performance. In this work we will present results from a HyCon® system (see Figure 1) using direct coupling of concentrated multi-junction solar cell with a single PEM electrolysis cell. Focus is on the electrolysis level with performance as well as Electrochemical Impedance Spectroscopy measurements from single electrolysis cells for the HyCon® system under laboratory conditions. Fluid flow simulations for different types of flow fields and solar to hydrogen efficiencies under outdoor conditions will be shown.

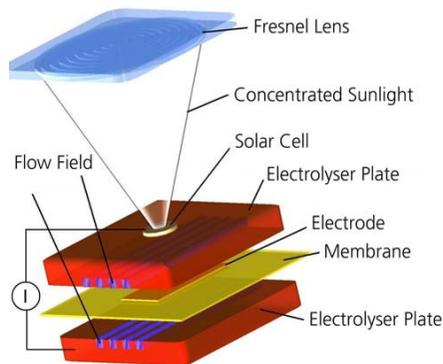


Figure 1: A schematic illustration of a HyCon® system for high efficient solar hydrogen generation.

A0508

Design Optimization of the 1kW Residential Power Generator with PEMFC

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Abstract

The residential power generator (RPG) has been focused as one of the highly efficient new generators lately. Since the RPG based on a fuel cell stack supply not only electric energy but also heat energy, its overall energy efficiency is more than 80 %. However the efficiency of the RPG can be changed to 10 %. The major factors effect the efficiency of the RPG are as followings: 1) efficiency of the components such as an air blower, a water pump, a power management system and so on; 2) the change of heat and power demand which should be followed by the fuel cell system; and 3) the control strategies to manage power between the fuel cell system and a grid as well as heat between a sub-boiler and a cooling system. In order to effectively operate the RPG, the computer-aided simulation is necessary because the simulation can estimate the RPG efficiency based on the various conditions of the efficiency control factors mentioned above. In order to improve the RPG efficiency, so many trials should be conducted and thereby cost and time are wasted. If we have the RPG simulation program, the operational efficiency can be effectively enhanced with lower cost and time. In this study, the computer-aided simulation for a 1 kW RPG using PEMFC stack is introduced. The group made the 1 kW RPG based on PEMFC by ourselves and used the RPG to verify the accuracy of the proposed simulation program. This developed simulation is expected to be applied to the real-time optimization of the RPG according to the highly dynamic changes of heat and power demands.

A0509

Study on purge performance improvement of fuel cells with a pulsating flow

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Abstract

This research describes how residual water taken-up in Nafion membrane is removed more effectively by a pulsating gas flow than by a constant gas flow. Generally, residual water in the membrane should be removed mostly to start up in a subzero condition since ice formed in that condition can plug pores of the catalyst layer so that fuel cannot be supplied properly. Therefore, purge process is needed to dry out the membrane and help a proper cold start. However, it is predicted that it takes long time to dry out the membrane if the purge is not effective. In this study, the effect of purge with a pulsating flow before shut down is investigated by experiment to improve effectiveness of purging. Furthermore, a cold start-up at -10 and -15°C after purge was performed to observe voltage variation. According to the results, purge performance with a pulsating flow is higher than that with a constant flow and the purge performance becomes higher as the pulsation frequency of the pulse generator increases. Moreover, the time before shut down at -10 and -15°C was extended enormously which is up to 48% for the frequency of 12 Hz due to the increasing lateral mass transport between the purge gas and the membrane.

A0510

The influence of CO on the current density distribution of high temperature polymer electrolyte membrane fuel cells

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Abstract

In this work, the effect of stepping the CO amount at the anode gas feed from 0.0 % to 1.5 % or 3.0 % on the feed of a high temperature polymer electrolyte membrane fuel cells (HT-PEMFC) is addressed using a PBI/ H₃PO₄ based MEA. The poisoning was assessed at 160 °C based on the transient behavior of the fuel cell voltage and current density distribution. The current density distribution at similar voltage and global current density were also compared for pure hydrogen and CO balanced hydrogen. Furthermore, the I-V and power density curves were obtained.

Two different cell anodes were used to obtain the current density distribution, 1) a metal segmented flow field and 2) a non-segmented graphite flow field where it was applied a printed circuit board as segmented current collector.

The presence of CO caused a performance loss, which was aggravated for higher CO concentrations and higher global current densities. The current density distributions obtained with metal segmented flow field showed that the use of CO balanced hydrogen originated a spatial distribution of CO at the anode, which was more evident for higher CO concentrations and global current densities. On the other hand, no significant change on the current density distribution was observed with the graphite flow field.

A0511

Water Droplet Dynamics in a Micro-Tubular, Proton Exchange Membrane Fuel Cell

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Abstract

With a recent interest in tubular geometry to be employed for proton exchange membrane fuel cells, this study considers the effect of liquid water transport in a micro-tubular channel. The necessity of two different surface coatings in a conventional design, i.e. hydrophilic channel walls and a hydrophobic gas-diffusion layer could be eliminated in a tubular design, where the whole periphery could be of uniform coating angle. The elimination of complicated channel/rib configuration further helps in water exhaust through the tubular geometry. By taking into account the above benefits of tubular geometry, water exhaust capability has been examined by varying the air flow rate, surface coating angle and the droplet size. The results show that a hydrophobic inner surface of the tubular geometry could be effective in water exhaust. In a horizontally positioned tube with a hydrophilic inner surface, water is attached to the bottom concave of the annular shape and slowly exhausted. The vertically oriented tube could take the benefit of gravity effect in dislodging the droplet through the channel.

A0601

Fuel Cell Buses in Transit Use – Update on Canada and London

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Abstract

Hydrogen fueled buses using hybrid electric drive and advanced forms of fuel cell engines and electrical power storage have been successfully introduced into daily transit fleet service. Herein we review the implementation of fuel cell powered transit service, including:

The Canadian program of a fleet of twenty fuel cell buses, serving Whistler Village British Columbia, The London program for hydrogen fueled buses, Other recent programs in California and in Europe.

Maturing hybrid electric and fuel cell technologies now offer unique opportunities in providing clean, quiet and efficient public transport. Replacing diesel fuel with hydrogen is the closing step to offering a zero emission ride which can be fueled from renewable sources while providing the smoothest and quietest transit experience. BC Transit now operates twenty hydrogen fueled buses. London has five and will take delivery of more this year. The bus drive trains were designed by ISE1 with coach fabrication by New Flyer and Wrightbus respectively.

The Canadian and the London buses are distinct designs: Whistler Village buses use 150kW fuel cell power, a 40 kWh Lithium-ion battery, and have GVW of 22 ton. The London buses have a 75kW fuel cell, ultra-capacitor energy storage, and a 15 ton GVW made possible by the aluminum body.

The Canadian fleet was introduced into service in early 2010 and provides the majority of transit service in Whistler Village. The availability of these buses has of late been in excess of the 85% goal. Although the London buses have been in service for only a few months, they are serving the same duty cycle and hours as the older Transport for London Buses of conventional technology. Design improvements in these buses further improve the availability and maintainability.

¹ ISE Corporation, formerly ISE Research, failed and went out of business early 2011.

A0602

CHIC – Clean Hydrogen in European cities

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Abstract

The Project CHIC - Clean Hydrogen in European Cities will be the essential next step to full commercialization of hydrogen powered fuel cell (H₂FC) buses. The project will facilitate the integration of 26 fuel cell hydrogen busses in daily operations and bus routes in 5 cities across Europe.

The key facts:

- 25 partners from around the world
- 5 cities
- 26 fuel cell buses
- 2 filling stations per city
- Demonstration phase 2010-2016
- 25.9 Mio. EUR funding
- 81.9 Mio. EUR costs
- at least 3 different bus manufacturers

The CHIC project will:

- Intensively test the **technology** to generate learning for the final steps towards commercialisation in 5 European model regions by:
 - **Operating a minimum of 26 H₂FC buses** in medium sized fleets in normal city bus operation and
 - Substantially **enlarging hydrogen infrastructure**
- **Embed** the substantial **knowledge and experience** gained from previous H₂FC bus projects (CUTE & HyFLEET:CUTE).
- Accelerate the development of clean public transport systems in 14 **new** European Regions.
- Conduct a life cycle based **sustainability assessment** of the use of H₂FC buses in public transport, based on a triple bottom line approach considering **environmental, economic and social aspects**.
- Build a **critical mass** of public **support** for the benefits of 'green' hydrogen powered transport, leading to increased visibility and political commitment across Europe.

The project is based on a staged introduction and build-up of H₂FC bus fleets and the supporting infrastructure across Europe. A phased approach will link experienced cities with new cities in partnerships, greatly facilitating the smooth introduction of the new systems now and into the future.

A0603

Hydrogen Pathways in France: Results of the HyFrance3 Project

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Abstract

HyFrance3 is French project that involved ten partners that consists of major players from a range of energy, scientific, research and engineering institutions: ADEME (partner and co-funding), AFH2, LEPIL, IFPEnergies nouvelles, Air Liquide, EDF, GDF Suez, Total Raffinage Marketing, ALPHEA and CEA (coordinator). HyFrance3 has been launched to focus on the economic competitiveness of different steps of the hydrogen value chain, at the time horizon of 2030 in France: industrial demand, wind energy production, mass storage and distribution for automotive supply. The current annual production of hydrogen in France should increase to values over 1 Mt per year at the time horizon of 2030, and the steelmaking could represent very high additional supply requests. Two petroleum scenarios have been analysed, that led to 20% and 40% in fuel consumption decreases respectively in 2030, in comparison to 2008, and additional hydrogen production capacities that depend on the scenario. The cost of producing hydrogen from wind-generated electricity vary widely depending on the configurations tested, mainly the demand profiles: from 4 €/kg for a BtL station supply "with the current" when the system is connected to the grid (about 9 €/kg when isolated), up to 20€/kg for an isolated refuelling station. The storage cost represents the major part of the overall system. Hydrogen mass storage dimensioning in thick salt deposits in the Rhône-Alpes and PACA regions has been evaluated, as well as filling and emptying rates, depending on different requests scenarios and supply shut down assumptions. The ECOTRANSHY tool worked out an economic model to provide the main optimal features of hydrogen supply in two French regions, supplying a set of delivery points (refueling stations) in those regions, at various time steps from 2010 to 2050. In the long term, the transportation by pipelines is cheaper than the use of trucks. Costs range between €0.40/kg and €0.60/kg for this date depending on the energy price estimates (particularly for electricity) and the distance from the storage site.

A0604

Fuel Cells for Green Corridors

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Abstract

The definition of Green Corridors along important traffic lines in Europe is a positive approach in the efforts to reduce the greenhouse gases, mainly CO₂, because the traffic sector has so far not been included in the considerations of renewable energies. The development of fuel cells with hydrogen from renewable sources and energies opens the view to the traffic sector and puts it closer to realization.

The intermediate part of the Munich-Verona TEN-1-axis with the Brenner Base Tunnel as central stretch has been defined as a Green Corridor. Railroad and highway companies are active partners to realize this idea. Renewable electricity for the railroad is already one of the main traction sources in the alpine regions. Hydrogen produced with local available renewable energies on the site of its use will be the base for FC vehicles to find an extended infrastructure in the corridor.

It is the political-strategic task of a region to provide for the setup of infrastructures dedicated to production, distribution and service. It is the task of the car and fuel cell manufacturer to make use of these infrastructures.

Fuel cells are not only of interest for vehicles but have remarkable applications in many other sectors and lead to a new development of hydrogen technology, but the citizen must be involved on a large scale in this development.

The Green Corridor Brenner has started to be developed. The hydrogen highway between Munich and Modena with a production and distribution site at a distance every 100 km is in construction, the first and central point is Bozen/Bolzano, this will be ready by the end of 2012, and the whole H₂-highway will be ready by 2015.

The success of the Green Corridor depends on the cooperation of all the stakeholders, i.e. the producers of renewable energies, the producers of hydrogen on-site, its use in the traffic and private sector. The stakeholders are therefore the politicians, responsible for the strategic milestones, the entrepreneurs for applications and services, the researchers for the development of the entire technology and interesting applications, the citizen with their acceptance and use of the solutions offered. It creates local added value and will help the new technology to its breakthrough. Green Corridors offer a wide platform for it.

A0701

Surface properties of Pt and PtCo electro-catalysts and their influence on the performance and degradation of high temperature polymer electrolyte fuel cells

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Abstract

An investigation of the behaviour of carbon-supported Pt and PtCo cathode electro-catalysts was carried out to evaluate their performance and resistance to degradation. Nanosized Pt and PtCo catalysts with similar crystallite size (2.7-2.9 nm) were prepared by using a colloidal route. The surface properties were investigated by X-ray photoelectron spectroscopy (XPS) and low-energy ion scattering spectroscopy (LE-ISS). The formation of a Pt skin layer on the surface of the alloy electro-catalyst was obtained by using a pre-leaching procedure. As result, a significant surface Pt enrichment was observed for the leached Pt-Co electrocatalyst. This characteristic appeared to influence catalysts' performance and degradation. Accelerated tests (electrochemical cycling) at 130 °C in a pressurised PEMFC showed a better stability for the PtCo alloy as compared to Pt. Furthermore, better performance was obtained at high temperatures for the pre-leached PtCo/C as compared to the Pt/C cathode catalyst.

A0702

Towards stable catalyst supports

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Abstract

Despite great progress in enhancing the performance of PEM fuel cells, durability remains one of the critical issues that need to be solved in order to successfully penetrate the automotive market.

We have demonstrated that in automotive field tests the durability of the membrane-electrode-assembly (MEA) plays a major role in the overall lifetime of the stack. Transient conditions are responsible for MEA performance loss: power (or voltage) cycling increases the rate of electrocatalyst surface area loss; start-up/shut-down induces membrane degradation and carbon corrosion. Carbon under PEM fuel cell operating conditions is thermodynamically unstable and will be oxidized/corroded at potentials near the open circuit voltage of a fuel cell (about 1.0 V), with the oxidation rate increasing along with potential. It has been demonstrated that at start-up the lack of hydrogen at the anode is critical for carbon corrosion at the cathode. Carbon corrosion will finally result in Pt particles agglomeration and loss of performances.

In the present study we have been focusing on the development of new catalyst support materials, as alternatives to conventional carbon supports to overcome the corrosion related issues. We have developed durable catalyst supports, using high throughput discovery and optimization, with enhanced electrochemical stability and improved electrical conductivity to sustain the electrochemical reactions.

The present work will investigate the effect of different properties such as the chemical composition and crystallinity of the newly developed materials on the electrical conductivity and stability. In the design of the new support we paid special attention to the synergetic effect of the support on the catalyst, aiming at promoting higher catalyst activity and stability.

A0703

Continuous preparation of highly active Pt/CNT catalysts

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Abstract

Direct methanol fuel cells (DMFs) are considered to be an attractive power source for portable application because of their simplicity in construction, high energy density and low emission of pollutants. For their widespread commercialization electrocatalysts with high metal loading and uniformly metal distribution are needed. To find a suitable method for catalyst preparation is still a challenge of fuel cell catalyst research, because it can strongly influence the catalyst morphology, particle size and moreover its catalytic activity.

Commonly fuel cell electrocatalysts are prepared in batch processes using a heat mantle or an oil bath as a heat source. In this contribution we present the use of a continuously operated tubular reactor as a novel method for synthesis of carbon nanotube supported platinum catalysts. The as-prepared catalyst shows uniform dispersion of metal nanoparticles on the support material, an average crystallite size of 1.77 nm confirmed by XRD analysis and a Pt loading of 31 wt. %. Excellent electrocatalytic activity towards oxygen reduction reaction (ORR) of this catalyst was evaluated in a working DMFC environment. The reached maximum power density of 103 mW cm⁻² was 60 % higher than for Pt/CNT catalyst prepared in a conventional batch process.

A0704

Ultrasonic Spraying of PEM-FC Electrodes

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Abstract

One of biggest challenges for fuel cell manufacturing companies is to bridge the gap from the research and development stage to a high volume production environment, while, at the same time, achieving quality results consistent with those found in the laboratory. This paper discusses an investigation into the feasibility of using automated ultrasonic spraying technology to deposit catalyst inks onto fuel cell electrodes.

Deposition technologies currently used for high volume fuel cell electrode coating have been found to produce electrodes with poor uniformity and repeatability, in addition to unwanted agglomeration of particles and low mass transfer efficiency to the substrate. In order to quantify this variability in catalyst distribution uniformity, commercially available electrodes were measured using X-ray fluorescence (XRF).

An automated FC electrode coating testbed was designed and built for conducting research on uniform thin film deposition. In addition to atomization and drying capabilities, the testbed includes a continuous flow liquid delivery system that utilizes two ultrasonically agitated syringes capable of reducing problematic agglomeration. The method of optimizing spraying parameters for thin film deposition will be discussed.

The testbed allows for control the of atomized ink droplet size through the use of different ultrasonic frequencies, which can affect the morphology and porosity of the catalyst layer. Due to the low droplet velocity produced by ultrasonic atomization, overspray is reduced (high transfer efficiency), resulting in less waste of the expensive catalyst materials.

A0705

PEM systems with Pt-free cathodes using FlowCath[®] Technology

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Abstract

ACAL Energy Ltd is a leading developer of low cost Proton Exchange Membrane (PEM) Fuel Cells, powered by ACAL Energy's proprietary platinum free cathode technology (FlowCath[®]). The company is backed by venture funding led by the Carbon Trust and including corporate funds from Solvay and a couple of major Japanese corporations.

ACAL Energy is developing Fuel Cell modules and the chemistry behind the catalyst system for a range of uses requiring greater than 1 kW of power including back-up and remote power – replacing diesel gen-sets and battery technology – and ultimately automotive applications. The substantial cost savings and performance improvements will accelerate the adoption of PEM Fuel Cell technology.

ACAL Energy's radical approach to the challenges of the oxygen electrode (cathode), creates a system that has demonstrated the potential to provide substantial cost savings, system simplification and durability advantages for PEM fuel cells. By the use of a liquid-based cathode, the need for precious metal catalysts on the cathode is removed, a simpler balance of plant is required (eg innate cooling system by the liquid), and the major durability issues for the standard system are avoided all together (eg peroxide is not formed at the cathode). Performance is very comparable to current PEM technology.

ACAL Energy's technology has been scaled up to the 1-2 kW scale, with the assembly of prototype systems. The next stage is to place units in application sites such as the peroxide plant at Solvay in Warrington. This will gain the necessary field experience, before proceeding to commercialisation with the first product being a sub-10 kW module. The talk will describe the basis of the technology and associated benefits as well as the progress in performance and scale up.

A0706

Effect of oxide formation on the oxygen reduction kinetics on Pt and PtCo PEMFC cathodes

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Abstract

Understanding the impact of platinum oxide (PtOx) on the oxygen reduction (ORR) kinetics of proton-exchange membrane fuel cell cathodes is relevant to improve fuel cell performance.

The ORR kinetics was investigated as a function of PtOx coverage. PtOx coverage was determined by cyclic voltammetry, while to measure the ORR kinetics at constant PtOx coverage a procedure based on fast transient polarization was developed. Electrochemical impedance spectroscopy was used to measure the ohmic resistance of the MEAs and the effective proton resistance of the cathode catalyst layer. Tafel analysis was applied to estimate the kinetics parameters.

Results obtained indicate a dependence of the cathode specific activity and exchange current density on the conditioning potential (i.e. PtOx coverage). The exchange current density exhibits a maximum at ~0.85 V for both Pt and PtCo cathodes. The observed variation in exchange current density and Tafel slope with conditioning potential is more significant for PtCo cathodes. The trends observed for the ORR kinetic parameters are consistent with the previously reported "doubling" of the Tafel slope measured at steady-state. The behavior observed could be related to the presence of different PtOx surface species. H₂-crossover, and the non-faradic currents related to PtOx reduction were identified as possible sources of error in the measurement of the PtOx coverage and ORR kinetics.

A0707

Integrated Electrodes with Pt Nanowires in Direct Methanol Fuel Cells

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Abstract

Due to one-dimensional features, Pt nanowires can overcome some shortages of extremely small nanoparticles which suffer from the "particle size effect" and aggregate readily leading to lower mass activity and efficiency as catalysts in low temperature polymer electrolyte fuel cells (PEFCs). Several research works have showed that Pt-based nanowires exhibited a better catalytic capability than supported or un-supported Pt nanoparticles as catalysts in fuel cells, especially under the high Pt content-loaded conditions that is typically required for direct methanol fuel cells (DMFCs).

Using formic acid as reducing agent, single-crystal Pt nanowires along the <111> direction can be prepared from precursor at room temperature, without using any templates, organic solvents or inducing growth catalysts. With the carbon paper as gas diffusion layer (GDL) support, single-crystal Pt nanowires, with a length ca. 100–200 nm, were in-situ grown onto the micro-porous layer surface of GDLs and used directly as integrated gas diffusion electrodes (GDEs) in DMFCs. This route is much simpler than the conventional method for preparing GDEs because there were no processes needed to make the ink or print the catalysis layer.

In this work, membrane electrode assemblies (MEAs) were manufactured with the as-prepared Pt-nanowire GDEs and test as cathodes in a 5 cm² DMFC in comparison with a commercial cathode. Full cell and cathode polarization measurement and cathode cyclic voltammetry were performed to evaluate the as-prepared GDEs. A life-test was also undertaken to investigate the GDE durability by voltage ramp repeated in 3000 loops. The results showed that the Pt nanowire GDEs possessed a higher catalytic performance and a better durability, but a lower electrochemical surface area than did the commercial products.

A0709

Pt based thin films deposited by magnetron sputtering for PEMFC and DMFC fuel cells

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Abstract

Recent research effort in low temperature fuel cell field, namely PEMFC (Proton Exchange membrane Fuel Cell) and DMFC (Direct Methanol Fuel Cell) are devoted to electrode manufacturing using plasma processes [1, 2]. Several reasons justify this choice. Unlike liquid way methods [3], plasma deposition has the advantage to get ride of solvents, which ask the question of treatment and recyclability. This method allows depositing various materials (Pt, C, PTFE, composites...), that can be components of the electrode [4].

In this frame, MID develops several research activities on pre-industrial plasma equipments. Advantages of plasma sputtering to deposit Pt for PEMFC electrodes have already been demonstrated: very good results (i.e. 20 kW/g_{Pt}) have been obtained [5].

The study we present here concerns magnetron sputtering of various electrode components realised thanks to a multi-target configuration in the P3 prototype. Depositions are performed onto two commercial supports: Nafion[®] 212 membrane, and uncatalyzed gas diffusion layer E-Tek[®]. Layer morphology is determined thanks to SEM observation, growth rate are estimated using profilometry measurement.

Finally, membrane electrode assembly (MEA) performances are measured on a fuel cell tester (H₂/O₂) in the MID laboratory. Those performances, compared from one support to the other, are discussed on the analyses base.

A0710

Development of Membrane Electrode Assemblies for PEFC based on Aromatic Membranes

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Abstract

The paper presents the development and electrochemical testing of membrane electrode assemblies prepared by the DLR dry-spraying coating method on JSR aromatic membranes. The JSR membranes are composed of (sulfonated) aromatic block copolymer. The aim of this work is to demonstrate operation at elevated temperature up to 95 °C at reduced humidification of the cells on the way to achieve a temperature flexible stack. High temperature cell performance and stability is beneficial for numerous applications – e.g. in aircraft or residential cogeneration - as the cooling requirements are reduced and the cells and stacks can be operated with reduced control complexity. JSR membrane has contributed to the extension of the PEFC's operating temperature range (from temperatures of below zero to nearly 100 °C (or hot-dry conditions)). Using electrodes prepared by dry spraying the high temperature behaviour can be ascertained and a performance of 1 A cm⁻² at 600 mV can be achieved at 95 °C. Variation of catalyst loading as well as gas diffusion layers demonstrates the balance between the conflicting goals of performance, cost reduction and durability.

An impedance spectroscopy analysis of the cells for different membranes shows a good correlation with the expected conductivity of the various aromatic membranes as derived from ex-situ measurements and indicates a stable membrane performance. Observed degradation is mainly attributed to the electrodes thereby demonstrating the need to further optimize and develop the electrodes specifically for aromatic membranes. Further steps in this development process will be discussed.

A0712

CNTs grown on Carbon paper as a cathode for PEMFC

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Abstract

Since the discovery of the carbon nanotube(CNTs), they have attracted much attention because of unique properties that may impact many fields of science and technology. The considerable properties of CNTs include high surface area, outstanding thermal, electrical conductivity and mechanical stability. However, uniform deposition of Pt nanoparticles on carbon surface remains inaccessible territory because of the inert carbon surface. In this study, we prepared directly oriented CNTs on carbon paper as a catalyst support in cathode electrode. Carbon surface was functionalized using aryl diazonium salt for increasing adhesion of Ni particles which is precursor for growing CNTs. For fabricating electrode, CNTs on carbon paper were grown by chemical vapor deposition using Ni catalyst and Pt nanoparticles were deposited on CNTs oriented carbon paper by polyol method. Figure 1 shows uniformly deposited Ni catalysts on carbon paper. Using CVD technique, CNTs were grown on carbon paper as shown figure 2. Pt nanoparticles deposited on CNT directly grown carbon paper were used cathode of PEMFC. The performance was measured using Proton electrolyte Membrane Fuel Cell (PEMFC). The structure and morphology of the Pt nanoparticles on CNTs were characterized by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The average diameter of Pt nanoparticles was 3nm.

A0901

Ru_xSe_y cluster-like as cathode catalyst in a formic acid laminar flow fuel cell

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Abstract

Based on a previous design reported in Ref.: [1] an oxygen-breathing LFFC, we report on a comparative study between Ru_xSe_y/C and Pt/C cathode catalysts in formic acid fuel cells in LFFC and MRFC regimes. The catalyst nanoparticles were synthesized in aqueous medium via the carbonyl chemical route. Commercial Pd/C (2.4 mg cm⁻²) was used as the anode. The maximum power density, with 1 and 5 M HCOOH and Ru_xSe_y catalyst, did not change significantly (7 and 8 mW cm⁻², respectively) working either on LFFC or MRFC regime as a consequence of its high tolerance to small organics.

A0902

Oxygen reduction reaction (ORR) on Ir, Rh, and Ru selenides

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Abstract

Selenides of Ir, Rh, and Ru were synthesized by a simple chemical reduction process without heat-treatment. Their ORR activities, methanol tolerance, and peroxide formation were characterized using an RRDE set-up. The catalysts were also characterized using H_{upd} and Cu_{upd} . The activities of selenides were compared with bare Ir, Rh (without Se), and standard Pt catalyst.

In the literature, chalcogenides are considered as possible alternative to Pt. Particularly, in presence of methanol, the ORR activities of chalcogenides are better than that of Pt. Further understanding is desirable to develop such catalysts; moreover, a direct comparison of various chalcogenides (prepared by the same method) is not available. Often the focus has been on comparing a higher peroxide formation on selenide catalysts (~ 6% and above) with that of Pt (~ 3%) [1]. The most interesting part of our electrochemical measurements is their H_2O_2 formation. On Pt/C, peroxide formation was negligible up to ~ 0.5 V and it gradually increased at lower potentials. In the H_{upd} potential region, as reported in the literature, we observed a significant rise in H_2O_2 formation; this, we attribute to the blocking effect by the adsorbed hydrogen species [2]. The H_2O_2 features were entirely different on Ir and Rh. While scanning the potential from 1 to 0 V, the H_2O_2 decomposition current went through a maximum at ~ 0.6 V, and then decreased at lower potential of H_{upd} region (0 - 0.35 V). In the reverse scan (from 0 to 1 V) the peroxide formation was significantly lesser – particularly, in the 0.35 – 0.7 V range of potential. We attribute this difference in peroxide oxidation currents in the forward and reverse scans to noticeable differences in the coverage by oxygenated species on the catalyst surface. On the other hand, on selenides of Rh, Ir, and Ru, the peroxide oxidation features were different from that of the bare metals. Peroxide formation rose to a maximum, and it almost stabilized at lower potentials of 0.0 - 0.35 V. The forward and reverse peroxide currents were almost overlapping and we could explain this effect by the surface blocking by Se that might happen on the electrode surface at various potentials. Additional support to this finding was obtained from both H_{upd} and Cu_{upd} . Selenium modification of Ir, Rh, and Ru almost blocks the surface electrochemical process that happens on the electrode surface below 0.75 V. All catalysts were found to be methanol tolerant, and in presence of methanol, their ORR activities were higher than that of Pt. Their activities were in the order $RuSe > RhSe > IrSe > Rh > Pt$. In all selenides, we observed an increase in ORR activity improvement (compared to bare metal surface). Both Cu_{upd} and H_{upd} were used in establishing the electrochemical features.

A0903

Methanol Electro-oxidation by Carbon Supported Cobalt and Nickel based Catalysts

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Abstract

Novel Co-Ni based catalysts on activated carbon support were prepared using $NaBH_4$ as a reducing agent and examined with respect to electrocatalytic methanol oxidation. The surface morphology and composition of the synthesized materials were examined using transmission electron microscopy (TEM), scanning electron microscopy (SEM), energydispersive X-ray spectrometry (EDX), thermogravimetric analysis (TGA), X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS). Cyclic voltammetry (CV) was employed in order to confirm the typical metallic electrochemical response of the Co, Ni and Co-Ni (1:1) based materials. The metal hydroxides/oxides species were found to be dominant and this combination along with nanoparticles in the activated carbon support plays a key role in methanol electro-oxidation. The nickel based catalysts showed an excellent response and the presence of Co is capable of providing stability, low onset potential, cost effectiveness and anti-poisoning strength. The current response per mg of Ni for $Co_{1.65}Ni_1/C$. ($I_{0.65} = 3.9 A/mg_{Ni}$) catalyst is higher than Ni/C ($2.7 A/mg_{Ni}$), and signifies the importance of effective utilisation of surface composition. Overall, these materials have potential either alone or as an alternate binary/ternary composition in order to reduce the amount of precious platinum, to provide stability and to increase the anti-poisoning strength of the catalyst, all of which are highly desired for commercialisation of direct methanol fuel cells.

A0904

Effect of the hydrophobicity of the electrocatalyst support on HT-PEMFC and vapour-fed DMFC performances

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Abstract

High temperature direct methanol fuel cells (DMFC) have the advantage of an improved electrochemical reaction rate at the anode when operating at temperatures higher than 120 °C. The use of polybenzimidazole (PBI) doped with phosphoric acid (PA), as electrolyte membrane, has shown promising results and namely low methanol crossover values [1]. However, PBI loses phosphoric acid during fuel cell operation due to the water presence.

The most widely used carbon support for fuel cells is carbon black, with a high electronic conductivity and surface area and low cost. However, non-conventional nanocarbon structures such as graphene, carbon nanofibers, carbon nanotubes, carbon nanospheres and carbon nanohorns are under study due to their tailored morphology and excellent electrical and mechanical properties. Single-wall carbon nanohorns (SWNH) have a horn shape sheath of single wall graphitic sheets [2]. The preparation of electrocatalysts based on SWNH showed a higher surface chemical activity towards Pt deposition when compared to carbon black [3]. Recently, our group reported an increase of 60 % in the power peak density in both PEMFC and DMFC when carbon black was replaced by SWNH as the electrocatalyst support, at 50 °C [4, 5].

SWNH and carbon black have different hydrophobic characters, being SWNH more hydrophobic than carbon black. In this work, it is addressed the effect of the hydrophobic character of SWNH on preventing excessive PA leaching and on the overall fuel cell performance when compared to the more hydrophilic carbon black support. The effect of this feature was studied in high temperature PEM fuel cell (HT-PEMFC), at 160 °C. It was observed that SWNH prevented the leaching of PA during fuel cell operation more efficiently than carbon black. Moreover, the SWNH based MEA performed better than the carbon black one, at higher current densities, probably by removing more efficiently the water produced at the cathode side. Preliminary work on a vapour phase DMFC is also addressed aiming the study of the effect of the hydrophobicity support on vapour phase DMFC performance. A PBI/PA electrolyte membrane synthesized by the sol-gel method [6] showed a quite stable performance in vapour phase DMFC environment after 18 hours of methanol feeding and commercial electrodes. Future work is undergoing in order to evaluate the effect of the hydrophobicity of the electrocatalyst support on a longer time running vapour phase DMFC.

A0905

Preparation of core shell structured Pt@Au/C electrocatalysts for oxygen reduction reaction

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Abstract

Carbon-supported Pt@Au core shell nano-structured catalysts have been synthesized by the seed-mediated growth method. The nano-structured catalysts have been characterized by UV-vis spectroscopy, X-ray photoelectron spectra (XPS) and transmission electron microscopy (TEM) techniques. The oxygen reduction reaction (ORR) activity of the Pt@Au/C was tested by means of linear sweep voltammetry (LSV) by employing a rotating disk electrode (RDE). It reveals that Pt@Au(4:2)/C (atomic ratio) catalyst exhibits the best catalytic activity towards ORR. Pt@Au(4:2)/C proceeds by an approximately four-electron pathway in acid solution, through which molecular oxygen is directly reduced to water. The performance of the membrane electrode assembly (MEA) prepared by Pt@Au(4:2)/C as the cathode catalyst in a single proton exchange membrane fuel cell (PEMFC) generates a maximum power density of 479 mW cm⁻² at 0.431V.

A0906

Promising Non-Ru Methanol Electro-Oxidation Catalysts for Direct Methanol Fuel Cell Application

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Abstract

Pt/CeO₂-MC, Pt/PrO₂-MC, Pt/NdO₂-MC, and Pt/SmO₂-MC methanol electro-oxidation catalysts were prepared by synthesizing high-surface area CeO₂-MC, PrO₂-MC, NdO₂-MC, and SmO₂-MC, followed by impregnation with Pt to form the desired methanol electrooxidation catalysts. The prepared nano-oxides and catalysts were characterized using BET surface area, EDS, and XRD. High surface areas of 684 – 778 m²/g were achieved for the CeO₂-MC, PrO₂-MC, NdO₂-MC, and SmO₂-MC, which enabled excellent dispersion of the Pt nanoparticles. The catalysts performance was studied using cyclic voltammetry and compared with the commercial Pt-Ru/C (E-TEK). The Pt/CeO₂-MC catalyst showed the highest activity, which is about 3.5% more than that of the commercial Pt-Ru/C (E-TEK) catalyst. All the prepared catalysts showed reasonable stability. The prepared catalyst samples have potential for used as DMFC anode catalyst due to their high activity, reasonable stability and low cost.

A0907

Methanol tolerance of Pt-Co catalysts

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Abstract

Pt-Co is one of the most thoroughly investigated ORR alloy catalysts in low temperature fuel cells; several studies has proven that such catalysts provide an activity improvement of ~30 mV in hydrogen based polymer electrolyte fuel cells (PEFCs). In alcohol fed fuel cells, such as direct methanol fuel cells (DMFCs), additional constraint of methanol tolerance deteriorates the overall fuel cell performance. Potential candidate materials, reported as alternative to Pt, do not show the required activity. Therefore, development of methanol tolerant ORR active electrocatalysts has been extensively reported in the literature. Carbon-supported catalysts are not suitable for DMFCs because highly flooded cathode catalyst layer in DMFCs require a higher catalyst loading, and therefore the best performance in DMFCs is reported with Pt black catalyst. Unfortunately, all the alloy catalysts are prepared by a high temperature heat-treatment method and that limit the alloy catalysts to supported materials; carbon support helps to prevent the catalyst sintering at high temperature to great extent. To our knowledge, alloy black catalysts are not reported in the literature, and here we present an initial step towards producing alloy black catalyst for use in alcohol fuel cells. For convenience we tested the catalysts (synthesized without heat treatment) in an RDE configuration. The catalysts exhibited improved activity and their electrochemical features were comparable to that obtained on well-defined alloy catalysts as reported by Ross *et al* [1]. The ORR activity improvement is attributed to skin layer effect, and to a certain extent to surface faceting. Both Cu_{upd} and H_{upd} are indicative of these conclusions. Moreover, it was found that the alloy catalysts exhibit significant methanol tolerance. We studied the ORR in presence of a range of methanol concentrations starting from 5 mM to 100 mM on both Pt and Pt-Co catalysts. These measurements indicate that the alloy catalysts have superior ability to handle methanol crossover effect. Finally, we implemented the model proposed by Schmidt *et al*. [2] and found that at relatively lower concentration of methanol (< 0.1 M) the alloy catalyst certainly possessed good methanol tolerance. The MOR rate was suppressed on alloy catalyst at potential higher than 0.6 V - most likely because of reduced methanol adsorption. The results indicate that alloy black catalysts will provide improved ORR activity and methanol tolerance in DMFCs.

A0910

Studies of the Synergetic Effects of Sb_2O_4 on Pt Electro-catalyst for Intermediate Temperature DMFC Application

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Abstract

We report here for the first time the enhanced performance of an intermediate temperature (90-140 °C) direct methanol fuel cell (IT-DMFC) due to the synergetic effects of antimony tetraoxide (Sb_2O_4) nano-particles with Pt electro-catalyst. Sb_2O_4 nano-particles were prepared by calcination of Sb_2O_3 and mixed with commercial Pt electro-catalyst. The synergetic effects between Sb_2O_4 and Pt electro-catalyst on a half cell under ambient temperature and single cell performance under intermediate temperatures were systematically investigated. The oxygen reduction reaction (ORR) mechanism was studied by cyclic voltammetry (CV), rotating disc electrode (RDE), electrochemical impedance spectroscopy (EIS) experiments and DMFC single cell tests. The improved ORR activity and DMFC single cell performance indicated that Sb_2O_4 would be a promising co-catalyst for commercial nanosized Pt electro-catalyst under conditions typical of intermediate temperature DMFC operation.

Key words: Direct methanol fuel cell (DMFC); antimony tetraoxide (Sb_2O_4); intermediate temperature; oxygen reduction reaction (ORR), catalyst

A1001

PEMFC ageing: effect of operating conditions on performance and MEA components degradation

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Abstract

Increasing Proton Exchange Membrane Fuel Cells (PEMFC) durability as well as reducing their cost is two objectives to be reached for large scale development and systems commercialization. Understanding Membrane Electrode Assembly (MEA) components degradation is the first step towards the long lifetime objective. In order to address this issue, work is conducted mainly in the frame of the European project DECODE, on the degradation analysis of MEAs operating in conditions representative of real systems, particularly for automotive application. As far as MEAs are concerned, membrane and electrodes components degradation during fuel cell operation are sooner or later leading to performance degradation with high voltage losses due to membrane weakening or to active surface area decrease. For the membranes, mechanical degradation seems to be the main drawback for cycling operation because it leads to fuel cell failure. However, when the membrane is chemically stabilized and edge protected mechanical problems can be delayed. Concerning the active layers, several degradation mechanisms are known for the standard catalytic material used in our studies, which is platinum nanoparticles supported on carbon powder: electrochemical Ostwald ripening, ions migration and reduction leading to Pt nanoparticles inside the membrane, and corrosion of the carbon support. Focus of this paper is on the environmental and local conditions affecting first the performance degradation, that can be reversible or non reversible, and then the different degradation mechanisms. MEAs made with specific electrodes and membranes have been tested in automotive like conditions following dynamic load cycles or in stationary operation at fixed i. Voltage loss versus time is measured in parallel with the evolution of electrochemical properties evaluated in-situ by electrochemical impedance spectroscopy and cyclic voltammetry; materials local degradation is analyzed by various ex-situ techniques like different type of electron microscopy, X-Ray photoelectron spectroscopy, or IR Atomic Force Microscopy. The parameters that have been particularly considered thanks to in-situ ageing tests performed in parallel by different groups are the operating mode, that can be stationary at fixed current density or dynamic cycles; the co or co-counter flow supply of the gases (hydrogen and air); the relative humidity of the gases and the application of humidity cycles; the essential aim being to evaluate the effect of the water content.

A1002

Degradation of Fuel Cell Materials Investigated by Atomic Force Microscopy

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Abstract

In this contribution the ability of atomic force microscopy (AFM) for investigation of fuel cell components and determination of their degradation is demonstrated. In particular the mapping of adhesion force and dissipation energy of surfaces analyzed by an advanced material sensitive AFM technique - the HarmoniX™-mode (Bruker Corp.) - has been used as a measure for the relative polytetrafluoroethylene (PTFE) content of surfaces. Differently operated microporous layers (MPL) of commercial gas diffusion layers (GDL) have been investigated before and after operation and were compared to reference samples. The degradation of the cathode material compared to the anode was found to be higher. Another example for exploring the potential of AFM is the investigation of a cell with a segmented anode flow field. The relative change of surface properties at MPLs detected with AFM analysis was compared to the direct measurement of PTFE content by infrared spectroscopy (FTIR-ATR) and a good correlation of both results has been found for the analyzed segments. The ionically conductive structure of electrolyte membranes has also been investigated by conductive AFM in humid environment. High resolution images show a heterogeneous conductivity with non-conductive regions even after fuel cell operation. Sharply defined areas with same mean magnitude of current at the surface indicate the presence of an interpenetrating network of ionic channels connected beneath the surface. A correlation with surface properties measured by the PeakForce Quantitative Nanomechanical Property Mapping (QNM™) is observed.

A1003

New Aryl Monomers, Polymers and Membranes for PEMFC and DMFC

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Abstract

This contribution comprises an overview about the work done by our research group in the development of ionomers/ionomer (blend) membranes for membrane fuel cells. The topics include the development of novel sulfonated arylene nonfluorinated and partially fluorinated monomers and their polycondensation to homopolymers, block and statistical copolymers; the preparation of ionically cross-linked membranes prepared by mixing these polymers with different polybenzimidazoles (PBI); the application of these membranes to PEFC and DMFC; development of novel base-excess PBI/sulfonated polymer/H₃PO₄ blend membranes, and test of these membranes in fuel cells at intermediate fuel cell operation temperatures (170-200°C). From the sulfonated homo- and block-co-ionomers, acid-excess ionically cross-linked membranes have been prepared by mixing the sulfonated ionomers with different PBIs. These membranes have been tested in a DMFC in order to investigate their suitability for the DMFC up to a temperature of 60°C under atmospheric pressure which is interesting for the use of DMFC as power supply for mobile electronic applications, under comparison with Nafion®. The i/U polarization curves of the membranes along with their meOH permeability showed a better performance than Nafion® which is due to the lower meOH permeability of the arylene ionomer membranes, compared to Nafion®. Acid-base blend membranes were also applied to the HyS electrolysis process, showing good stability and electrolysis performance. Phosphonated polymers and ternary PBI/sulfonated polymer/H₃PO₄ blend membranes for the application in intermediate T fuel cells have been developed as well. These membranes showed good performance in fuel cells in the temperature range 125-200°C, their chemical stability being even better than that of pure PBI membranes, which was ascertained by H₂O₂ and Fentons degradation test during H₂O₂ treatment, the base-excess base-acid PBI blend membranes showed markedly less molecular weight degradation than pure PBI or sulfonated polymers, as determined by gel permeation chromatography (GPC).

A1004

Influence of different Micro Porous Layers on electrochemical performance of PEMFCs

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Abstract

In this paper the investigation on the rheological, morphological and electrical behaviour of the addition of carboxymethylcellulose (CMC) in two different inks (used to coat a Micro Porous Layer or MPL) was studied. For the sake of comparison two inks with and without the CMC and the same amount of PTFE (12 wt%) were prepared. The presence of CMC drives to a different rheological curve with respect to that obtained for standard composition ink and, in particular, to a general increase in viscosity and to a more shear-thinning behaviour.

Two Gas Diffusion Layers (GDLs) were obtained by coating via doctor blade technique the MPLs onto the carbon cloth. Hydrophobicity and morphology of the MPLs coatings were assessed by contact angle measurements and SEM analyses.

The two GDLs so obtained, were also tested in a single Polymer Electrolyte Membrane Fuel Cell and its performances evaluated. The membrane electrode assembly was made of Nafion® 212 with Pt load 0.3/0.6 mg cm⁻² (anode/cathode). The cell testing was run at 60°C and 80°C, fed with 80%RH hydrogen and air at two different RHs (60 and 100%). PEMFC performances in the various configurations were assessed by polarization and power curves.

A1005

Study of the TiO₂ content as filler in PBI-based membranes for high temperature PEM fuel cells

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Abstract

In recent years, polymeric electrolytes based on hydrocarbons have been considered as an alternative to Nafion membranes for PEM fuel cells and great efforts have been made to develop high-temperature ($T > 100^\circ\text{C}$) polymer electrolyte membrane fuel cells (HT-PEMFCs). In addition, these cells show an enhanced CO tolerance and therefore there is no need to use high purity H₂. The high operating temperature also enables a better connection between the hydrogen storage and the fuel cell systems. Polybenzimidazole (PBI) is one of the best alternatives to Nafion membranes for its use in PEMFCs. In order to reach acceptable proton conductivity, the membranes must be doped with an acid, typically phosphoric acid, or an alkaline (KOH). These kinds of membranes have good conductivities up to 200 °C, do not need humidification, so water management issues can be virtually eliminated and operating at higher temperatures also increases both anode and cathode reaction kinetics [1]. Composite membranes are a group of membranes which contain dispersed particles such as zirconium phosphate, ZrO₂ or SiO₂ [2]. The introduction of these materials into the membrane means an improvement in their features, such as proton conductivity or fuel cell stability.

Recently, the authors have published a study about a novel titanium PBI-based composite membrane for high temperature PEMFCs where a good improvement of the fuel cell performance was achieved [3]. In this work, PBI-based membranes with different amount of TiO₂ as filler were prepared in order to study the influence of this filler on the features of the membrane. It was observed an increase of the H₃PO₄ doping level (using the same acid bath concentration) when small amounts of TiO₂ were used, which resulted into an increase of the ionic conductivity of the membrane, measured out of the fuel cell.

Different techniques and measurements were carried out to the different membranes prepared in this work such as XRD, FT-IR, thermogravimetric (TGA) analysis or membrane swelling. Moreover, fuel cell tests were also made in order to evaluate not only the performance of the titanium based composite PBI membranes but also the durability of the membranes at harsh conditions during 120 h approx.

A1006

Determination of “good” or “bad” protic ionic liquids or molten salts for high temperature PEMFC electrolytes

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Abstract

Protic ionic liquids (PILs), which are formed upon proton transfer from a Brønsted acid to a Brønsted base [1], exhibit negligible volatility, non-flammability, good thermal and electrochemical stability and relatively high ionic conductivity. Due to these remarkable properties they have been actively studied for the application as electrolytes in high temperature (100–200 °C) polymer electrolyte membrane fuel cells (PEMFCs) [2, 3]. As a result, it is of great significance to distinguish “good” from “bad” protic ionic liquids or molten salts for these applications.

In this work, we studied the physicochemical properties of some non-aqueous sulfonate-based PILs, namely, 1,2,4-triazolium methanesulfonate, 1,2,4-triazolium trifluoromethanesulfonate and imidazolium methanesulfonate, with an emphasis on electrochemical properties.

Impurities were determined by Karl Fischer titration for water content and ion chromatography for halide, nitrate and sulfate contents. Thermogravimetric and infrared analysis were performed on the chosen PILs. Ionic conductivity was measured by impedance spectroscopy with a conductivity cell (model 6.0908.11, Metrohm). Meanwhile, the ΔpK_a value, which is defined as the difference of the pK_a values of the protonated base and the acid [$pK_a^{(base)} - pK_a^{(acid)}$] in the aqueous solution [4], was calculated. The pH values of the aqueous solutions with each single PIL mass fraction of 0.10 % were also measured.

As depicted in Figure 1, the electrochemical properties, such as electrochemical window, proton conduction evidence, redox activity in H₂ or O₂ atmosphere, open circuit voltage and fuel cell polarization curves were studied with a three-electrode system with Pt disk, Pt plate and Pt wire (in H₂ bubbling atmosphere) as working electrode (WE), counter electrode (CE) and reference electrode (RE), respectively. The electrochemical window was measured with linear sweep voltammetry scanned at 10 mV sec⁻¹, proton conduction evidence with chronoamperometry under H₂ versus N₂ atmosphere, redox activity in H₂ or O₂ atmosphere with cyclic voltammetry scanned at 100 mV sec⁻¹ and fuel cell polarization curves with potentiodynamic polarization scans. As a result, 1,2,4-triazolium triflate was found to be an excellent high temperature electrolyte for PEMFC [5].

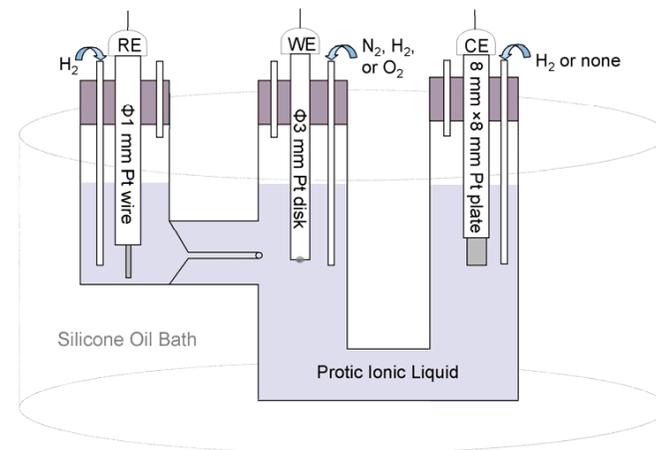


Figure 1: Scheme of the three-electrode system. WE (working electrode): Φ3 mm Pt disk; CE (counter electrode): 8 mm × 8 mm Pt plate; RE (reference electrode): Φ1 mm Pt wire.

In conclusion, electrochemical characterization of PILs is a reliable and necessary screening method for the development of “good” PILs as high temperature PEMFC electrolytes.

A1008

Development of High Performance and Durable Fuel Cell Membranes Based on Radiation Grafting

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Abstract

Proton conducting membranes prepared by pre-irradiation induced grafting of styrene monomers onto a thermally and chemically stable base polymer film, such as ETFE, offers the prospect of a low-cost and tailor-made material for the polymer electrolyte fuel cell (PEFC). The procedure involves the electron-beam irradiation, followed by the grafting reaction and, finally, the sulfonation of the polymer to introduce proton exchange sites. The properties of the membrane are governed by those of the base film and the type and amount of graft component introduced.

The membrane needs to be mechanically robust under fuel cell operating conditions to maintain its separator functionality. The tensile properties of ETFE based radiation grafted membranes are superior to those of Nafion 212 membranes at 80°C and 80 % relative humidity in terms of tensile strength and toughness.

Generation 2 membranes, based on co-grafted α -methylstyrene (AMS) / methacrylonitrile (MAN), show improved chemical stability, demonstrated *ex situ* as well as *in situ*, compared to Generation 1 membranes based on grafted styrene. In general, the Gen 2 membranes show fuel cell performance comparable to that of Nafion 212, yet with substantially lower H₂ permeability, which is expected to lead to a lower rate of radical formation due to reactant crossover.

The thinnest membranes prepared and tested had a thickness of 18 μm , using 12 μm thick ETFE film as base polymer. They could be operated for several hundred hours in a 6-cell stack together with Nafion 212. Some of the PSI membranes outlasted Nafion 212, which failed prematurely due to crossover failure.

A1009

High-Temperature Polymer Electrolyte Membrane Fuel Cells: The Effect of Compression

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Abstract

Temperature, pressure and compression have significant impact on the performance of membrane-electrode-assemblies (MEAs) in polymer electrolyte membrane fuel cells. The present study examines the effect of compression on high-temperature MEAs containing phosphoric acid doped polybenzimidazole membranes. A single cell compression system allows measurements either (I) by applying a constant compressive pressure or (II) by maintaining a constant thickness of the MEA. The results of the electrochemical characterization of the MEAs at different compressive pressures and MEA thicknesses are presented.

A1010

Stability of Suspensions and Manufacturing of Electrolyte Films

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Abstract

Ceramic electrolyte films are prepared by deposition of the slurries (or suspensions). The nature and composition of its constituents play a critical role in the suspension stability and film's performance. It is therefore important to stabilise the precursor suspension of the electrolyte films. The more stable slurry will have a higher zeta potential and leads to a smaller viscosity. In this work the best conditions for the preparation of suspensions for the films for SOFC electrolyte were studied. For this intent the influence of the concentration of binder, PVA poly(vinyl alcohol), and dispersant, MFO (Menhaden Fish Oil), on the stability of the YSZ suspension precursors of electrolyte films for solid oxide fuel cells (SOFCs) was studied by zeta potential and rheological measurements. According to these results it was observed that the best concentration was of 1.0 % wt/wt for both binder and dispersant. The films were made-up according to the optimized conditions for the fabrication of the suspensions. The films were deposited by spray coating on the NiO/YSZ anode. This technique was appropriated to obtain a dense and homogeneous film. The films which were sintered at 1500°C for 6 hours showed 1.0 % of porosity, according to the treatment of the scanning electron microscopy images.

A1011

Preparation and characterization of new sulfonated partially fluorinated polyarylenethioethers and their blends with a polybenzimidazole

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Abstract

Partially fluorinated arylene main-chain ionomers should have better chemical and thermal stabilities than the F-free ionomers, due to the much higher stability of C-F bonds, compared to that of C-H bonds. In this sense novel partially fluorinated and sulfonated poly(arylenethioether)s and poly(aryleneether)s were successfully synthesized via nucleophilic polycondensation of 2,3,5,6-tetrafluoropyridine-4-sulfonic acid or 2,3,5,6-tetrafluoro(trifluoromethyl)sulfonic acid with 4,4'-thiobisbenzenethiol (TBBT) or 4,4'-dihydroxybiphenol. All of them were analyzed in terms of their thermal stability. Both the novel poly(arylenethioether)s and poly(aryleneether)s were characterized by gel permeation chromatography (GPC). The poly(arylenethioether)s and poly(aryleneether)s were blended with PBI-Celazol to yield base-excess blend membranes. The base-excess blend membranes were doped with H₃PO₄ and were subsequently applied in intermediate temperature (170-200°C) PEFC, DMFC and electrolysis cells, respectively. All membranes were analyzed in terms of their thermal and oxidative stability in 5% H₂O₂ solutions. Moreover the blend membranes were characterized by gel permeation chromatography (GPC) before and after the oxidation procedure to get insight into the degradation process. The novel poly(arylenethioether) blend showed an excellent T_{SO₃H}^{onset} of 335°C.

A1012

New High Performance Proton Conducting Membranes for Hotter, Drier Operation of Polymer Electrolyte Fuel Cells

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Abstract

Proton exchange membrane (PEM) fuel cells are still the most desirable component of future zero emission, high efficiency automobiles. However, their unit cost, ease of operation, and reliability must be reduced which includes eliminating the humidifier from the fuel cell system. Currently the commercial proton exchange membrane (PEM) is fabricated from a perfluorosulfonic acid (PFSA) polymer such as Nafion[®]. Unfortunately PFSA ionomers must be fully hydrated to achieve their maximum proton conductivities and practical levels of proton conductivity can only be achieved in vehicles operating at an inlet RH of 80% which still necessitates the use of a humidifier and undesirable complex water management and recovery systems. To achieve the goal of a PEM that can operate at temperatures from freezing to 120°C using dry inlet gases it will be necessary to develop new PEMs that are based on new chemistries.

We have created this new class of PEM by polymerizing heteropoly acid (HPA) monomers with appropriate co-monomers to produce films with unique proton conducting properties. While HPA have been previously polymerized they have not until now been fabricated into proton conducting films. We use this methodology to fabricate hybrid HPA in which olefinic functionalities are introduced to fabricate hybrid HPA monomers.

By changing the chemistry of the other components of the system and the loading of the HPA we are building a mechanistic picture of proton conduction in these systems. DC conductivity and EIS are used to measure the proton conductivity and NMR is used to measure diffusion coefficients and the films water content. NMR is also used to probe the molecular motions in the film. We have recently concluded a series of experiments of in-situ SAXS measurements at the advanced photon source under varying conditions of temperature and humidity which are giving us additional insights in to the morphology of these unique polymers. This chemistry is now expanded to three new polymer backbones which promote enhanced phase separation and new morphologies. We will discuss these new systems in terms of structure activity relationships. The analogous system using Zr to promote proton conduction in a poly phosphonic acid polymer will also be compared and discussed.

A1014

Thermally stabilized PVA-g-PAA substituted benzimidazolium group membranes for Fuel cell Applications

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Abstract

In this work the focus has been on membrane and in an effort to replace the Nafion membrane, we synthesized the crosslinking agent 3-Amino -4-[3-(triethyl ammonium sulfonato) phenyl amino] phenylene (Compound-I). We subsequently synthesized grafted polyvinyl alcohol polymers and reacted them with cross-linking agent. The grafted polymers gave benzimidazole substitution with acid functional group on heating and treating with 20% Orthophosphoric acid. The polymer was characterized using various characterization techniques and all were essentially similar in nature showing that benzimidazole grafted polymers can serve as substitute for polybenzimidazole membranes. We also synthesized cross-linking agents 3-Amino -4-[3-(triethyl ammonium sulfonato) phenyl amino] phenylene (Compound-II), Bis -4 [1, 2 diamino phenyl]-phenyl sulfone (Compound III) and 1, 4 [1, 2 diamino phenyl] Phenylene (compound IV). These were also reacted with grafted polyvinyl alcohol polymers to give benzimidazole grafted polymers.

The membranes were tested in laboratory made Fuel cell set up. Fuel cell bipolar plates were made of SS316 which were fabricated using computed numerically controlled machine to get serpentine channels on anode and parallel channels on cathode side. They were then gold coated to make them more conducting. We have synthesized Pt/Ru (anode) & Pt (cathode) loaded on carbon by silica immobilization technique. The maximum current density we are getting is around 55mA/cm² at 0.575 V and the maximum power density obtained is around 35mW/cm² for Compound-I membrane. Nafion 117 membrane was also tested under the same conditions to get 33mA/cm² at 0.435V & power density of 15mW/cm². Also the methanol permeability was order of magnitude less compared to Nafion.

A1015

Development of covalently cross-linked sulfonated PEEK/heteropoly acid composite membranes for PEMFC

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Abstract

There is widespread effort to develop non-perfluorinated polymer in place of Nafion for polymer electrolyte membrane fuel cells (PEMFC). Many promising polymers are based on aromatic thermoplastics such as poly (ether ether ketone)(PEEK), which have excellent mechanical properties, high thermal stability, good chemical resistance and low cost. The polymer is applied as electrolyte membrane by attachment of sulfonic groups to the polymer's chains. But, despite superior proton conductivity, the sulfonated PEEK having high sulfonation degree is immoderately water-swollen or soluble in water. And it leads to decline of their mechanical properties.

In our study, the membrane for PEMFC is prepared by cross-link reaction and is blending with inorganic materials to resolve the problem. Covalently cross-linked SPEEK polymer is prepared from sulfonation-sulfochlorination, partial reduction and lithiation reactions. The polymer is cross-linked by reaction with 1,4-diiodobutane and then blended with inorganic nanoparticles such as heteropoly acid(HPA). And then, the membrane is prepared via a casting method and subsequently hydrolyzed of the sulfochloride groups by aqueous post-treatment.

The characterization of membranes is confirmed by FT-IR, Thermogravimetry(TGA), water uptake test, tensile test and single cell performance test for PEMFC, etc. Cross-linking and blending with HPA decide on the distinctive properties of membrane. It can reduce the membrane swelling, which leads to a better mechanical and thermal stability of the membrane. Besides, the membrane shows good ion exchange capacity and proton conductivity. The PEMFC single cell test of cross-linked SPEEK/HPA composite membrane exhibits stable performance at various temperatures.

A1016

Characterization of anion exchange membranes for use in alkaline anion exchange membrane fuel cells

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Abstract

Mechanical, chemical and thermal stability of membranes are the most relevant issues in fuel cells. Anion exchange membrane fuel cells (AEMFC) have recently been recognized as a good solution to overcome fundamental drawbacks of proton exchange membrane fuel cells (PEMFC) [1, 2]. Much effort has been put into the AEMFC development over the last years [3-7]. It has been proved that AEMs that were pre-exchanged to OH⁻, HCO₃⁻ and CO₃²⁻ forms are able to conduct the CO₂ from the anode [8]. Moreover, an increase in AEMFC performance was observed when CO₂ is inserted in the cathode gas stream, [9] making this type of fuel cell an interesting candidate as a tool for CO₂ separation from flue gases.

In this work, we evaluate the properties of commercially available AEMs for use in AEMFCs for CO₂ concentration. The membranes were immersed in sodium hydroxide, sodium bicarbonate and sodium carbonate aqueous solutions for anion exchange. Different characterization methods such as water uptake, thermogravimetric analysis, infrared spectroscopy, and anion conductivity by electrochemical impedance spectroscopy have been done. The CO₂ transport through the membrane and the overall fuel cell performance can be influenced by the type of the exchanged anion.

A1017

Novel ultrathin composite membranes of Nafion/PVA for PEMFCs

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Abstract

The technique of electrospinning was used to prepare polyvinyl alcohol (PVA) nanofiber mats which were infiltrated with Nafion[®] polymer. The nanofibers showed diameters between 200-300 nm and they were functionalized on their external surface with sulfonic acid groups in order to cooperate in the proton conductivity of Nafion[®]. These Nafion/PVA membranes were characterized in their mechanical properties, proton conductivity and fuel cell performance at different thicknesses. Conductivity of the composite membranes was below the showed by pristine Nafion[®] due to the non-ionic conducting behaviour of the PVA phase, although the incorporation of the PVA nanofibers strongly reinforced the mechanical properties of the membranes. These reasons make ultrathin (<20 µm) composite Nafion/PVA membranes promising candidates as ion-exchange membranes for fuel cell applications. In addition, the low amount of Nafion[®] polymer present within such composite membranes suggests that potential savings in materials and money can be achieved.

Comparison between in-plane and through-plane measurements of conductivity revealed the anisotropic characteristic of this parameter for the Nafion/PVA membranes due to their heterogeneous structure.

Measurements carried out in a single cell fed with H₂/air confirmed the high performance exhibited by a 19 µm thick nanofiber reinforced membrane.

A1101

Status and Accomplishments of Worldwide SOFC Demonstration

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Abstract

SOFC technology has been in the pipeline for many years now without reaching the readiness level and first commercial acceptance the PEFC or DMFC, for instance, have achieved. Of course, this has to do with the main application of SOFC, which is stationary power generation, and the extremely high reliability and lifetime expectations users in this sector have.

Nevertheless, SOFC projects, both in mobile and stationary applications, are under way and a number of demonstration projects have already been conducted. As the technology matures and grows nearer to first markets, more and more results from projects have become available and allow a first overview of technology achievements.

The presentation will compile information on SOFC demonstration projects and compare and benchmark the results with other fuel cell types and competing technologies.

A1102

Fuel Cells for Commercial Buildings

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Abstract

Globally, the stationary fuel cell market has been bifurcated into two main segments: industrial and residential. Many fuel cell manufacturers have designed their stationary fuel cell systems (FCSs) for a market segment providing electricity and heat to large commercial buildings and small industrial facilities, and thereby sized their FCSs at 100 kilowatts electric (kWe) and above.^{1,2,3,4,5,6,7,8,9,10} Other manufacturers have targeted the residential buildings market segment, sizing their FCSs at five kWe or less.^{11,12,13} By contrast, few manufacturers have targeted the light commercial buildings market, for FCSs ranging between five kWe and 25 kUWe.¹⁴

This publication discusses progress with the United States (U.S.) Department of Energy (DOE)'s \$3 million program to deploy and independently-monitor stationary micro-combined heat and power (CHP) and combined cooling, heating, and electric power (CCHP) FCSs throughout the U.S. in light commercial buildings. FCS manufacturers from all countries have been invited to participate. These CHP and CCHP FCSs will provide electricity between a range of five kWe to 25 kWe and heat between ranges of roughly three kilowatts (kW) to 60 kW. CCHP FCSs may combine fuel cells with absorption chillers to convert unrecovered heat into cooling power, or provide cooling power via another thermodynamic cycle design. This publication discusses results from Pacific Northwest National Laboratory (PNNL)'s research effort to independently monitor these CHP and CCHP FCSs for engineering, environmental, and economic performance.

A1103

How close to the market? The Fuel cell heating appliance Galileo 1000 N

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Abstract

Starting in 2007, more than 90 Galileo 1000 N systems (status April 2010) have been installed up to now and are in operation at customer's sites and in the lab. Thereby, the architecture and design of the Galileo 1000 N system has in general proved itself. The main development work during the last years was focused on the stack and the fuel cell module, especially with respect to enhancing lifetime but also increasing power output and electrical efficiency. Currently also a redesign of some BoP components is under way to further improve reliability and reduce cost.

The main achievements and current status of development are:

- Reduction of steady state degradation on real system operation to a level of 1.5 – 2.5 %/1'000h (in constant-voltage-operation). This corresponds to about 1%/1'000h degradation in constant-current-operation which is shown on short stack tests.
- 30-40 % increase in stack performance due to a shift in electrolyte material and improved electrodes. The market specification of 1 kW (AC, net) power out and 30-35% electrical efficiency (AC, net) has been achieved.
- Increased cycling-stability of the cells (redox and thermal cycles) to a level where operation over some years seems possible if the periphery is running reliable and stable.

Systems at customer's sites are mainly installed and operated within the project callux in Germany. Availability of the systems was higher than 95%. Long-term data from the heating period 2010/11 and also performance data from the improved type of cell under real conditions will be shown at the conference.

Based on the current experiences market launch is expected to be done from 2013. Now, the package around Galileo 1000 N has to be defined, the system has to be optimized and sales channels have to be prepared.

A1201

Bio-Ethanol Reformer with HT-PEM Fuel Cell for Residential Combined Heat and Power Generation

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Abstract

The aim of the project presented here is the demonstration of a combined heat and power reformer fuel cell system fuelled with bio-ethanol. It is designed to provide 6 kW_{th} for residential application. This is enough for hot water supply and for space heating in a house which has a primary energy consumption of 60 kWh/m²a, according to the German Energy Saving Ordinance (EnEV). The electricity produced by the HT-PEM fuel cell can either be used directly in the building or sold to the utilities company, according to the German Electricity Feed Act (EEG).

The system combines the advantages of the fuel cell, i.e. high efficiency, low emissions, and low noise with those of bio-ethanol. This fuel represents a CO₂-neutral approach to energy supply. It is non-toxic and commercially available worldwide. The technology significantly contributes to a move towards decentralization.

In the system ethanol and water (at a steam to carbon ration of 2.5) are catalytically converted to a reformat gas with about 50 vol.-%_{dry} H₂ and 25 %_{dry} CH₄ and less than 1 %_{dry} CO at temperatures of around 400 °C. This is achieved with an innovative catalyst. Due to the low CO content, the reformat gas can be fed directly to a HT-PEM fuel cell, where electricity and heat are produced. As opposed to conventional reformer fuel cell systems, no gas cleaning step is required. As a result, the system is much simpler. The CH₄-rich anode offgas fuels a burner which provides heat for the evaporation and superheating of the ethanol-water feed. Due to the comparatively low reforming temperature, there is still excess heat in the burner offgas, which contributes to the system heat production. A complex heat exchanger design will ensure that the system is small enough to fit into the design of the SolvisMax® heating system by Solvis GmbH & Co KG.

A1202

Integrated fuel cell APU based on a diesel steam reformer and a PEM fuel cell

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Abstract

Fuel cell systems based on steam reforming of liquid fuels have a great potential as auxiliary power units especially in recreational niche markets. In a joint research project with partners from industry and academia Oel-Waerme-Institut is developing an integrated fuel cell system with an electric power output of up to 4 kW_{el} based on a fuel processor for diesel and domestic heating oil.

This work focuses on the coupled operation of the fuel processor and a low-temperature PEM fuel cell. A gas clean-up module was developed to achieve the carbon monoxide concentrations required for the low-temperature PEM fuel cell. The fuel processor including gas cleanup was successfully coupled to the fuel cell and stability testing was performed at various operating points using a diesel surrogate. Measurements of carbon monoxide and residual hydrocarbon concentrations in the reformat gas were applied to define operating conditions for coupled operation. Decreasing fuel cell voltage was observed for an increasing amount of residual hydrocarbons in the reformat gas, but it could be restored with an appropriate reformer regeneration strategy. More than 100 hours of coupled operation with two 5-cell stacks and successful coupling with an 80-cell stack were accomplished.

A1203

An overview of current micro-structured fuel processing activities from fundamental studies to early markets application

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Abstract

For both mobile and stationary applications, high and low temperature fuel cell systems, there is a pressing need for compact(er) hydrogen production systems [1]. For completely integrated fuel processing systems then size is a crucial issue. The advantages of microstructured technology are many. However, the enhanced heat and mass transfer that is achieved together with the ease of system integration via integrated heat exchanger reactor designs leads to highly intensified systems. Generally speaking, a fuel processor consists of a reformer and various CO-cleanup reactors depending on whether the target fuel cell is SOFC or PEM based, all of which fall within the product portfolio of IMM. This contribution is focused on the continuing development of all reformer types i.e. those based on steam reforming, autothermal (ATR) and partial oxidation (POx), from W to kW scale. Primarily, if the final objective is increased compactness of the finished system(s) then POx of light hydrocarbons such as propane and LPG is particularly interesting. Major challenges here are (a) coke formation as lifetimes of up to at least 10,000 hours must be achieved and (b) hot spot formation caused by the large exotherm which can be solved by operating in the integrated reactor/heat exchanger mode. This requires improvements in catalytic efficiency and application which for the most part is achieved through the enhancement of the heat and mass transfer characteristics. Catalyst development work performed by IMM has shown that carbon formation was neither observed at the reactor inlet or over the noble metal based catalysts applied but rather at the reactor outlet, i.e. by the product. It could be suppressed by coatings inactive for the Boudouard reaction [2]. All parts of the development chain will be addressed from fundamental studies, catalyst screening, reactor design and fabrication to final integration of various systems. A complete fuel processor, integrated to a HT-PEM system, which has been operated for up to 3500 hours will be briefly discussed together with ongoing measures that are being adopted to address issues related to mass production of such systems. These include the obstacles that must be surpassed with respect to (a) continuous catalyst coating techniques e.g. by screen printing, (b) sealing techniques e.g. by high powered continuous wave laser welding and (c) structuring for the cost effective introduction of such units to a more widespread utilisation.

A1204

Hydrogen Quality for LT-PEM Fuel Cells - Commercial and Operational Aspects of Selective Methanation

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Abstract

Gas fine cleaning or CO-removal from reformat gases is essential for commercialization of low-temperature fuel cell systems operated with reformers. The paper emphasizes on the fundamentals of the selective methanation (SelMeth) technology, practical application in FLOX compact steam reformers and compares it with state-of-the-art preferential oxidation (PrOx) with regard to efficiency, operational, cost and life-time aspects.

It is shown, that meeting the operational temperature window, given by the catalyst system is the engineering challenge. The window is limited at the lower edge by activity, at the upper temperature by acceptable selectivity against "CO₂ methanation".

Results in 1 kW and 4 kW FLOX[®] fuel processing modules reveal, that thermal and physical integration with the CO-Shift-stage is beneficial. Life-time tests over 10.000 h show, that the gas processors provide reformat without CO at all loads and the operation window can be met without additional control efforts at reasonable reforming parameters, thus enabling to operate the fuel cell without air-bleed.

The comparison with state-of-the-art PrOx / air bleed technology shows, that SelMeth has got several benefits:

- Better performance: CO between 0-10ppm is possible at reasonable reforming parameters
- Less parts lead to significantly lower cost and higher reliability
- Saving parasitic power is the dominant positive effect on the electric system efficiency
- Avoiding air bleed on the anode saves cost and leads to potentially longer stack lifetimes

A1205

Design and evaluation of a cyclic fixed bed reactor for hydrogen purification

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Abstract

The cyclic water gas-shift reactor (CWGSR) is an alternative to the sequence of water gas shift reactors for the removal of carbon monoxide from reformat gases. It is based on the alternating reduction of a fixed bed of iron oxide using reformat gas and the subsequent re-oxidation of the iron with steam (Fig. 1). The gaseous product during the oxidation phase is a mixture of hydrogen and steam, which can be used in low temperature fuel cells.

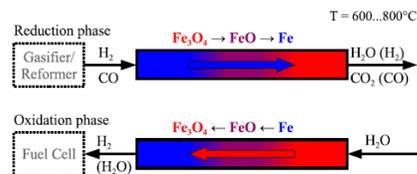


Fig. 1: Principle of the cyclic water gas-shift Reactor (CWGSR).

In our contribution, we will present various results that are essential for the development of the CWGSR. With regard to the fixed bed material, we have developed a suitable mixture of metal oxides which combines high oxygen capacity, high catalytic activity and good stability properties. To validate the reactor concept experimentally, a tubular fixed bed reactor has been applied. It shows

that the reactions occur in reaction zones which travel slowly through the reactor (Fig. 2).

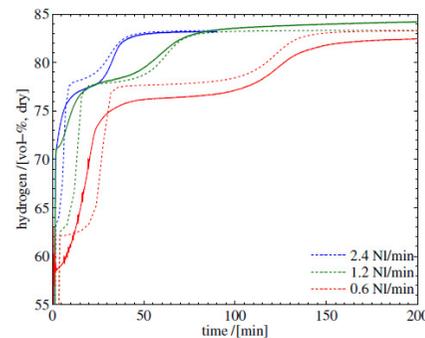


Fig. 2: Experimental (solid lines) and Simulated (dotted lines) output hydrogen Fraction during several reduction experiments

Their breakthrough behavior dominates the reactor dynamics. Based on these experimental results, we demonstrate a mathematical model for the detailed design of the reactor and show some results of a study that evaluates the performance of the CWGSR in systems employing PEMFCs or SOFCs or a combination of both against systems with conventional shift reactors.

A1206

CHARACTERIZATION OF A 500 We PEMFC STACK DURING AGEING

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Abstract

Lifetime and degradation rates are key points for fuel cells penetration in the market and therefore reliable diagnosis tools are needed. In the scope of a broader study aiming at studying the effect of operating conditions on stack performance and degradation, a 500 We PEMFC stack was aged for 1200 h. All along the experimental campaign, between two different studied operating conditions, the stack was operated and characterized in "nominal" operating conditions (70°C and 0.5 A/cm^2 , inlet gases relative humidity of 50%). This paper presents, for these conditions, the evolution of each cell and total stack performance together with the heterogeneity in cell voltage distribution. Some other process parameters' evolution, such as pressure drops in each compartment was also studied. In addition, all along the experiment, the stack was characterized by current steps according to a predefined profile with applied current densities ranging between 0 and 0.6 A/cm^2 . A very fast data acquisition system (100 kHz sampling rate) allowed the determination of some characteristic variables (ohmic resistivity, double layer charge time and capacitance...). Finally, all these variables were considered as potential sensors to evaluate stack's state of health.

A1207

Surface characterization of Ni-based anode after poisoning with low concentration of H₂S in MCFC

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Abstract

The surface rare metal oxide films on Ni-based anode were characterized and the relationship between the characterization and the adsorption of H₂S on anode was studied. The surface oxide films on Ni-based anode were obtained by dip coating method of anode in rare earth metal precursor followed by heat-treatment in various steps of oxidizing-reducing atmospheres. The characterization was performed using a scanning electronic microscopy (SEM), X-ray fluorescence (XRF) and X-ray diffraction (XRD). The optimum heat treatment procedures were determined by SEM and XRD analysis. The first oxidation procedure was performed to eliminate the remaining precursor and the formation of rare-earth metal oxide. The reducing procedure at higher temperature was conducted to remove NiO on the surface of Ni-based anode as well as to increase the interaction between coating material and the substrate.

Poisoning of the surface of anode during the H₂S exposure was studied using symmetric cells with and without applied load. The changes in the surface phase and the morphology of rare earth metal oxides coated on Ni-based anode for molten carbonate fuel cell upon exposure to a fuel containing 12 ppm of H₂S at elevated temperatures were investigated using XRF. The XRF revealed that the anode surfaces underwent sulfidation when the sample was tested under applied load. In comparison no sulfides were detected when the cell was maintained at open circuit voltage state even under the same poisoning level. The electrochemically formation of Ni₃S₂ seemed to be the key point to prepare high sulphur resistance for Ni-based anodes of MCFC.

A1208

Highly integrated micro fuel cell system based on a methanol steam reformer and a HT PEM fuel cell

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Abstract

Recreational niche markets offer a great potential for the introduction of a portable and highly integrated micro fuel cell systems based on a methanol steam reformer in combination with a high temperature polymer electrolyte membrane (HT PEM) fuel cell due to moderate requirements regarding target prices and durability. As an energy source Methanol is an attractive energy carrier especially for small fuel cell systems because of its high energy density and easy handling. In a joint research project the participating partners from industry and academia have developed a fuel cell system on basis of a methanol steam reformer and a HT PEM fuel cell with an electric power of 30 W. The system is used as an energy supply for golf-caddies.

After demonstrating the durability of the steam reformer and the HT PEM fuel cell in separate long-term experiments, the complete system with 20 HT PEM cells was built up. An overall system control including a start-up strategy was implemented and operating cycles were carried out.

In this paper, we focus on the coupled operation of the methanol steam reformer and the HT PEM fuel cell. We give a close view on the coupled system start and the resulting effects. Furthermore we show the improved solution to achieve longer durability.

A1209

Influence of Gas Composition on the Polymer Membrane Fuel Cell (PEFC) Performance

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Abstract

Polymer electrolyte fuel cells (PEFCs) are one of the most interesting alternatives for a pollution-free energy production. One of the major challenges in the development of PEFCs is to exploit the whole capacity that inherits a given membrane electrode assembly (MEA). Mass transport effects lead to an inhomogeneous electrochemical activity over the electrode area. In order to investigate in detail the influence of gas composition on the cell performance and to elucidate mass transport effects in the cell current-voltage curves and electrochemical impedance spectra (EIS) were recorded. The cathode of the PEFC was fed with gas with different oxygen content ranging from 100% to 5%. The other gas component was helium or nitrogen. Results can be used to improve cell components, to validate models and to detect inappropriate detrimental operating conditions of the fuel cell.

The measured EIS can be simulated using an equivalent circuit taking into account the uncompensated membrane resistance (electrolyte resistance), kinetics of the oxygen reduction reaction, the kinetics of hydrogen oxidation reaction and the porous structure of anode and cathode. The used model is the cylindrical-pore model proposed by Göhr, where the impedance elements of the pore's wall surface are the double layer capacity (C_{dl}), charge transfer resistance (R_{ct}) and impedance elements of oxygen diffusion (Z_{diff}).

A1301

Understanding Water Removal from Fuel-Cell Gas-Diffusion Layers

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Abstract

It is well known that for PEFCs operating below 100°C, water management is a critical issue. If there is too much water, then the catalyst layers and GDLs will become saturated with liquid water and flood; if there is too little, then the membrane becomes highly resistive. In terms of flooding, the liquid water blocks the access of oxygen to the reaction sites. Key in controlling water management is the impact of the GDLs, especially on the cathode side of the cell. Within these layers, two-phase flow dominates and, especially at lower temperatures, where water is removed from their surface in liquid form. Single-droplet existence has been studied by various groups, but these studies do not necessarily include the impact of multiple droplets and also depend on contact-angle hysteresis of droplets placed on the GDL surface to predict the adhesion force. The above issues will be discussed and an approach to alleviate them introduced including experimental measurements of the adhesion force and droplets using a tilted goniometer. Combined with a theoretical treatment of the pressure force, one can begin to predict droplet instability and movement. In addition, an approach using a combined liquid-surface coverage and a fluctuating capillary-pressure boundary condition will be discussed along with capillary-pressure measurements for the liquid saturation.

A1302

Two phase Pore Network Model of the cathode catalyst layer of the PEMFC: application to the analysis of gas diffusion and effect of wettability

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Abstract

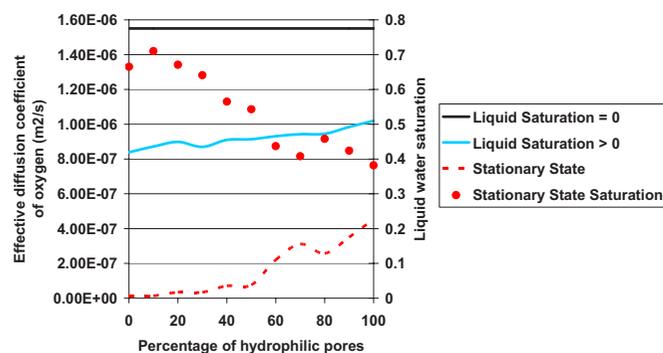
Understanding the liquid and gas phase transport inside the cathode catalyst layer (CCL) of the PEM fuel cell is an important step in the process of performance improvement.

The reactant (oxygen) is transported by diffusion, and water is supposed to be produced in liquid phase from the oxygen reduction reaction (ORR). Water transport is mainly driven by capillary effects. The two-phase transport phenomena are coupled through the ORR.

The pore network modelling (PNM) is well adapted for the multiphase transport in porous medium. It is used in this work to simulate the two-phase transport inside the secondary pores of the CCL. 3D regular networks made of spherical pores and cylindrical throats are constructed to describe the porous structure of the CCL. The effect of the structural and wetting properties of the CCL on the two-phase transport is studied.

The results show that liquid water clusters have different shapes depending on the wettability (hydrophobic, hydrophilic and mixed) of the pores, which affects the liquid water distribution inside the network, and then the oxygen effective diffusivity.

Effect of wettability on oxygen diffusion



A1303

A Numerical Model Predicting Liquid Water Saturation within the Cathode Electrode of a Proton Exchange Membrane Fuel Cell

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Abstract

A two-phase, half cell, model of a proton exchange membrane fuel cell cathode has been developed with emphasis on the liquid water saturation within the three porous layer structure, i.e. the catalyst layer, the micro-porous layer and the gas-diffusion layer. The model was run under varying current density, operating temperature, relative humidity and gaseous flow rate. The results show that the calculated liquid saturation profiles strongly depends on the local distribution of these variables which are highly coupled. For example, an under-humidified gas feed entering into the cell, first undergoes through the evaporation regime at low current densities, followed by liquid-water generation at moderate current densities, and finally evaporation of the liquid-water at higher current densities due to increase in the cell temperature. The increase in air flow rate enhances the liquid-water saturation within the catalyst layer, near the channel area, and reduces its amount under the ribs. The reduced liquid-saturation under the ribs is due to higher local temperature because of increased reactant transport that results in its evaporation. In summary, prediction of liquid-water saturation within the cathode is a highly complicated phenomenon that is strongly coupled to the above variables.

A1304

Aging mechanisms in Lithium-Ion-Battery and PEM-Fuel Cell and their influence on Hybrid-Systems

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Abstract

As the dependency on the non-renewable energy sources are increased and the environmental concerns are illuminated, research on zero emission energy source PEM fuel cell has been intensified. One of the main hurdle to commercialize PEM fuel cell as a main energy source in automobile application is the degradation (aging) of the fuel cell. To accomplish the customer wishes, battery as a secondary energy source in automobile have been used. The aging (degradation) mechanism and aging failures of lithium-ion battery and PEM fuel cell have been investigated and stress factors have been identified focusing on specific aging test. Modeling and validation of aging mechanisms have been illustrated. Moreover, the hybridization phenomenon has been described and the effect of hybridization on aging of lithium ion battery and PEM fuel cell has been illuminated.

A1305

Numerical study on the water distribution in GDL and channels of PEMFC applying microchannel bipolar plate

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Abstract

Water management is an important factor in the implementation of proton exchange membrane fuel cells (PEMFCs). The ionic conductivity of a membrane is dependent on the properties of membrane and water content. However, excessive water amount causes flooding, which disturbs transport of reactant gases. Many researchers have studied proper water management and methods to prevent flooding. Especially, understanding two-phase flow in porous gas diffusion layer (GDL) is needed to prevent flooding. In this study, the effects of operating conditions on the cell performance and water content were studied by a three-dimensional fuel cell model. In addition, the water removal effect of a microchannel manufactured in the bipolar plate was investigated. The active cell area was 10.2 cm² and flow fields in anode and cathode were parallel channels. The operating temperature was 50 °C at atmospheric pressure. Stoichiometries of anode and cathode were 1 and 2, respectively. Water content in GDL increased with an increase in the cell temperature. At high stoichiometry condition, total amount of air decreased due to water removal by excessive air. The humidity of air had significant effect on amount of water. The water removal using the microchannel bipolar plate was more effective than that using the conventional bipolar plate. In addition, the water content in GDL using the microchannel bipolar plate was more evenly distributed.

A1306

Influence of nature and concentration of iron ions on the degradation of PEMFCs: a modeling study

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Abstract

Polymer Electrolyte Membrane (PEM) Fuel Cells represent a promising technology for high-efficiency energy conversion as an alternative to fossil energies. However, under practical operating conditions, the durability of the current technology is not high enough yet to be economically viable. Modeling is becoming a more and more important tool for understanding degradation mechanisms and predicting the lifetime of fuel cells. For this goal, we apply multiphysics elementary kinetic models that describe electrochemical reactions and transport processes in a highly detailed way [1-4]. This allows a reliable prediction of the long-time behavior of the cell, which always involves temporal extrapolation away from short-term measurements [5-7].

This presentation deals with a 1D model of the PEM chemical aging, which represents one of the major mechanisms inducing irreversible PEMFC performance decay. The model describes water, gas and ion transport across the PEM, production of hydrogen peroxide in the anode CL, transport of peroxide into the PEM, its decomposition, and chemical degradation of the PEM through radicals attack. Parameter identification and model validation is performed using published experimental work from several groups.

It has been observed experimentally by Kodama *et al.* that the degradation rate depends nonlinearly on the concentration of iron ions in the membrane [8]. Particularly, under very aggressive conditions the membrane degradation is not as high as expected. This study shows a model-based analysis of the influence of ion concentration on the degradation rate. The different effects of Fe²⁺ and Fe³⁺ are quantified.

A1307

Numerical Simulation of Solid Oxide Fuel Cell for Impedance Analysis

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Abstract

The purpose of the current study is to model and simulate the impedance of a solid oxide fuel cell (SOFC) anode. The electrochemical impedance spectroscopy (EIS) is a powerful non-destructive method for obtaining the individual losses, characterization of materials, investigation of transport properties and the performance optimization of SOFCs. Efforts are devoted to develop tools that numerically evaluate the EIS experimental results.

In this study a planar SOFC anode is modeled and the electrochemical spectra at the anode are obtained. The simulation is based on transient model of the anode when a periodic voltage is imposed. The model fully couples electrochemical kinetics with gas phase diffusion. The electrochemistry at the anode is modeled using Butler-Volmer equation, and gas diffusion model is based on the species equations. An in-house finite difference based code is used to solve the system of nonlinear equations. It is found that the Nyquist plot shows a capacitive semicircle which is identical to the gas conversion impedance as reported in literatures. A parametric study is also carried out by changing parameters, such as supplied gas compositions and cell dimensions, and the results are discussed. Furthermore, it is shown that the simulation results are in good agreement with published results.

A1309

Kinetic Monte Carlo Simulation of Ion Conduction in Ydoped Barium Zirconate

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Abstract

Y-doped Barium Zirconate (BYZ) has been extensively studied for the proton-conducting ceramic fuel cell (PCFC) application due to its high proton conductivity and high chemical stability. However, most studies were performed experimentally with only few studies focusing on the ionic conduction mechanisms in atomic scale. Therefore, in this study, the quantum simulation complemented with kinetic Monte Carlo (KMC) method was employed to understand the ionic conduction and defect association mechanisms in BYZ. The quantum simulation based on density functional theory (DFT) was first used to create the migration energy barrier database and explore possible pathways for ion transport. The DFT calculation results reveal the effect of defect association among proton (H⁺) oxide ion vacancy (V) and Y atom. The highest binding energy was -0.18 eV, corresponding to the attractive interaction of H and the first nearest neighbor Y atom. The defect association also affects both proton and oxide ion migration barriers causing the difference in the migration energy at different Y arrangements around the diffusion centers. The KMC simulations were then performed using Boltzmann probabilities based on the calculated DFT barriers to determine the effect of the doping concentration and the water uptake on the ionic conductivity of Ba(Y_xZr_{1-x})O_{3-δ} supercell with x increasing from 0.08 to 0.4. The KMC simulation results show that proton conductivity is at least 2-3 orders of magnitude higher than oxide ion conductivity at all doping concentrations. The optimum doping concentration for the highest proton conductivity depends strongly on the amount of the water uptake. The results will be subsequently compared with the experimental results.

A1310

A Parameter Estimation Method for Fuel Cell Diagnostics

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Abstract

Researchers and developers typically use I-V curves (current vs. potential) as a means to demonstrate good data fitting of a model under experimental validation. Despite the popularity of this method, assessment of the results can be intuitive rather than mathematical, and usually, when such a demonstration occurs, information on the quality of the parameter estimation is not given. On the contrary, it has been shown that simple model fitting on I-V curves cannot give statistically reliable results on the values of the model parameters since the confidence intervals are quite high.

In previous work we used a model-based Design of Experiments method to establish optimal measurements on SOFC's, in order to improve the parameter estimation's reliability. Based on this theoretical analysis we proceeded to experimental validation with measurements on SOFC button cells. This work led to the development of a different method for sampling and treatment of data taken from I-V curves. This method facilitates production of histograms for each parameter –instead of simple values– allowing the researcher to observe their stochastic behaviour and assess the discrepancies of the calculated parameters. Furthermore the calculation of their variances and covariances are based on experimental data instead of the theoretical linear approach of the output model's partial derivatives with respect to the parameters.

In this work we present part of the produced results from this method using an advanced electrochemical and mass transport model for the cell.

The proposed method can be used as a tool to improve model validation procedures, for fuel cell diagnostic applications, research on degradation etc.

A1311

Multiphysics Model of the Anode of a Direct Methanol Fuel Cell

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Abstract

A multiphysics across-the-channel model is presented for the anode of a liquid-feed Direct Methanol Fuel Cell (DMFC). The model considers both two-dimensional (2D) single-phase anisotropic transport of methanol in the anode gas diffusion layer (GDL) and anisotropic electron transport from the catalyst layer to the current collector rib, coupled to a one-dimensional (1D) model for the membrane and the cathode, which describes the electrochemical reactions kinetics, water and methanol crossover, and oxygen transport from the cathode channel to the cathode catalyst layer. As new contribution, the 2D model takes into account the effects of the inhomogeneous compression of the GDL associated with the repetitive rib-channel pattern, including non-uniform porosity, diffusivity and bulk electrical conductivity distributions, as well as non-uniform contact resistances over the GDL-rib and -membrane interfaces, which affect mass and charge transport phenomena. As a straightforward application, we have investigated the effect of the clamping pressure acting on the stack on the overall fuel cell performance.

A1401

Using Electrochemical Impedance Spectroscopy for fuel cell control

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Abstract

Performance, lifetime and efficiency of Polymer Electrolyte Membrane Fuel Cells are strongly influenced by many parameters like membrane water content, reactant supply and cell temperature. Thus, an adequate adjustment of these parameters is of great significance in the design of controlling strategies for fuel cell systems. One key issue for fuel cell performance is the water balance inside the fuel cell. Accumulation of liquid water inside the gas diffusion layer has to be avoided while the membrane needs proper humidification to ensure good proton conductivity

Some approaches using Electrochemical Impedance Spectroscopy as an input value to control a fuel cell system have been described in literature. Improvements compared to traditional controller designs include performance, durability and stability of operation. However, a complex and bulky measurement setup is needed and makes therefore integration into a fuel cell system difficult.

In this study, impedance spectra of commercial stacks and of a stack developed in-house at Fraunhofer ISE are analyzed at different operation conditions. Parameter variations include load condition, humidification, stoichiometry and temperature. Single cell spectra were measured simultaneously which provides detailed information about the entire stack. The frequency sweep is further reduced to only two discrete frequencies to derive information about the water balance inside the fuel cell. High frequency impedance was used to estimate the membrane water content while low frequency impedance provides information about mass transport limitations. These data can be used as additional information for improved controlling algorithms due to the fact that change of impedance is more significant than change of cell voltage and therefore provides more information about the state of health of the fuel cell.

A1402

Numerical Study of PEMFC Water Management for Control and Diagnosis Strategies Design

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Abstract

Water management is one of the most important topics for Proton Exchange Membrane Fuel Cells (PEMFCs) since it affects the achievement of high/peak power performance. This research work deals with the main water dynamics from the viewpoint of the fuel cell control and diagnosis to improve on-field operation.

Therefore, attention has been given to the achievement of synthetic but comprehensive models, which can be easily applied for both control and diagnosis strategies design and on-board applications. The paper focuses on the effects of water transport mechanism through the components of the cell on PEMFC's performance. For this purpose, it is assumed that evaporation and capillarity are the predominant processes in the water flow through the gas diffusion layer (GDL). These mechanisms are simulated through accurate, computationally fast and low order models (mean value models - MVM). Fast simulation time is achieved by lumping the space dependence of the main variables.

The novelty of the work lies in the fusion of a comprehensive PEMFC stack model with a map-based simulation model, which reproduces the water transport through the GDL and at the interface between GDL and gas flow channel (GFC). This approach can lead to the exploration of advanced control strategies to enhance stack performance, improve fault diagnosis and increase system durability.

A1403

Application of Proton Exchange Membrane Fuel Cell for Lift Trucks

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Abstract

In this study a general PEMFC (Proton Exchange Membrane Fuel Cell) model has been developed to take into account the effect of pressure losses, water crossovers, humidity aspects and overpotentials in the cells. The model is zero dimensional and it is assumed to be steady state. The effect of concentration loss is neglected while the effect of activation and ohmic losses is investigated in the system. Some semi-empirical equations are required to predict the amount of exchange current density for calculation of ohmic loss and water diffusion coefficient through membrane. These equations are applied in order to account for water back diffusion. Further Membrane water content is assumed to be a linear function of thickness.

PEM fuel cell is working at rather low operating conditions which makes it suitable for the automotive systems. In this paper motive power part of a lift truck has been investigated thermodynamically. The system includes a compressor, an air humidifier, set of heat exchangers and a stack which together build up the anode circuit, the cathode circuit and the cooling loop. Since fuel humidification is carried out via water cross over from cathode to anode, there is no humidifier in the anode side. The electricity needed for auxiliary components is produced by the stack. The system is set at different electrical powers. In this paper several issues are discussed; voltage losses, system efficiency as well as electrical power at different operating conditions.

Key words: PEMFC, fuel cell, anode recirculation, ohmic loss, activation loss, concentration loss, exchange current density, back diffusion

A1404

Nonlinear operating behaviour of PEM fuel cells

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Abstract

Proton exchange membrane fuel cells (PEMFCs) possess a multitude of sources that can result in a nonlinear operating behaviour. On the one hand, there are strongly nonlinear rate laws for the electrochemical reactions taking place. On the other hand, mass transport within the various fuel cell layers follows nonlinear kinetics, considering multi-component, multi-driving force transport mechanisms, and even two-phase flow that is caused by the condensation of product water. It is therefore not surprising that effects that seemed to be outliers or fragments in the data of early experimental studies are now the subject of systematic analyses.

In the present contribution, a brief overview on the field of nonlinear operating behaviour of PEM fuel cells and a classification of corresponding experimental findings and theoretical predictions of the last decade are given. In particular, examples for bi-stable and oscillatory behaviour of PEMFC are discussed. Bi-stability was experimentally observed during the operation in auto-humidification mode (e.g. [1,2]) and at low hydrogen partial pressures or low noble metal content (e.g. [3]) as well as predicted to be caused by two-phase flow in the porous structures of the gas diffusion layers (e.g. [4,5]). As examples for oscillatory behaviour of PEMFCs nonlinear pattern formation during exposure of CO-containing feed gases (e.g. [6-8]) as well as voltage oscillations supposed to appear as a result of degradation effects (e.g. [9]) are discussed.

A1405

Model-based Analysis of the Environmental Operating Range of Direct Methanol Fuel Cell Systems

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Abstract

Active direct methanol fuel cell (DMFC) systems deliver power in the range of 10W – 2 kW and are as such mostly used to power portable, mobile or off-grid appliances. This contribution presents model-based studies on the theoretically achievable operating range and the stability of DMFC systems. The main model represents a reference system with each component serving only one purpose. The simulations show that maintaining a stable water content in the system is the main challenge for autonomous operation of the system at varying environmental and operating conditions. The water level can be stabilised over a wide range of environmental conditions by adjusting the condenser temperature at the cathode outlet. However, the system eventually loses its autonomy at high environmental temperatures and low humidity.

Besides the operating range of the reference DMFC system, the effectiveness of methods to extend the feasibility envelope are discussed as well as the influence of modifications of the process design on the feasibility envelope and on the required cooling duty of the coolers to maintain a stable water level. The gas/liquid separation of cathode and anode flow in a single separator is attractive for reducing volume and weight of a portable DMFC system – the joining of both streams shows however to have a strong influence on the system's methanol efficiency. Finally, the influence of fuel cell design on the feasibility envelope of the system designs is discussed.

A1406

Thermal Management of Fuel Cell Air Independent Propulsion System

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Abstract

A dynamic simulation model of fuel cell air independent propulsion system (FCAIP) for underwater vehicle is presented. A conventional air independent system is very difficult to meet the required efficiency target with high performance as the system is applied to the tactical operation of underwater vehicle. The fuel cell system with liquid oxygen is applied to the air independent propulsion of submarine which can promise wider tactical range than conventional system. The dynamic simulation model is developed to evaluate the performance of the fuel cell air independent propulsion system. The model includes two cooling modules, liquid oxygen supply module, and metal hydrogen supply module. In particular, a simulation model of oxygen stack is a cascading fuel cell stack model which is very effectively rejecting water from the fuel cell stack. An oxygen supply model is composed of sub-system such as liquid oxygen tank, pressure build-up evaporator and principal evaporator. A metal hydride is contained in cartridge type cylinders. One cooling module is internal circuit for temperature control of fuel cell stack while the other cooling module is used as thermal reservoir. The second cooling circuit delivers thermal energy from the fuel cell stack to the hydrogen supply module and liquid oxygen supply module. Since the cooling circuits work very important duties, the operating strategies and configuration of thermal management system are very important. This study applies the FCAIP simulation model to understand the complicated operating strategies, the effect of thermal management criteria, cooling configurations so that the fuel cell stack is able to be operated properly.

A1407

The characteristics study on thermal management of the proton exchange membrane fuel cell system for the unmanned aerial vehicle

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Abstract

Proton exchange membrane fuel cell (PEMFC) is a promising alternative power source for unmanned aerial vehicle (UAV) due to low operating temperature and silent operation. Since the UAV is flying in the air, it is crucial to maintain the performance of PEMFC. Especially, the thermal management is important for determining the performance of PEMFC during load changes.

In this work, in order to develop the optimal control strategy of thermal management for UAV, both of the simulation and experimental study were performed. The thermal management system (TMS) model developed by Matlab/Simulink® consists of two-dimensional dynamic model of compact heat exchanger (HEX) and pump lumped model. The HEX model was validated with experimental data. In order to estimate the performance of HEX for UAV, thermal management system (TMS), wind tunnel, and heater were manufactured.

The parametric study of HEX was performed with various air flow rates, coolant inlet temperatures, air temperatures, and coolant flow rates. The dynamic response of the heat exchanger was captured at the instant change of the heat generation from the stack. This work can be helpful to optimize the thermal management of the PEMFC.

A1408

MatLab/Simulink as design tool of PEM Fuel Cells as electrical generation systems

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Abstract

Design of electrical power generation systems based on fuel cells demands for an electrical model for these ones. In fact, designing engineering systems is based on accurate simulation tools that require accurate models of components and subsystems. MatLab/Simulink shows a general approach and it is very common tool for designing electrical control systems. To design electrical generation systems based on hydrogen using the MatLab/Simulink as design tool demands for accurate electrical models of the fuel cells. The behavior of PEM fuel cells is dependent on many parameters; so obtaining an accurate model of a PEM fuel cell, including dynamical behavior, becomes essential to design electrical power generation based on fuel cells.

For that purpose, a mathematical model of a PEM fuel cell system developed in MatLab/Simulink is demonstrated. However, the difficulty emerges in the lack of manufacturer data about the exact values of the parameters needed for modelling. The analytical formulation of the fuel cell behavior is based on a set of equations demanding knowledge on several parameters whose values are dependent on cell operation as well as on operating temperature. The method adopted in order to determine the optimum set of parameters is the Simulated Annealing (SA) optimization algorithm, which proves to be well adapted to satisfy the goal of a fast convergence to establish the right values for the cell parameters. The good agreement between the simulation and the experimental results shows that the proposed model provides an accurate representation of the static and dynamic behavior for the PEM fuel cell. As the model is already established, the paper shows that the designing of electrical generation systems based on fuel cells can be easily performed in MatLab/Simulink environment. The results carried out in designing a DC/DC converter appropriate to take control and optimization of operation point of a fuel cell show that the model is appropriate to be applied in designing electrical generation systems. The simulation results are compared with real data from commercial systems.

A1409

Numerical study on the capillary effect of microchannel in bipolar plate in PEMFC

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Abstract

Water management is an important factor in the implementation of PEMFC. The ionic conductivity of a membrane is dependent on the properties of membrane and water content. But excessive water amount causes flooding, which disturbs transport of reactant gases. Many researchers have studied on proper water management and the method to prevent flooding. Especially, understanding of two-phase flow in porous gas diffusion layer is needed to prevent flooding.

In this paper, the capillary characteristics of a microchannel manufactured in the center of ribs of a bipolar plate are investigated. The microchannels induced effect of water emitting from GDL. Water distribution in GDL and the performance variation were studied by using a three dimensional CFD. The active area of cell is 25cm² in the modeling. Anode and cathode flow field are multi line serpentine channel. The operating pressure is at atmosphere and operating temperature is 70°C. Stoichiometries of anode and cathode are 1.5 and 2.5, respectively.

A1410

Development of a Dynamic Model and Control of a PEM Fuel Cell

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Abstract

This paper presents a finite difference dynamic model of a single unit PEM stack. The model applies a detailed electrochemical and thermal analysis of the fuel cell yielding internal cell profiles for any relevant thermodynamic and electrochemical cell variable. Dynamic simulations are carried out starting from a steady state condition with average current density of 5000 A/m² with a fuel utilization of 75%, applying a ramp current change to the system. Results of the simulation show that a $\pm 20\%$ load current change determines significant variation of the cell key variables such as the fuel utilization and the maximum MEA temperature. Given the importance of these parameters on both cell performance and cell durability, a simple control strategy based on two PID's is added to the system: the PID1 acts on the fuel valve opening to maintain a constant fuel utilization factor, while the PID2 acts on the air fan rotational speed thus regulating the cathode air inlet to control the cell maximum temperature. It is shown that with an appropriate tuning of the PID parameters it is possible to maintain an effective cell operation under different load variations.

A1411

Increasing the Efficiency of High Temperature PEM Fuel Cells by Using Simulated Optimized Flowfields

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Abstract

Numerical simulations of complex systems, e.g. the characteristics of chemical reactions, open new possibilities for enhancing the effectiveness of fuel cells. With an appropriate approach it is possible to simulate the interactions between anode and cathode and to predict the flow distribution of each gas. With respect to the velocity distribution in each flow-channel it is important to calculate all reaction products realistically.

User defined program modules, which are integrated into the commercial software Ansys CFX, allow obtaining detailed information on the flow distribution in the flow channels. Simulation results show a nearly realistic distribution in the MEA. The volume fractions of the different gases in the channels correspond to reality, while, at the same time, the total system is in good electrochemical balance. With this program it is possible to simulate complex designs or even stacks on standard workstations.

In the case of high-temperature PEM fuel cells, which operate at temperatures of approx. 130-180 °C, the calculation of water saturation or water content can be neglected. Designing a new, optimized flow field requires meeting the conflicting requirements of uniform gas distribution, good electrical contact and an overall low pressure drop simultaneously. With the new simulation program it is possible to develop and construct flow field designs with higher efficiency and better performance than the standard meander or pin-structure geometries.

B0401

Fabrication of Low-Profile and Large Size Solid Oxide Fuel Cell Combined with Strength Reinforcement Layer and Shrinkage Control Layer

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Abstract

The power output of a planar SOFC can be increased by enlarging the cell size and providing the fuel gas to the reaction site more effectively. For this reason, a SOFC tends to be larger in area and thinner in thickness. However, in a planar SOFC, larger area causes bigger camber in co-firing process due to larger shrinkage mismatch between layers such as the electrolyte, the anode function layer and the support. It is even more difficult for a large cell to achieve low cell thickness because reduction of cell thickness worsens the camber. Moreover, thinner cells show much lower mechanical strength in a ring-on-ring test, which means more problems in handling, stacking and operating in SOFC stacks. Last year we presented a fabrication route which enabled us to achieve large SOFCs with high performances. In this study, we demonstrate a new fabrication method to make large and thinner cells having small camber without undermining mechanical strength. The support of the cell consists of two types of layers with different functions. One is for reinforcing the mechanical strength and the other is for controlling the shrinkage rate in co-firing. For the designated functions, each layer is controlled by YSZ/NiO ratio, Y₂O₃ contents in YSZ and pore former amounts. All layers constituting electrolyte, anode function layer and support were fabricated by tape casting of wet slurry, and lamination by automated multilayer stacking machine. In the new structure, cells show very small camber and no decrease in mechanical strength even if cell dimensions were 0.7 mm in thickness and 704 cm² in area. From the button cell test, the maximum power density of 0.7mm thickness cell was 11% higher than that of 1.1 mm thickness cell. Additionally, it was proved by the large size single cell test that the thinner cell was superior to the thicker one in high fuel utilization condition. Besides increasing power density and fuel utilization, thinner cells will be also advantageous for reducing the volume of SOFC stack and materials cost.

B0402

Sol-Gel Process to Prepare an Anode Supported SOFC

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Abstract

Yttria-doped zirconia (ZrO₂-8%Y₂O₃) is widely studied as an electrolyte material for Solid Oxide Fuel Cells due to its high ionic conductivity at high temperatures (900-1000°C). In order to decrease the working temperature of anode-supported cells, either new materials can be prepared or microstructure and thickness of electrodes and electrolyte can be controlled.

In this work, the sol-gel process is used to prepare YSZ electrolyte in the 5 to 20 μm thickness range.

The sol-gel process is interesting to make thin electrolyte (~ 10 μm) as it allows a very good control of the thickness and microstructure of the deposited layers.

Several ways of obtaining sol-gel YSZ films on a commercial YSZ-NiO support are reported. Gas-tight thin electrolytes (~ 10 μm) are obtained with two types of composite sols made with commercial powder dispersed either in a polymeric or a colloidal sol. Both ways are studied, the most environmentally-friendly being the synthesis with the colloidal sol as it is made in aqueous media.

The entire cell is then processed with YSZ/LSM or with a mesoporous gadolinia-doped ceria (GDC) layer [1] between YSZ and the LSCF (La_{0.8}Sr_{0.2}Co_{0.8}Fe_{0.2}O_{3-δ}) cathode to improve the cell performances.

Electrochemical characterizations will be presented to demonstrate the cell performances.

B0403

SOFC Degradation Quantification Using Image Analysis

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Abstract

SOFC cell degradation is, amongst others, related to changes in the morphology and chemical composition of cell layers, to the deposition of impurities and chemical species in layers, or the reaction of compounds with each other or emissions from other SOFC stack components.

Up to today, the dependency of the actual loss of power (or voltage) on specific changes in morphology or composition are only qualitatively known. The existing models use empiric or statistic evaluation of responses of fuel cells to operating conditions in order to fit models of degradation.

Obviously, there must be a relationship between the changing structures and compositions of the layers in an SOFC cell with the corresponding degradation mechanisms. Nevertheless, it has proven difficult to quantify this relationship and turn the achieved insight into models predicting degradation. The main problem is the way of turning microstructural data, for instance from microscopy images (SEM, BSE, EDX etc.), into quantified information that can directly be correlated with measured effects.

Within the project Image-SOFC, the Institute of High Temperature Electrochemistry (Ekaterinburg), the Institute of Mathematics and Mechanics (Ekaterinburg), and Forschungszentrum Jülich have conducted a project developing image analysis methods that are capable of reliably identifying not only pores but also different phases in SOFC cell layers. The method delivers quantitative figures on the morphology and phase distribution that allows direct insertion in equations describing temporal evolution of cell properties. Examples of results that will be presented are the detection of chromium poisoned cathode layers and changes in anode nickel cermet morphology due to nickel agglomeration.

B0404

Direct Methanol Solid Oxide Fuel Cell: A Resistant Anode towards Carbon Deposition

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Abstract

A composite Ni-modified $\text{La}_{0.6}\text{Sr}_{0.4}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3 / \text{Ce}_{0.9}\text{Gd}_{0.1}\text{O}_2$ electrocatalyst was prepared by incipient wetness. The product thus obtained was calcined at 1100°C for 2 h in static air. After thermal activation, Ni was mainly present as highly dispersed La_2NiO_4 on the surface of perovskite surface. The thermal reduction at 800 °C caused the occurrence of metallic Ni on the surface. Surface area was determined by BET measurement. The catalyst was investigated for the autothermal reforming (ATR) and was used as anode in IT-SOFCs fed with methanol. A comparison was made between the performance of SOFCs fed with hydrogen, syngas and methanol. The results with methanol are promising both in terms of energy density as well as suitable performance for portable power sources.

B0405

Influence of artificial woodgas with alkali salt vapors on the Solid Oxide Fuel Cell Ni-cermet anode

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Abstract

Influence of inorganic impurities on the electrochemical performance of SOFC anode is an important issue which has to be clarified for the utilization of carbonaceous fuels such as gasified biomass, lignocellulosic ethanol and natural gas in the SOFC, and for further system development and optimization. Compared to most bituminous fuels, one of the important features of biomass materials is the presence of considerable quantities of alkali and alkaline earth compounds (mainly K, Na, Mg and Ca) [1]. The influence of various inorganic salts in gasified biomass (NaCl, NaCO₃, KCl, KCO₃, K₂SO₄, ZnCl, etc.) on the SOFC anode performance and the influence of salt particle size on the anode degradation kinetics are not only unclear, but to the best of our knowledge, have hardly been addressed. Versatile salt vapor condensation reactor was built for generating the low concentration (ppm level) salt aerosol-vapor mixtures to carry out SOFC anode impurity tests [2]. This system is based on evaporation and subsequent condensation of low concentration salt vapour to the salt vapour-aerosol mixtures representative of salt vapors typically present in biomass gasification and hot gas cleaning processes. The flexibility to produce vapor-aerosol mixtures with different concentrations and particle size distributions is proved, and suitability of these aerosols for anode testing in long term fuel cell test was evaluated. Mid-term durability tests of SOFC Ni-cermet anodes were performed on the artificial woodgas in the presence of low concentration KCl, NaCl salt aerosol-vapor as well as in HCl for reference. Dependence of the total resistance of unit cell on time was recorded and *post-mortem* electrodes were analysed with XRD, ESEM, EDX and XPS methods. Small changes on the electrochemical performance as well as electrode microstructure were observed. To demonstrate the necessity of low salt vapour concentration tests the high salt concentration test was performed. Fast changes in the charge transfer and ohmic resistance were observed in the anodes fuelled with gas mixture containing high KCl vapor concentration.

B0406

Fabrication and cell performance of anode-supported SOFC made of in-house produced NiO-YSZ nano-composite powder

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Abstract

The cell performance of anode-supported SOFCs fabricated from in-house produced NiO-YSZ nanopowder was investigated. NiO-YSZ nanopowder was fabricated via a single-step modified sol-gel method using sucrose and pectin as organic precursors. The obtained nanopowder was characterized by TEM and XRD measurements. The powder was then pressed into pellets in a uniaxial press and pre-sintered to be used as supports. Thin 8 mol% yttria-stabilized zirconia (8YSZ) electrolyte films (~15 µm) were obtained by a dip-coating process from ethanol suspensions using phosphate ester (PE) and polyvinyl butyral (PVB) as dispersant and binder, respectively, followed by a co-sintering step. The microstructure of the obtained films was characterized by SEM. Dense electrolyte films were obtained on anode supports which undergo a relative linear shrinkage of 23% during co-sintering. LSM-YSZ paste was then screen-printed on the 8YSZ electrolyte/anode followed by a screen-printed layer of pure LSM to form a cathode comprising an active layer and a backing layer to assemble a single fuel cell. The cell performance was tested in the temperature range of 700-1000°C

B0407

Effect of Sr Contents of (Ba,Sr)(Co,Fe)O_{3-δ} Cathodes on Chromium Poisoning Phenomena

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Abstract

This study is concerned with Cr poisoning phenomena on Ba_{1-x}Sr_xCo_{0.8}Fe_{0.2}O_{3-δ} (BSCF) cathodes as a function of Sr contents. For this purpose, five kinds of cathode powders are synthesized by using glycine nitrate process and the Gd_{0.2}Ce_{0.8}O_{1.95} (GDC) powder is prepared by solid state reaction method. Fe-Cr alloy was used as the interconnect. From the XRD analysis, it can be found that all kinds of cathode materials have pure perovskite structure. To investigate the Cr poisoning on cathode material, impedance and polarization are taken under a constant current density of 200 mAcm⁻² in air at 900°C for 20 h. In impedance results, both ohmic resistance and polarization resistance are increased as the cathodic polarization time increases. These results show that the Cr poisoning directly affects the electrochemical performance, and the high Sr contents have bad influence on the cathode performance. From SEM image analyses, the Cr deposits are formed near the cathode particles and agglomerated to each other. At long-term test at 900°C for 100 h, the cathode with low Sr contents shows stable performance. After test, the cathode is analyzed by XRD and the Cr deposits such as BaCrO₄ and SrCrO₄ are found on the cathode surface.

B0408

Development of Anode-supported Flat-tube SOFC Stack having a New IC Design

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Abstract

A flat-tube design of SOFC combines the advantages of both tubular and planar designs, e.g., no requirement of high-temperature seals, high volumetric power density and improved mechanical stability. SOFC operations at lower temperatures lead to an improvement in the durability of cells and stacks by reducing problems associated with thermal cycling and performance degradation due to the reaction between individual components. In addition, the reduced-temperature operations allow for use of less expensive materials, leading to cost reduction.

This paper presents the development of anode-supported flat-tube SOFCs with high power density. Emphasis is on the advanced cell designs to achieve high power density at reduced-temperatures and the fabrication processes. At first, the processing conditions of porous Ni/YSZ anode support tube (e.g., particle sizes of starting materials, pore-former content and drying/sintering conditions) were tailored and optimized to obtain suitable mechanical strength, porosity, and gas permeability.

In order to increase the power density at reduced-temperatures, an alternative combination of electrolyte and electrode materials was developed that could reduce ohmic and polarization losses: (i) composite cathode layer made of (La,Sr)(Co,Fe)O₃ (LSCF) and gadolinium-doped ceria (GDC), (ii) GDC electrolyte layer on the cathode side, (iii) scandia-stabilized zirconia (ScSZ) electrolyte layer on the anode side, (iv) Ni/ScSZ anode functional layer, (v) Ni/YSZ anode support.

Cost-effective coating processes such as vacuum-slurry coating were developed, which has been very successful in fabricating reliable thin-film layers at lower cost. The process parameters were optimized to obtain the required microstructures and to form adherent interfaces between individual layers. The developed cell exhibits a power density as high as 550 mW cm⁻² at 0.7 V and 650 °C.

Finally, the developed cells were stacked in series electrical connection using a new metal-glass composite interconnects and (La,Sr)MnO₃-coated metal meshes.

B0501

Low Temperature Preparation and Characterization of LSGMC based LT-SOFC Cell by Aerosol Deposition

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Abstract

A low temperature ($\leq 650^\circ\text{C}$) process for fabricating nano structured $(\text{La,Sr})(\text{Ga,Mg,Co})\text{O}_{3.5}$ (LSGMC) electrolyte / $(\text{La,Sr})(\text{Co,Fe})\text{O}_{3.5}$ – $(\text{Gd,Ce})\text{O}_{2.5}$ (LSCF-GDC) cathode films, ~ 7 and $\sim 25 \mu\text{m}$ in thickness, respectively, was developed using an aerosol deposition (AD) process for use in the low temperature solid oxide fuel cell (LT-SOFC). NiO-GDC was used as an anode substrate for fabrication of anode-supported type cell. The deposited LSGMC electrolyte and LSCF-GDC composite cathode film maintained good adhesion with the NiO-GDC anode, even though the whole process was completed at a temperature lower than 650°C . The LSGMC electrolyte was composed of nano-sized grains smaller than 30 nm. Electrical conductivity of the LSGMC electrolyte fabricated at room-temperature was higher than 30 mS/cm at 650°C . The LSCF-GDC composite cathode showed higher than 20% porosity with the grain size smaller than 100 nm. The peak power density of the LSGMC electrolyte-based, anode-supported-type cell with the nano-structured LSCF-GDC cathode produced at room temperature by AD was 0.39 W/cm^2 at 650°C .

B0502

Discussion on the feasibility of SOFC anodes based on CeO_2 - ZrO_2 mixed oxides

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Abstract

The performance of solid oxide fuel cells (SOFCs) with $\text{Cu-Ce}_x\text{Zr}_{(1-x)}\text{O}_2$ -yttria stabilized zirconia (YSZ) anodes have been investigated in relation of the ceria-zirconia composition. For this purpose three ceria-zirconia compositions, with a low ($\text{Ce}_{0.20}\text{Zr}_{0.80}\text{O}_2$, CZ20), medium ($\text{Ce}_{0.50}\text{Zr}_{0.50}\text{O}_2$, CZ50) and high ($\text{Ce}_{0.80}\text{Zr}_{0.20}\text{O}_2$, CZ80) amount of ceria, were synthesized by solution-combustion amorphous citrate route and the electrode composites were prepared by infiltration of the corresponding solutions into porous YSZ anode matrices. By comparing the performance of the cells, higher power density was obtained as the amount of ceria increased. The CZ80 resulted the most suitable catalyst because of its better electrical and redox properties with respect to the other compositions. However, the effect of redox cycles on this material limited its use since as a result of these treatments the material underwent large mechanical stress that caused the destruction of the anode compartment. On the other hand, the cell with a CZ50 anode showed an increased performance of one order of magnitude after a redox cycle. This is probably due to the promotion of its catalytic and electrical properties upon the redox treatment. Based on these results, the Cu-CZ50-YSZ composite seems the best candidate in order to develop anodes stable to the redox cycles that could occur during SOFC operating conditions.

B0503

Nd-Nickelate Solid Oxide Fuel Cell Cathode Sensitivity to Cr and Si Contamination

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Abstract

The stability of Nd-nickelate, considered as an alternative solid oxide fuel cell (SOFC) cathode material, was evaluated in this work on its tolerance towards contaminants.

Symmetrical cells with Nd_{1.95}NiO_{4+δ} (NNO) electrodes on gadolinia-doped ceria electrolyte supports were monitored over time-spans of 1000 h under polarization in an air-flux with deliberate chromium contamination. Impedance spectroscopy pointed out a polarization increase with time by the growth of the low frequency arc describing the electrode's oxygen reduction and incorporation processes.

Post-test observations revealed polluted cathode regions with increasing amounts of Cr accumulations towards the electrolyte/cathode interface. Cr deposits were evidenced to fully cover active nickelate grain surfaces forming Nd-containing Cr oxides.

In addition to exogenous Cr contamination, endogenous contamination was revealed. Silicon, present as impurity material in the raw NNO powder (introduced by milling during powder processing), reacts during sintering steps to form Nd-silicate phases, which decreases the active cathode surface.

Nd-depletion of the nickelate, as a result of secondary phase formation with the contaminants Cr and Si (NdCrO₄ and Nd₄Si₃O₁₂), then triggers the thermally induced decomposition of NNO into stoichiometric Nd₂NiO_{4+δ} and NiO.

Summarized, the alternative Nd-nickelate cathode also suffers from degradation caused by pollutant species, like standard perovskites.

B0504

Preparation of SOFC materials via co-precipitation

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Abstract

A simple and cost-effective synthetic procedure involving the co-precipitation in aqueous medium of carbonates is proposed for the preparation of electrolyte, anode and cathode materials for solid oxide fuel cells. La_{0.8}Sr_{0.2}Ga_{0.8}Mg_{0.2}O_{3-δ} (LSGM) electrolyte, La_{0.75}Sr_{0.25}Cr_{0.5}Mn_{0.5}O_{3-δ} (LSCM) anode and YBaCo₂O_{5+δ} (YBC) cathode have been prepared using this simple procedure. The precipitation yield and the final stoichiometry of the compounds have been studied by means of ICP-MS analysis of the mother liquors and of the sintered materials, and a complete structural and microstructural characterization has been performed. Minor deviations from the nominal stoichiometry were found in LSCM (about 7% for strontium) and YBC (about 8% barium), while larger discrepancy was found in LSGM electrolyte (about 20% of magnesium). The experimental conditions affecting the precipitation yield were investigated via evaluation of the heterogeneous equilibria carried out using the software Medusa and the thermodynamic data database therein.

B0505

Functional Layers Design Between Multiple Doped Electrolyte and Perovskite Electrodes

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Abstract

Multiple elements doped ceria-based electrolyte (LSBC) with high ionic conductivity at intermediate temperature is prepared by citric acid-based combustion technique (SV) process. A mixed ionic electronic conductor (MIEC) with perovskite structure (Sr,La)TiO₃ is utilized as anode. Functional layers or core-shell particles are formed as gradient composition between LSBC electrolyte and MIEC anode. Such a core-shell gradient composition actually compensates the thermal expansion mismatch of electrolyte and electrodes as well as reduces the interface polarization. The AC impedance measurement at 500°C shows the ionic conductivity increasing and the interface polarization decreasing using functional (shell) layer between electrolyte and anode. The perovskite core-shell anode proves a higher reduction resistance and a lower surface resistance than the anode without core-shell treatment. The experimental results exhibit higher power efficiency for functional layers or core-shell gradient composition between electrolyte and electrodes than that without any gradient composition design.

B0506

Correlation of electronic structure and electronic transport in LaSrFeNi-oxide – a potential IT-SOFC cathode material

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Abstract

LaSrFeNi-oxide is a potential cathode material for the IT-SOFC. We provide a complete description of how electron hole doping by substitution on the A-site and B-site cause structural transformations which are accompanied by significant changes in the electronic structure that affect the electronic transport properties. In particular do we analyze the hybridized Me(3d)-O(2p) and hole states in the valence band and their quantitative variation with substitution and temperature, which allows us to formulate a numerical expression which scales surprisingly well with the relative electron hole concentration and the polaron activation energy.

B0507

Composite Cathodes Assisted Low Temperature Micro-SOFCs

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Abstract

One of the important questions in micro solid oxide fuel cells (SOFCs) that are operated at low temperatures concerns the required triple line boundary (TBL) density for obtaining high current densities. We investigated this issue by means of micromachined cells with a cathode electrode having a defined TBL value. The cell design allows for single side electrical characterization on a probe stage. The electrolyte consisted of a 150 nm thick gadolinium doped ceria (CGO) layer (anode side) and a 500 nm thick yttrium stabilized zirconia (YSZ) layer. The first is obtained by reactive RF sputtering from an alloy target, the latter by RF sputtering from a ceramic target. The inner side of the 200 μm diameter membrane is uncovered up to a diameter of 160 μm . Given the CGO can be considered as a mixed conductor when exposed to reducing Ar: H₂ fuel, it is the cathode limited to a circular TBL. This allows for measuring the current density per TBL length since the Pt layers stayed unchanged as dense films at these low temperatures. For the currents at maximal power output, we obtained 0.9 mA/m at 450 °C. Extrapolating these values to a chess board like porous microstructure of a cathode layer covering the whole electrolyte uniformly, each element having a sidelength of 50 nm, and assuming no resistive losses, current densities of roughly 1.0 A/cm² corresponding power densities of 1 W/cm² are calculated for 450 °C. The OCV reaches 0.93 V and stabilizes at an operating temperature of 450 °C. From these studies, the porous Pt/YSZ composite thin films were deposited by co-sputtering in order to further optimize the TBL value. Peak power densities improved 10 times even though Pt dewetted in the composite making phase segregation. Our results provide fundamental insight to pathways of high performance micro-SOFC membranes.

B0701

Advanced Electrolysers for Hydrogen Production with Renewable Energy Sources

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Abstract

The 3-year FCH project ADEL (ADvanced ELectrolyser for Hydrogen Production with Renewable Energy Sources) targets the development of cost-competitive, high energy efficient and sustainable hydrogen production based on renewable energy sources. A particular emphasis is given to the coupling flexibility with various available heat sources, allowing addressing both centralized and de-centralized hydrogen production market. The ADEL 3-year-project target is to develop a new steam electrolyser concept, the Intermediate Temperature Steam Electrolysis (ITSE) aiming at optimizing the electrolyser life time by decreasing its operating temperature while maintaining satisfactory performance level and high energy efficiency at the level of the complete system composed by the heat and power source and the electrolyser unit. The project is built on a two scales parallel approach:

- At the stack level, the adaptation and improvement of current most innovative cells, interconnect/coating and sealing components for ITSE operation conditions aims at increasing the electrolyser lifetime by decreasing its degradation rate
- At the system level, to facilitate an exhaustive and quantified analysis of the integration of this "new generation ITSE" with different heat and power sources like wind, solar, geothermal and nuclear, flow sheets will be produced with adjustable parameters. For selected cases, in depth energy efficiency evaluation will be done based on obtained stack data at intermediate temperature, and on comprehensive description of energy sources.

The paper presents the project approach and the initial efforts of the project started in January 2011.

B0702

Status of the RelHy project on innovative Solid Oxide Electrolyser Stacks for Efficient and Reliable Hydrogen production

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Abstract

Electrolysers based on solid-oxide technology offer hydrogen production with high electrical efficiency and low carbon footprint. High hydrogen production rates have been demonstrated on single cells, but it has also been shown that high current density causes high degradation rates, especially in stacks. The RelHy project (www.RelHy.eu) launched in 2008 aims at reaching an acceptable compromise between performance and durability in electrolyser stack environments. The performance target at 800°C is a current density close to 1.0 A cm⁻² maintaining cell voltages below 1,5 V with a steam utilisation above 60% and a degradation rate ranging close to 1 % per 1000 h.

To achieve these ambitious targets, the RelHy project has adapted the most promising SOFC cell and stack technology for electrolysis operation. Regarding electrolyte-supported cells (ESC), the RelHy performance target has not been attained by single cell testing of reference LSCF/YDC/3YSZ/GDC/Ni-GDC/NiO whereas the degradation rate target was reached. Both performance and degradation targets were finally accomplished by improved ESC integrating 10Sc1CeSZ electrolyte. Improved and stable interconnect contact resistance with air electrodes has been obtained on LSM or LSCF coated Crofer22APU during ex situ testing. Several glass and mica based seal materials have demonstrated good compatibility with hydrogen electrode and interconnect materials on samples aged during 1000h and have provided satisfactory leak rates in ex situ testing.

Testing of single repeating units has highlighted issues such as electrical contacts between the cells and interconnects which are responsible for enhanced degradation. Five-cell reference materials short stacks containing cathode or electrolyte supported cells have shown reproducible behaviour and low degradation rates, at 0.4 and 0.6 A.cm⁻². These results fit the industrial specification road map developed in the project.

B0703

Coupling an SOFC System with a High-Performing Metal Hydride Storage

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Abstract

In many fuel cell applications metal hydride tanks offer an interesting method of storing hydrogen as an alternative to compressed or liquefied hydrogen due to low pressure requirements and high volumetric capacity. Nevertheless, the weight fraction of hydrogen in the total storage system is less than 2 wt.% with today's standard materials. This prevents metal hydride storage tanks from being broadly used, especially in mobile and portable applications.

Helmholtz-Zentrum Geesthacht in Germany has been working on metal hydride materials with a storage capability of up to 11wt.%. Such a high value suggests reconsideration of this technology. However, the high hydrogen absorption capability comes together with a high temperature required to enable hydrogen release (>300°C).

Coupling this type of storage with a high temperature fuel cell, though, offers an opportunity of accessing the high storage capacity through the use of the off-heat of the fuel cell and at the same time exploiting the high conversion efficiency of the SOFC system of around 60% net.

Questions arise, though, on the sizing of the system components and the transient behaviour during start-up.

JÜLICH and Helmholtz-Zentrum Geesthacht have teamed up in analysing basic system properties for an application in rail buses or boats where an APU is required, but weight is of marginal importance.

B0704

Catalytic Hydrogen Combustion on Porous SiC Ceramics

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Abstract

A novel catalytic diffusion burner for hydrogen, based on highly porous silicium carbide (SiC) ceramics and platinum (Pt) as catalyst has been developed for applications like cooking stoves or room heating.

By preventing gaseous hydrogen and oxygen from mixing prior to the catalytic reaction zone, a high passive safety standard is assured. Through the self igniting property of hydrogen and oxygen in contact with platinum no ignition spark is required.

Highly porous SiC foams are used in the combustion zone due to their high temperature stability and thermal shock resistance. Platinum is applied as catalyst on the SiC surface, as it has a high catalytic activity with hydrogen and oxygen even at low temperatures.

To prevent any pre-mixing of fuel and oxidant prior to the catalytic zone and thus assure a very high safety standard, hydrogen is fed from below the porous Pt coated SiC foam and air as the oxidant is supplied to the top. In this manner the oxidation process occurs only inside the Pt coated porous ceramic structure and no open flame is developed. The thermal power can easily be regulated by adjusting the hydrogen and air flow rate and thus temperatures up to 1000 °C can be reached.

The combustion of hydrogen produces no carbon oxides and below 1200 °C no nitrogen oxide is generated, the only exhaust product from the reaction is water vapour. The new developed burner system can thus be used safely indoors without any air ventilation system.

In the applied cooking stove design, the gas under glass technology was introduced by using a conventional glass ceramic cover for a comfortable and convenient appliance.

B0705

SOFC Module for Rapid Start-Ups and Many Applications

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Abstract

The compact SOFC module characterized by its rapid start-up capability has been further improved. An optimized afterburner with catalytic ignition has been added, as well as innovative heat exchangers for fuel-exhaust-to-fuel and air-exhaust-to-air. The current module can be run on hydrogen, as well as on reformat from hydrocarbon fuels or alcohols. The stack temperature can be raised to 700°C in less than five minutes by electric heaters placed in all bipolar plates. The heating power may be drawn from a battery which can be later recharged at times of low power demand. Only about 4 Wh of energy are needed per installed cell. As the nominal cell output is 10 Watts, start-up energy is recovered in about 24 minutes of operation.

The complete and functional modules are packaged in sealed metal containers. The current 200 Watt demonstration module has a diameter of 100 mm (4") and is 100 mm (4") tall. The suspended stack of 20 planar cells of 60 mm x 60 mm size can deliver up to 200 Watts of DC power at around 800°C. However, the design of the module can be expanded to power levels of 1 kW or more.

The module design and experimental data will be presented.

B0706

Development of Anode Supported Tubular Solid Oxide Fuel Cells with Low Cost and High Performance

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Abstract

The cells were composed of multiple layers (8YSZ electrolyte, Ni/8YSZ anode, and LaSrMnO₃ cathode) and electrolyte buffer layers, placed on between electrolyte and cathode layers. The anode was extruded and fired to 1200°C followed by the electrolyte slurry coating and firing at 1450~1500°C. The cathode layer was fired at ~1200°C.

The NiO-YSZ anode support tube were tailored and optimized to get better porosity, mechanical strength, and finally lower cost. For the cost reduction, the less expensive raw materials were used and non-oxide powders were evaluated as a support material. In addition, porosity and mechanical strength were enhanced by a change of YSZ matrix composition. In order to increase the power density, vacuum slurry coating method has been used for a flat and homogeneous electrolyte layer fabrication. The developed large scale tubular cell had a length of 0.5 meter and exhibited a power density as high as 370 mW/cm² at 0.7V and 800°C. In addition, the structure and fabrication process of interconnect-type current collector in anode supported tubular cell has been also carried out not only to investigate the effect of current collector geometry on the cell performance but also to make a compact bundle and stack without loss. The optimal condition of interconnect current collector has been established to minimize the resistance in the collector and current path of cell surface.

Then, we are currently trying improvement of reduction-oxidation robustness of a cell and the long-term durability, and compactness of bundle for realization of SOFC module and system. In this study, we report the current status toward development finally for the large scale SOFC stack technology.

B0707

Composite materials for molten carbonate fuel cell anodes

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Abstract

Subsequent to the Kyoto Protocol Guidelines raises the demand for developing new technologies to produce energy from renewable sources. Biomass is an energy source particularly interesting due to its versatility on the biofuels production. Because of low energy content of biomass, it is requested to couple it with high energy conversion technologies such as fuel cells. Biogas is a potential biofuel for molten carbonate fuel cell for its suitable composition including CH₄ and CO₂. Unfortunately the utilization of biogas as fuel for MCFC presents problems such as sulfur poisoning of nickel-based anode affecting cell performance decreasing power output and durability. Sulfur poisoning can be overcome covering the anode surface with a thin layer of sulfur sorbent material such as porous CeO₂ and Zr_xCe_{1-x}O₂ solid solution. Zirconium improves chemico-physical characteristics of CeO₂ promoting high resistance against sulfur poisoning and high regenerative capacity. In particular CeO₂-ZrO₂ solid solution presents higher sintering resistance than CeO₂ promoting stable porosity with unchanged molten carbonates distribution into cell components. Cerium in CeO₂-ZrO₂ solution has higher reducibility from Ce⁴⁺ to Ce³⁺ corresponding to higher trap capacity of CeO₂ towards H₂S. Finally, ZrO₂ promote high oxygen storing capacity that improves regeneration capacity of the anode

B0708

BZ-BattExt – DMFC as Battery-Extender in solar-boat application

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Abstract

For special applications Direct Methanol Fuel Cells (DMFC) are close to commercial application or already commercialized today. However for the step from laboratory to a broader market of fuel cells, a significant cost reduction, as well as an improvement in life time and power density of the systems is needed. These items were the focus of the project BZ-BattExt, to be reached by new knowledge in alternative materials, operation strategies as also the realization of enhanced sub systems. This project is funded by the German Federal Ministry of Education and Research in the program of Micro fuel cells. In the project the feasibility of a micro-DMFC system is evaluated which enables a minimized system periphery due to an improved system architecture. For this, alternative materials and functional components were developed and investigated. New membranes with reduced water and methanol permeation allow operation at low air stoichiometry and favorable system efficiency. Gas diffusion layers of various compositions were tested and optimized material was selected. New sealing materials with good methanol stability and optimized processibility in commercial production process were developed. MEA preparation was adapted to the new materials. The use of a simple, cost-effective way of stack production was demonstrated for DMFC use. The investigation and construction of enhanced subsystems and operation strategies, which enable and optimize the use of new components and materials, as also the realization of the micro-DMFC system were focus of the project. The technical feasibility of the results was investigated in the application, which means it is tested as battery extender of a solar boat. The DMFC fuel cell system serves as a basis for an efficient, compact and cost effective alternative for battery- or battery-extender systems and can fulfill a broad variety of applications.

B0709

Optimization of MCFC Hybrid Plant Design for CO₂ Recovery

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Abstract

Carbon Capture and Storage (CCS) is an important part of the greenhouse gas (GHG) mitigation portfolio. Post-combustion Carbon Capture (PCC) is one option for CO₂ capture from flue gas of a thermal power plant and it is in the demonstration stage for commercial deployment. Cost is the hottest issue in CCS commercialization because PCC may cause COE increase of up to 70-90% and about 10% of efficiency penalty. As a novel and cost-effective technology, CO₂ capture using Molten Carbonate Fuel Cell (MCFC) was investigated in this study. MCFC power system generates the electricity and high temperature heat while O₂ is transferred from the cathode side to the anode side, as it concentrates the CO₂ in the anode exhaust gas. Flue gas which contains about 12vol% of CO₂ from a coal-fired power plant are used as cathode feeding for an MCFC, and PCC is located at MCFC downstream. Due to electrochemical reaction of MCFC, CO₂ is concentrated to the anode side of up to 50 ~ 70vol% (dry basis) which makes downstream PCC much easier and cheaper. The most important feature of MCFC hybrid plant is that MCFC can generate steam by heat recovery from high temperature MCFC off gas. Therefore, no steam extraction from the steam turbine in an existing power plant is required, which avoid power loss due to steam extraction. This paper presents techno-economic analysis of the MCFC hybrid plant configuration for the effective heat recovery. As a result, the optimal configuration which has less than 3% power efficiency loss was proposed.

B0710

A Quantitative Comparison on SOFC Power Cycles

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Abstract

Eight different concepts for a 1kW-class small SOFC system have been investigated, and a comparison of the concepts is made based on net system efficiency. The reference concept (case 1) consists of a SOFC stack, steam reformer, external burner, air/fuel blower, water pump, catalytic combustor, and recuperator. As reforming options, steam reforming (SR), partial oxidation (POX), and auto-thermal reforming (ATR) have been considered and compared with one another. To improve cycle efficiency, various ideas for the cycle configuration such as integration of the catalytic combustor and reformer, internal reforming, and anode off gas recirculation have been applied to the SOFC system and their effects on net system efficiency have been examined. Among the eight concepts, Case 5, adapting a catalytic combustor integrated reformer, partial internal reforming, and anode off gas recirculation, exhibits the best efficiency, 57.9%, 26.4% higher than that of the reference cycle, Case 1.

B0901

Performance of SOFC stacks under partial internal reforming of methane

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Abstract

Solid oxide fuel cell systems (SOFC) are developed for their electrical efficiency and versatility. Versatility stems from their tolerance towards CO and CH₄, which allows for the use of various reformed fuels. Efficiency results from the direct conversion of the chemical energy of fuels into electricity and the availability of high temperature heat for internal steam reforming.

In this study, short SOFC stacks provided by SOFCpower were tested under methane steam reforming conditions. The stacks were coupled with a steam generator and a Ni-based steam reformer. The effect of the stack operating temperature, the steam-to-carbon (S/C) ratio and the methane flow density on the electrical performance of the stack are investigated. The temperature of the reformer was varied between 430 and 700°C in order to tune the degree of methane pre-reforming, and so study the effect of internal reforming on the stack performance.

With increasing stack temperature from 750 to 800°C, there is almost no improvement in performance since the reduction in area specific resistance (ASR) is compensated by that of the Nernst potential. Variation of the CH₄ flow from 1.25 to 0.5 Nml·min⁻¹·cm⁻² at 750°C, allows to increase the LHV electrical efficiency at 89% fuel utilisation (FU) from 60 to 68% but with a corresponding loss in stack power density, from 0.46 to 0.21 W·cm⁻².

Changing the degree of methane pre-reforming from 95% to 20% by varying the reformer temperature did virtually not change the performance of the stack, indicating that reforming continues after the steam reformer itself, at the stack inlet, over the catalytically active anode supported cells. The observed effect is then mainly thermal since the stack inlet is cooled by the reforming reaction.

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B0902

Control of a Solid Oxide Fuel Cell System with Biased Gas Temperature Measurements

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Abstract

An efficient control system is paramount for the operability of fuel cell systems since, in ideal cases, it allows the regulation of power output, temperatures and economic performance under a dynamic working environment where they need to operate. Although several control strategies, scenarios and methodologies have been broadly investigated, it is usually taken for granted that the measurements from the system, necessary for the control feedback, are correct. Nonetheless, when simple thermocouples are used to measure gas temperatures there is a significant danger of systematic errors due to radiation effects between the surroundings and the thermocouple. The discrepancy between a real gas temperature and the one measured depends mainly on the temperature difference between the gas and the solids around as well as the gas velocity, radiation factors etc. The phenomenon has been described in our past publications. In this work we simulate an SOFC system and apply control scenarios in order to investigate potential problems arising from such systematic errors. The results show that important dysfunctions may occur and caution should be applied in design of both control and the systems themselves.

B0903

Single Layer or Electrolyte-free Fuel Cell

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Abstract

Our recent developments have been made on the single layer or electrolyte-free fuel cells using a homogeneous mixed semi- and ion conducting layer which can function as the electrodes, anode and cathode, and electrolyte simultaneously. We have achieved near 800 mW/cm² at 550°C. A number of material groups have also been developed for advanced SLFCs. This radical new invention has made this nice concept of SLFC into practical application and also opens a new fuel cell R&D strategy.

B0904

Estimating of the SOFC electrolyte/electrode contact area by impedance spectroscopy

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Abstract

Suspensions of lanthanum strontium **cobalt** iron oxide ($\text{La}_{0.6}\text{Sr}_{0.4}\text{Co}_{0.2}\text{Fe}_{0.8}\text{O}_{3-\delta}$) with different powder concentrations (50 % and 60 % by weight) have been deposited symmetrically on identical **yttria** stabilized zirconia (YSZ) pellets. The impedance characteristics of these cells were compared to that of a symmetrical cell with platinum electrodes deposited on a similar YSZ pellet. Assuming that the electrolyte resistance of the Pt/YSZ/Pt cell corresponds to almost perfect electrode/electrolyte contact, it is possible to estimate the average coverage of the LSCF porous electrodes. When the Average Electrode Coverage (AEC) parameter is applied on Nyquist impedance data, it is possible to compare electrode polarizations of different electrode compositions and materials with same coverage factor.

B0905

Parametric comparative analysis of lifetime energy demand and CO₂-eq savings of a SOFC m-CHP unit

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Abstract

The present paper utilizes the results of an environmental impact assessment through Life Cycle Analysis (LCA) for a Solid Oxide Fuel Cell (SOFC) microCHP unit for the determination of a critical operational threshold, over which the m-CHP unit lifetime primary energy demand and CO₂-eq emissions are lower than two reference cases: (a) a conventional system (gas boiler and grid electricity) and (b) a competitive m-CHP unit, powered by a gas fuelled Internal Combustion Engine.

Towards this objective, several runs of the built LCA model were performed under variable operational conditions (m-CHP electric efficiency and annual thermal load coverage). The results acquired were inter- and extra-polated within an operational range of the selected parameters. The contour graphs produced provide vital and comprehensive information regarding how to ensure and realise the environmental advantages of the SOFC technology in m-CHP applications.

Despite the weak environmental aspect of the SOFC unit identified (being – at present – powered exclusively by a fossil fuel – natural gas), the feasibility to outperform both competitive cases is herewith demonstrated. The overall environmental advantage of the SOFC unit modeled is realized through avoiding central generation emissions when the m-CHP electricity surplus is exported to the grid and achieving higher electric efficiency potential than m-CHP competition. The comparative Life Cycle Analysis performed identified a clear potential towards decreasing the Cumulative Energy Demand and the Global Warming Potential of covering domestic power loads.

B0906

Role of Sn Catalyst Mixture for Electrochemical Oxidation of Solid Carbon in Direct Carbon Fuel Cell

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Abstract

Direct carbon fuel cell (DCFC) utilizing various carbon sources such as coal, coke, and even biomass is a new relevant type of high-temperature fuel cell. DCFCs show relatively high conversion efficiency and only possible emission of high-purity CO₂. Several concepts of DCFC have been demonstrated by applying solid oxide, molten carbonate, and molten hydroxide fuel cells. In particular, the use of solid oxide materials as an electrolyte has been proposed in the DCFC system that has advantage of relatively higher reaction activity and more fuel flexibility due to its higher operating temperature (600–1000°C).

Herein, we apply Sn powder as anode material onto Ni-YSZ films in order to enhance the performance of DCFC. As the cell temperature rises, the cell performance becomes more active due to the better interface between solid carbon fuels and catalyst layers. In other words, carbon particles with liquid Sn can freely diffuse to the Ni-YSZ anode and provide better contact with the effective electrochemical reaction interface at which the Ni catalyst and YSZ oxygen ion conductor coexist with the carbon fuel. Moreover, a Sn liquid catalyst-carbon fuels modified by an additional Ni catalyst shows further improvements in cell performance up to 105 mW cm⁻² and it might due to better electron pathway.

B0907

Synthesis and Characterization of LaSr₂Fe_{3-y}CrO_{9-δ} Cathode for IT-SOFC

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Abstract

LaSr₂Fe_{3-y}Cr_yO_{9-δ} (LSFCr) powders were synthesized by glycine-combustion method. A perovskite single-phase as well as sub-micro-sized particles can be ascertained for the prepared powder. After forming, the discs and rectangular bars were sintered in the temperature range of 1200°C-1400°C. It was found that there is a monotonous decrease of the electrical conductivity with increasing y. In addition, the specimen with y=0.0 showed the maximum conductivity of 369.0 S·cm⁻¹ at 550°C, which is adequate to satisfy the requirement of electrical conductivity for the SOFC cathode. The average thermal expansion coefficient of these ceramics decreased from 14.6 to 13.3 × 10⁻⁶ K⁻¹ with increasing y between 40 and 650°C. Three-electrode half cell was adopted to characterize the electrochemical properties from 600 to 800°C. The active working electrode area was 0.39cm² and Pt paste was used as the counter and reference electrode. The smallest polarization resistance, 0.09 Ω·cm², was obtained with y=0.0 at 800°C. SDC film was prepared on the NiO-SDC disc calcined at 1200°C by slurry spin coating and co-fired at 1400°C for 4 h. The single cell of NiO-SDC/YSZ/SDC/LSFCr was fabricated by coating the LSFCr slurry on sintered NiO-SDC/YSZ/SDC and heated at 1100°C for 2 h. The largest power density, 344.2 mW·cm⁻², was obtained with y=0.0 at 700°C.

B0908

Development and Characterization of Biomass-derived Fuels Powered SOFC

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Abstract

Solid oxide fuel cell (SOFC) is the more efficient electrical power generator known and it is typically composed an oxygen ion electrolyte and ceramic electrodes constituting a combined electrodes-electrolyte ceramic device, also known as electrolyte-electrode assembly (EEA), which is the heart of an SOFC, where charge and mass transfer processes occur that give rise to electrothermal behavior of the device. Theoretically hydrogen, hydrocarbon fuels and ethanol can be used as a fuel, either directly or indirectly through the thermochemical reforming and water-gas shift reaction, thus providing the flexibility on fuel. However, nowadays, are the aspects related to performance and degradation of materials that are used in the EEA that limit the use of fuels more complex than hydrogen in SOFC systems. In Brazil there is great availability of biomass and it is environmentally interesting to use it efficiently. In this work solid oxide fuel cells, based on different solid electrolyte-electrode assemblies, have been constructed and tested on direct and indirect feeds of hydrogen, methane, biogas and ethanol mixtures, these last three biomass-derived fuels. Moreover, these charge and mass transfer processes are determined by the micro and nanostructural features of the EEA and its interfaces. In this sense, this work aims to characterize and evaluate the structural characteristic of combined electrodes-electrolyte ceramic with main focus on the analysis performed by microscopy techniques, X-ray diffraction and fluorescence analysis. The structural and compositional analysis results were compared with the electrical characterization performed by polarization curves and impedance spectroscopy, as well as gas chromatography and gas permeation results. The results show on one hand the importance of uniformity of porous electrodes and its relation to the deactivation and degradation of the device for different fuels used, and on the other hand, the high densification level and physical-chemical homogeneity of the electrolyte to the macroscopic electric performance of the device. The influence of bulk anode, anode-electrolyte interface and surface physical-chemical characteristics were analyzed and discussed based on experimental results and theoretical considerations. The SOFC performance and the kinetic degradation behaviors of EEAs for different fuel mixtures were determined.

B0909

Oxide Scale Formation in Different Metallic Interconnects for Solid Oxide Fuel Cells (SOFCs)

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Abstract

Metallic interconnects are promising candidates for SOFC interconnect application operating at intermediate temperature. However, the migration of the gaseous chromium species from these materials to the cathode, blocks the electrochemical active sites and degrades the cell performance.

The study of oxide layer formation was carried out with different starting commercial metallic interconnect materials, two ferritic stainless steels, Crofer 22 APU and SS430. The samples were treated at 800°C for 100 h and 1000 h in air under atmospheric pressure.

The crystal structures of the oxide scale formed compounds after 100 h and 1000 h was determined by X-ray diffraction (XRD) and the microstructural changes were evaluated by field emission scanning electron microscopy (FEG) equipped with an energy dispersive X-ray analyzer (EDX).

A spinel (Mn,Cr)₃O₄ outer layer and a Cr₂O₃ inner layer was formed for both ferritic stainless steels which reduce chromium volatility.

B0910

Electrochemical and Structural Properties of Li/K Carbonate Electrolyte in Matrix for MCFCs

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Abstract

In a molten carbonate fuel cell (MCFC), the electrolyte behaviour in matrix is one of the major factors affecting cell performance. Especially for predicting cell performance during operation, the consideration of the electrolyte property changes in various conditions is essential part.

In this work, to obtain the electrolyte properties related to the long-term operation of MCFCs, the investigation of electrochemical and structural properties of Li/K carbonate electrolyte in matrix was carried out. The electrochemical property of electrolyte in matrix, specifically the ionic conductivity, was determined by the analysis of the electrochemical impedance spectroscopy (EIS) with varying temperatures (520~700°C) and compositions (Li/K molar ratio, from 60:40 to 70:30). Concerning the structural property of electrolyte in matrix, the porosity was measured by the Archimedes method (ASTM, C373), and the pore size distribution and the tortuosity factor were obtained by the mercury porosimeter.

Obtained data show that the electrolyte ionic conductivity increases with temperature and there exists a specific temperature range, where the conductivity increases rapidly. From conductivity change and measured structural results, our target temperature and composition can be determined in the viewpoint of the electrolyte.

B0911

A Direct Carbon Fuel Cell Operating with De-Ashed Coal

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Abstract

A direct carbon fuel cell (DCFC) fuelled with de-ashed coal is proposed to produce electricity directly from chemical conversion of a solid carbon at high temperature. A tubular single cell is made of an yttria-stabilized zirconia (YSZ) electrolyte with a cermet anode of NiO/YSZ and a composite cathode consisting of strontium-doped lanthanum manganite (LSM) and YSZ. In order to use the de-ashed coal as fuel, ash (mineral matters) in coal is removed by using the solvent extract technology and it has an ash content of approx. 1 wt.%. This study proposes a feasibility of de-ashed coal for the fuel cell and measures its performance when temperature is varied from 600°C to 900°C. It is indicated that the development of new fuels and the optimization of tubular structures are desirable for the long-term stability of DCFC.

B1001

GDC Buffer Layer Coating by Aerosol Deposition

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Abstract

In this study, a thin (less than 1 micrometer) interlayer of ceria was applied by the aerosol deposition (AD) process at the interface between YSZ electrolyte and LSCF-GDC composite cathode. The interlayer was co-sintered with the screen printed cathode layer without any additional heat treatment step. For comparison, three kinds of powders were used as coating materials, pure ceria, mixture of ceria and 20 mol-% gadolinia (GAC) and 20 mol-% gadolinia doped ceria (GDC).

The results show that the ceria layers are dense enough to successfully prevent the formation of SrZrO₃ phase after cathode heat treatments. Performance of the cells with the ceria layers were evaluated with small button type cells. Maximum power densities increased from 0.68 to 1.42 and 1.79 W/cm² at 750°C according to the coating materials changed from pure ceria to GAC and GDC.

B1002

Synthesis, Electrical and Electrochemical Properties of Sr_{0.6}Ba_{0.4}Co_{0.3}Mn_{0.7}O_{3-δ} Cathode for Low-Temperature Solid Oxide Fuel Cells

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Abstract

A new perovskite structure cathode material with composition of Sr_{0.6}Ba_{0.4}Co_{0.3}Mn_{0.7}O_{3-δ}-SDC has been successfully synthesized by wet chemical method followed by sintering at 700°C for 4 hours and characterized by XRD and SEM. The particle size was determined between 20-30nm with the Scherer's formula and compared with SEM. Thermal properties were also investigated by TGA/DSC. Electrical conductivity measurement was carried out by the 4-probe DC method and was found 6 S/cm at air atmosphere. Electrochemical Impedance Spectroscopy (EIS) was also carried out at various temperatures using SDC ceria doped electrolyte to investigate the oxygen reduction mechanism. The activation energy was calculated 0.032eV via an Arrhenius plot. I-V and I-P curves were acquired in the temperature range of 400-550°C. The maximum power density reaches to 726mW/cm² at temperature 550°C.

B1003

Testing of mechanical performance of reactive-air-brazed (RAB) metal / ceramic joints for SOFC applications

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Abstract

Often the reliable mechanical integration of ceramic components into metallic frames is a basic requirement for safe operation of high temperature applications, for example SOFC stacks. As a solution for joining metallic and ceramic materials, reactive air brazing (RAB) has gained increasing interest. This paper gives a summary of the mechanical testing carried out at FZ Jülich, IEK-2, in order to supply material data for further improvement of component and stack design by finite element modelling as well as to provide suitable deformation and damage models for the adaption of stack operating strategies.

The mechanical properties are assessed using different testing methods. To test the adhesion behaviour of reactive air-brazed joints notched beam bending sandwich-specimens are used. Bending tests of specimens joined at the front face and uniaxial tensile tests of specially-designed composite specimens are carried out to investigate the tensile strength of different joining systems. Furthermore the creep performance of various braze/joining partner systems is evaluated by testing in compression- and shear-load configuration. Finally a summary of the results and an outlook is given.

B1004

Synthesis and Electrical Properties of Strontium Titanate-Based Materials for Solid Oxide Fuel Cells

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Abstract

A strontium titanate (SrTiO₃)-based material with a perovskite structure is considered to be one of the promising alternatives to LaCrO₃-based interconnect materials, since SrTiO₃ perovskite shows high chemical stability under both oxidizing and reducing atmospheres at high temperatures. In this work, La-doped SrTiO₃ materials with 'stoichiometric' and 'Sr-deficient' compositions were synthesized by the modified Pechini method. The synthesis parameters such as the chelating agent-to-metal ratio and the post-heat-treatment temperatures were controlled to prepare nano-sized, single-phase particles. Electrical, thermal and mechanical properties were determined on the 'stoichiometric' and 'Sr-deficient' materials sintered in an oxidizing atmosphere. Furthermore, a thin layer interconnect was coated on the porous Ni-YSZ anode support by using a screen printing process. The process parameters were optimized to obtain a dense interconnect and to form adherent interfaces between the interconnect and the anode support. The experimental results indicate that Sr-deficient, La-doped SrTiO₃ is a promising candidate for interconnect applications in high temperature SOFCs because it shows high electrical conductivity and sinterability as well as thermal expansion match with the other cell components.

B1005

Testing metallic Interconnects for SOFC with working “real life” parameters at 600°C

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Abstract

Ferritic Stainless steels (FSS) are since years the most investigated materials for interconnects in high and intermediate temperature fuel cells such as SOFC. Several commercial and innovative alloys belonging to this wide family have been tested in the past allowing to make a narrow selection of formulations where Cr is the main and most important alloying element. Nevertheless more studies are needed in order to investigate their behavior in real working conditions and how they affect the durability and therefore the risk of failure of a SOFC based stack. In this paper FSS commonly used as interconnects (Crofer 22 APU, AISI 441 and AISI 430) are discussed after simulation of their “real life”: 600°C, dual atmosphere, constant current flow (0.5 A/cm²). This has been possible by using a prototype of a new rig called Real Life Tester developed during the European FP7 project IdealCell. The results have been compared with classical setup for ASR measurements showing up the importance to realize tests as much as possible close to working conditions.

B1006

Electrochemical recycling of cobalt from cathodes of spent lithium-ion batteries for application in interconnects of solid oxide fuel cells

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Abstract

In this work, cobalt electrodeposition on 430 stainless steel was carried out. The cobalt solution was obtained from the dissolution of spent cathodes of Li-ion batteries. The cobalt electrodeposition was performed with 96% efficiency in potential equal to 1.50 V. The electrodeposited cobalt showed the face-centred cubic (23%) and hexagonal-centred phase (77%) phase. After oxidation at 850 °C for 1000 hours, the steel sample with cobalt layer presented Co₃O₄ phase. On the other hand, the sample without cobalt showed mainly Cr₂O₃ and FeCr₂O₄ phases. The cobalt electrodeposition improves the electrical and morphological characteristics of 430 stainless steel. After 1000 hours the area-specific resistance for steel sample without cobalt was 1.30 Ω·cm² and for sample with cobalt film this value was 0.038 Ω·cm².

B1007

Obtaining and characterization of 3YSZ+8YSZ mixtures for SOFC electrolyte

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Abstract

The sintering behaviour and electrical properties of 3YSZ (3mol% Ytria Stabilized Zirconia, TZ-3Y, Tosoh Corporation) and 8YSZ (8mol% Ytria Stabilized Zirconia, TZ-8Y, Tosoh Corporation) commercial mixtures have been studied. The commercial compositions investigated were 3YSZ, 8YSZ and 3YSZ:8YSZ mixtures of 25:75 and 75:25, respectively. A separate 8YSZ nanopowder, obtained in house via a modified sol-gel method using sucrose and pectin, was investigated and compared with the commercial compositions. All the final powders were characterized by TEM and XRD to determine the mean particles size, the mean crystallites size, the morphology and the crystal structure. Pellets were obtained from the final nanopowders by uniaxially pressing at 600 Bars followed by a cold isostatic press (CIP) at 12 bars. The pellets were sintered at 1450°C for 4h using a heating rate of 200°C/h. The densities of the sintered pellets were determined by the Archimedic method at room temperature, with ethanol as an intrusion medium and using the theoretical density calculated based on the XRD measurements. The electrical properties were studied by EIS as a function of temperature up to 1000°C using the sintered pellets. The surface microstructures of the sintered pellets were investigated after the EIS measurements by SEM. Results of the EIS measurements showed that the 8YSZ nanopowder obtained in house possess the highest conductivity followed by the commercial 8YSZ powder and 3YSZ:8YSZ = 25:75 mixture which presents similar conductivities at 1000°C.

B1008

Thin-film solid oxide fuel cells using proton conductor

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Abstract

Recently, many researches of fuel cells have focused on intermediate-temperature fuel cells such as high-temperature polymer electrolyte fuel cells (HT-PEFCs) and low-temperature solid oxide fuel cells (LT-SOFCs). One of these fuel cells, LT-SOFC, has strong advantages in terms of start-up time, material durability, and efficiency. Our group has investigated thin-film SOFC using Y-doped barium zirconate (BYZ) and yttrium-stabilized zirconate (YSZ). Among these two electrolytes, BYZ is a proton conductor with 10^{-2} S/cm conductivity at around 300°C. It is utilized as the electrolyte for fabricating thin-film SOFCs. This work includes very complicated processes in order to minimize pin-holes and electrical shorts on layer by layer (electrode, electrolyte and electrode).

B1009

Ceramic and glass composite interconnects for Solid Oxide Fuel Cells

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Abstract

Lanthanum chromite (LaCrO_3) is concerned as the most candidate interconnect materials since it has a stability in view of phase, microstructure in both oxidizing and reducing atmosphere as well as a similar T.E.C compared to other cell components. Lanthanum chromite which is a p-type conductor represents higher electrical conductivity when it is in oxidizing atmosphere than reducing atmosphere.

However, it exhibits insufficient electrical conductivity to use pure lanthanum chromite for interconnects. To improve electrical conductivity of lanthanum chromite, alkaline earth elements are doped at lanthanum or chromium or both sites. While doped lanthanum chromite has higher electrical conductivity than pure one, it shows low sintering behavior. In order to improve density of interconnect, several methods such as sintering in reducing atmosphere, using small particle size powder and addition of sintering aids have been reported.

The purpose of this study is to improve density of interconnects and electrical conductivity by using LCC ($\text{La}_{0.8}\text{Ca}_{0.2}\text{CrO}_3$) and glass composite. The liquefaction of glass in LCC/glass composite is generated during sintering and it penetrates among LCC particles, facilitating the wetting of each particle surface. The glass acts as liquid phase sintering aids and promotes densification of LCC in oxidizing atmosphere. In this work, LCC and glass powder were mixed with different composition and phase stability, electrical conductivities of LCC and glass composite were evaluated to determine optimum composition of LCC/glass composite.

B1011

New Laser-Based Glass Sealant Applications For Fuel Cell Stack Manufacturing

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Abstract

Efficient energy conversion is a popular research topic in the field of energy research. Fuel cells with high electrical efficiency, e.g. SOFC and MCFC, are in the focus of the development work. The success of these fuel cells with operating temperatures of 600 to 1000 °C is controlled by the availability and long-term stability of insulation and joining material. The material should join hermetically the single-cell layers to each other and electrically insulate at the same time. Central Technology Division (ZAT) of the Forschungszentrum Jülich GmbH develops technology and manufacturing process concepts for the production of stationary and mobile fuel cell stacks based on the materials developed of the scientific institutes. Self-developed glass solders are used as joining and insulation medium. The use of soldering materials has been limited to the furnace technology with rather small heating and cooling rates. The potential of the laser as a flexible tool for the manufacturing and repairing of fuel cell stacks were investigated as part of this study. The high power density of laser radiation-induced heating rates influence the properties of the glass solders and their interaction especially with metallic materials. First results on applications of different laser sources as joining tools in production of fuel cell stacks are shown and their application-orientated properties are explained. A new-developed manufacturing process for the joining of glass solder material using laser beam is introduced and the first application results indicate the potential of this development.

B1201

Spatially resolved analysis of water transport mechanisms

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Abstract

Unlike batteries, fuel cells enable the separation of the energy converter from the energy storage system. However, this advantage typically requires a flow field for reactant delivery. The inhomogeneities in gas concentration, humidity and temperature can lead to gradients in current and potential, especially at low stoichiometries. Moreover, the water management of low-temperature PEM fuel cells is sensitive to the effects of in-plane gradients (e.g., local dehydration of the ionomer or flooding of the porous media). Hence, these gradients must be minimized to improve durability and performance.

Spatially resolved performance data can be obtained from polarization measurements on a segmented fuel cell, but the knowledge gained from DC measurements is limited (e.g., in relation to the state-of-health of the measured fuel cell segment). In this work a novel Multi-Channel-Characterization-System (MCCS) is presented that extends fuel cell characterization tools beyond the traditional techniques.

The MCCS enables dynamic water management characterization by combining synchronized but independent potentiostats with a dedicated frequency response analyzer at each channel. In the present configuration, fifty segments can be loaded individually to different currents or potentials.

We report on spatially resolved measurements of water diffusion in the membrane, protonic conductivity, and transient flooding phenomena. The experimental results include the time-evolution of the high frequency resistance, transients in current generation and impedance spectra. These results are discussed and correlated to the relevant water transport mechanisms.

B1202

An in operando and time resolved x-ray absorption spectroscopy study of the ethanol oxidation reaction

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Abstract

X-ray absorption spectroscopy is one of only a few methods which render themselves suitable for in-situ investigations of technical catalysts. It is usually applied to investigate the nanoparticle structure of the catalyst. However it can also be used to obtain information about adsorbate coverage and binding sites using the $\Delta\mu$ XANES analysis [1,2] method. With this method it was possible to follow OH, n-fold O and C_n-species coverages of a fuel cell anode with time during the ethanol oxidation reaction (EOR), similar to previous studies in continuous operation [3].

In this study, coverage and current data were obtained during several potential steps. The interpretation of the data was done by modelling the essential reaction steps using a modified Butler-Volmer approach. The experimental data are closely reproduced by the simulation, as shown in Fig. 1. We were able to distinguish 3 different potential regions and the simulation shows that every potential region is characterized by another limiting mechanism of the EOR. The observed changes occur parallel to a change in OH or n-fold O coverage.

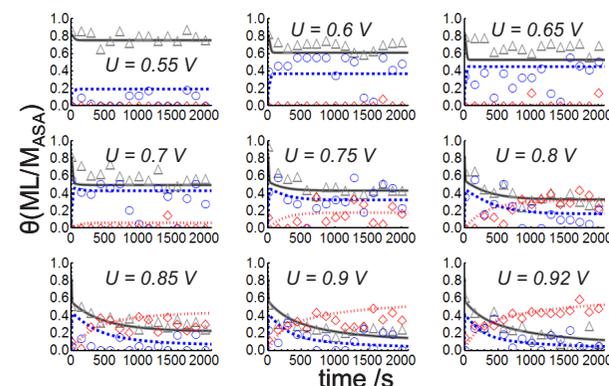


Figure 1. Time-resolved OH (atop) (○), O (n-fold) (◇) and C-species (Δ) coverage during EOR at several potential steps from 0.45 V measured vs. DHE.

- [1] Teliska, M., O'Grady W. E., Ramaker D. E., *J. Phys. Chem. B*, **108**, 2333 (2004).
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[3] Melke, J., Schoekel, A., Dixon, D., Cremers, C., Ramaker, D. E., and Roth, C., *J. Phys. Chem. C*, **114**, 5914 (2010).

B1203

On-line Gas Measurements within PEM Fuel Cell Flow Fields by Electric Arc Emission Spectroscopy and Raman Spectroscopy

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Abstract

Mechanical degradations of membranes as cracks or pinholes result mainly from local wetting and de-wetting cycles as well as from changes of local temperatures.

This contribution shows how early stages of such defects can be monitored on-line by optical spectroscopy. For this a new electric arc emission spectrometer was developed and used under various operational conditions of the cell. The arc emission spectrometer enables the detection of gases over a large scale of concentrations starting from measuring pure gases to concentrations in the ppm range.

Moreover, locally and temporally occurring gas distributions within flow field channels were investigated by two Raman spectroscopic approaches. A Raman microscopic setup recorded the passage of N₂ and O₂ from the cathode to the anode through a pinhole as well as water. Water was generated by a catalytic oxidation of H₂ at the rim of the pinhole. The pinhole was artificially prepared by aligning the laser focus onto the MEA surface. An accompanying strong local increase of temperature next to the hole was measured by changes in the intensity distribution of rotational H₂-Raman bands.

A multiple-fiber Raman spectrometer permitted the simultaneous record of gas flows, liquid water and water vapor at seven ports along the meander and showed how those species do change locally and which mutual interdependencies among them occur during operations. Furthermore, the proceeding poisoning of the MEA unit by CO (10 ppm CO was added to hydrogen) along the anode flow field was investigated by Raman spectroscopy.

The Raman spectroscopic measurements were part of a close cooperation with the German Aerospace Center in Stuttgart.

B1204

Microbial fuel cells: Electron transfer from the outer cell membrane to the anode

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Abstract

Microbial fuel cells (MFC) produce bio-hydrogen or renewable electricity from biomass. The process is based on hydrogen available as metabolic intermediate on cofactors and other biomolecules in all kinds of living cells. The outward electron/proton flux through microbial outer cell membranes is the basis for applications in power production, sustainable chemistry, bioanalytics, and robotics.

Efficient electron and proton harvest is an indispensable prerequisite for microbial fuel cell use. Microbes, such as *Rhodospirillum rubrum*, transfer electrons through the outer cell membrane due to their natural anaerobic respiration with extracellular iron contained in sediments. Their cultivation is feasible, but of limited use in established industrial microbial processes as typically employed microbes would need to be replaced. In consequence, the examination of electron transfer through any kind of outer cell membrane is of practical interest. Besides the direct transfer, the extracellular electron/proton transport in cultivation media also deserves attention in the quest for efficient microbial fuel cells.

In order to investigate the electron donor properties of various types of microbes, a bi-cathodic microbial fuel cell-type activity sensor was constructed to measure the electron transfer through cell envelopes. This device was initially tested with *Saccharomyces cerevisiae*. With the same setup *Escherichia coli* also donated electrons through the outer cell membrane when in physical contact with the anode. In contrast, the electron transfer through the cultivation media was found in both cases to be a background event. The electron transmission characteristics persisted when the artificial mediator Methylene Blue was used. In conclusion, the microbes deliver electrons when in physical contact with anodes. These results are of interest for envisaged multi-task applications such as waste water treatment where bio-hydrogen or renewable electric power is produced.

B1205

Electrochemical Impedance Spectroscopy – a Tool for Solid Oxide Fuel Cells Studies

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Abstract

This work presents some methods for enhanced performance of Electrochemical Impedance Spectroscopy (EIS) in SOFCs studies, which brings to improved data quality and enriched information capability. The implementation of measurements in two modes – potentiostatic and galvanostatic at different amplitudes depending on the sample's resistance guarantees high quality of the measured data in a larger frequency range. The elimination of the errors produced by the parasitic components of the testing rig increases the accuracy of the electrolyte resistivity estimation. The application of the Differential Impedance Analysis technique ensures model evaluation directly from the experimental data, i.e. without the use of a preliminary working hypothesis

The efficiency of the applied tools is demonstrated on EIS studies of an innovative dual membrane design of a high temperature fuel cell based on the idea for a junction between a proton conducting anode/electrolyte part and oxide ion conducting cathode/electrolyte part through a mixed H⁺ and O²⁻ conducting porous ceramic membrane. In this concept, hydrogen, oxygen and water are located in three independent chambers, which avoid the gases dilution with water. The examples summarize results obtained on different materials applied in high temperature fuel cells.

B1206

Multiscale and element specific microstructure characterization of SOFC assemblies with resonant ultra small angle x-ray scattering

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Abstract

The micro-, meso-, and nanostructure and architecture of electrochemical energy conversion devices are highly complex and heterogeneous. For example, presence of porosity in electrodes and its absence in solid electrolytes are critical for their functionality. Typically, engineers employ imaging techniques order to study structural details.

I show here small angle scattering with x-rays (SAXS) as an alternative. SAXS has been known to materials scientists for a long time and is able to quantify the topological structure parameters of ordered and disordered media such as particle size, pore size distributions, porosity, internal surface area, fractal dimensions. By default, SAXS is a 3D method and non-destructive.

The Fourier nature of the x-rays scattered in the reciprocal space warrants that these parameters are collected with statistical significance and high confidence – without need for complicated stereological considerations and laborious computational formalisms. Recent advancements in synchrotron instrumentation allow measuring pore space and its conjugated objects with sizes ranging from 1 nm to several microns (Ultra-SAXS) and to map the structure parameters of complicated cell assemblies in steps of 10 micrometers. Tuneable x-ray energies allow for contrast variation and thus for separation of scattering signals by chemical constituents in the material (Anomalous SAXS). Anomalous ultrasmall-angle X-ray scattering was employed to quantify the component phase and interfacial surface areas as a function of position within electrodes and electrolyte of a SOFC assembly. Primary structure parameters were determined over a contiguous scale from nm to microns in one single measurement with 20 micron spatial resolution normal to the electrode. Measurements at the Ni and Zr 2p absorption threshold have enabled different electrochemically-active solid components and their associated void morphologies to be distinguished from each other close to the electrode/electrolyte interfaces. We distinguish Ni rich or Zr rich component microstructures from adjacent phases, and determine the interfacial surface areas both between specific solid phases and between each phase and the void network. Such information provides improved insights in relating the morphology of the SOFC triple phase boundary to the extent to which these components interface with each other throughout the adjacent microstructure.

B1207

Investigation of the Transport Properties on the Strained Ceramic Proton Conductors under Pressure

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Abstract

Proton conductors are promising solid electrolyte materials for ceramic fuel cells operating at intermediate temperature. Our study focuses on the molecular mechanisms of proton conductivity of perovskite yttrium-doped barium zirconates and cerates. In-situ electrochemical impedance spectroscopy was used to study the effect of lattice volume and strain on the proton conductivity by applying the hydrostatic pressure up to 2 GPa. At high temperature, the activation energy of the bulk conductivity increases upon pressure up to 40%, confirming a previously suggested correlation between the lattice volume and proton diffusivity in the crystal lattice. Compressing the lattice decreases proton conductivity, indicating that the protons need "space" to move freely in the lattice. We are probing the proton diffusion in the atomic scale by quasielastic neutron scattering under high pressure. One strategy worth trying in the future development of the ceramic proton conductors could be to expand the lattice and potentially lower the activation energy under tensile strain.

B1209

Local measurement of electrical potential in a PEMFC stack using wire instrumentation technique

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Abstract

The development of proton exchange membrane fuel cells (PEMFC) is facing two major challenges: reducing the components' costs as well as increasing the cell durability. Both constrictions may be overcome by optimising the component's physical properties (porosity, mechanical rigidity, thermal and electrical conductivity, etc...) that leads to the optimal functioning conditions. The efficiency of such choices is strongly dependent on the understanding of the coupled phenomena taking place in the core of a PEMFC.

In addition to comprehensive modelling increasingly flourishing thanks to the calculus capabilities available nowadays, in-situ experimental diagnosis gives highly valuable information on the local behaviour of the PEMFC core. In this study, the wire instrumentation technique, first introduced by Freunberger et al [1], is adapted for the first time to the stack size. The experimental device consists of 25µm diameter microwires introduced in a five-cell stack. Those wires were used as electrical potential sensors and put in different areas of the cell corresponding to the gas inlet, to the middle of the cell and to the gas outlet. In the middle of the cell, the active parts of the wires were positioned so as to probe either rib or channel.

The study revealed different potentials in the three cell regions. Higher electrical potential was found at the gas inlet while the lowest potential values were picked out at the gas outlet. The wires located at the middle of the cell gave intermediate values pointing out however, specific potential for the rib and the channel area. Besides, the results show a relatively important potential drop at the gas outlet comparing to the other areas.

This study gives for the first time quantitative data to what was assumed theoretically concerning the functioning heterogeneity of a PEMFC cell stack. Indeed, many mathematical models predict decreasing local performances from the inlet to the gas outlet of a PEMFC cell [2]. This can be explained by fuel depletion as well as water flooding that inhibit gas access to electrochemical active sites. The flooding occurrence was pointed out by many studies using numerous scanning techniques [3]. Finally, our contribution will include as well degradation data of the in-situ performances in the different areas of the cell and a comparison with the ex-situ work of Pei et al. [4].

B1210

Analysis of the ethanol oxidation in alkaline media

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Abstract

Due to its high energy density and low toxicity, ethanol can be a very suitable fuel for portable power supply solutions using direct ethanol fuel cells. However, the conversion of ethanol in PEM type fuel cells under acidic conditions has proven to be difficult. Alkaline conditions are at least known to increase the reaction rates and thus the current density.

In this work, the ethanol oxidation at platinum electrodes was studied in more detail in order to elucidate possible advantages of the alkaline electrochemistry. For this purpose, the formed adsorbates were investigated in a first step using differential electrochemical mass spectrometry (DEMS). Subsequently, the effect of the ethanol concentration on the product distribution was studied. Finally, the effect of carbonate ion concentration and pH on the ethanol oxidation kinetics and product distribution was investigated.

In adsorption-stripping experiments in combination with DEMS it could be shown that the adsorption of ethanol onto clean platinum leads to the formation of two distinct C_1 adsorbates identified as CO_{ads} and $CH_{x,ads}$. The exact structure of the latter is still unclear. The results further indicate that exposure to bulk ethanol causes permanent poisoning of the electrode surface with loss of the ability to break the C-C bond. Consequently, C_2 adsorbates are formed leading to the formation of C_2 products. The nature of the products was shown to depend on the pH of the solution. At lower pH acetaldehyde gets formed whereas at higher pH acetic acid is preferred.

It was further shown that a certain carbonation of the electrolyte does not affect the ethanol oxidation but high degrees of carbonation decrease the activity and alter the product distribution. By correlation of the pH and the carbonate content of the different solutions with the product distribution it was found that the main influence on the product distribution originates from the change in pH rather than the change in the carbonate content.

B1301

The review of on-board hydrogen production and CO purification for transportation PEM fuel cells

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Abstract

Compared to current internal combustion engines, the fuel cell vehicle is believed to be the most environmentally friendly automotive propulsion mode in the immediate future. In particular, proton exchange membrane fuel cells (PEMFCs), represent the most common electrochemical technique driven by hydrogen and oxygen, which directly converts the chemical energy to electrical power for the vehicle. Due to the difficulty of on-board hydrogen storage and shortage of refueling infrastructure, the conversion of hydrocarbon fuels into hydrogen rich gas is, according to contemporary research, to constitute a transition period for commercialised fuel cell vehicles.

The technologies of fuel processing either by steam reforming, partial oxidation or autothermal reforming are relatively common in industry to generate hydrogen from organic chemical fuels, but these techniques are relatively difficult once applied to an on-board vehicle under variable driving cycles. Moreover, the reforming process usually produces an appreciable amount of carbon monoxide (CO), which is not feasible in the functioning of PEM fuel cells, since a trace amount of CO concentration (10 ppm) will poison the anode catalyst. Essentially, the CO removal process needs to be integrated with the fuel reformer to develop a complete on-board hydrogen feedstock for the PEM fuel cell.

For these reasons, this article reviews and discusses (1) fuel processing methods including partial oxidation, steam reforming, autothermal reforming and water gas shift for hydrogen production; (2) CO purification methods for the removal of existing CO after the reforming process through preferential oxidation, membrane purification, pressure-swing adsorption, methanation and electrochemical CO filter, to determine the best on-board fuel processing solution for the PEM fuel cell.

B1302

An experimental approach to the capability of metering units for future fuels

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Abstract

Automotive dosing pumps have been available on the market for more than 25 years now. Initially used for fuel fired heaters in mobile systems – trucks, passenger cars, e. g. –, this type of a reasonable dosing unit nowadays is applied in many fields. Based on the experience of delivering fuels of any kind, the dosing pump was further developed to deliver and dispense more or less any kind of liquid media. One of the most innovative operational areas of such compact metering units is the fuel cell reformer technology, wherein a constant flow of a certain amount of fuel is required.

The availability of liquid fuels as a source of energy for producing electricity within a fuel cell is the basis for the success of such systems. Future fuels, e. g. bio-fuels, are environmentally-friendly fuel sources. Thus, components for supplying these liquid fuels are needed, and then adapted to the challenging needs of these special fuels or fuel blends. This type of an automotive pump combines the abilities of priming, delivering respectively metering of liquids, in one very compact unit, thus helping to optimize existent systems. The widely advanced integration of functions and abilities makes many components as sensors, shut-off valves and injectors dispensable.

Dosing units have to continually deliver the exact amount of liquid during their lifetime. Hence, all pump designs were consequently tested in durability tests with different kinds of fuel, even biodiesel-fuels containing aggressive substances or gasoline-ethanol-blends. The global usage of metering units requires a robust design and robust materials as they are in direct contact to the fluids. Therefore these pumps have to be able to deliver all fuels that are commercially obtainable. Investigations have also been made to fulfil special demands for biomass fuels that potentially may degenerate. As they are designed as electromagnetically actuated piston pumps, the total flow rate is determined by the frequency of the piston's movement only, which is the basis for easy control to achieve the precise metering ability. Based on relevant test results, the interaction of dosing unit and the individual future fuels is taken into account.

B1303

Combined dry and steam reforming of biogas for generation of H₂ and CO rich fuel gas for SOFC

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Abstract

Biogas as renewable energy carrier offers great potential for the generation of electrical power. As a new approach a system including combined dry and steam reforming and a high temperature Solid Oxide Fuel Cell (SOFC) can improve the efficiency of electrical power generation from biogas at varying gas qualities when using the anode off-gas for supplying the necessary heat of the reforming reaction.

Biogas mainly consists of methane and carbon dioxide with fluctuating concentrations. Therefore the dry reforming of biogas using the CO₂ seems to be the most interesting reforming reaction. However, due to potential carbon formation during reforming at given biogas compositions, additional steam as oxygen carrier is necessary resulting in a combined dry and steam reforming.

This paper is focused on the design and performance data of a reformer module that has been developed for reforming cleaned biogas from a sugar plant waste water facility for coupling with a SOFC with an electrical power output of 1 kW. The reformer module consists of an evaporator, a super heater and a reformer/burner reactor. To obtain a high heat transfer metallic structures have been chosen for the reformer/burner reactor. Thermodynamic simulations have been made with focus on the boundary conditions of carbon formation at different CH₄ concentrations. Based on these data the reformer module has been designed and characterised. Tests have been performed at different O/C ratios resulting in a good agreement between thermodynamic simulations and experimental results. No carbon formation could be detected in the reformer.

Simulation results, thermodynamic calculations, system design and integration as well as experimental results regarding gas qualities and temperature profiles of the reformer module will be presented in this paper.

B1304

Pre-reforming of liquid hydrocarbons at atmospheric pressure

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Abstract

Pre-reforming of liquid hydrocarbons like naphtha or natural gas is a well known technique for increasing the efficiency of chemical plants. Normal operating conditions for a pre-reformer are characterised by raised process pressure in comparison to atmospheric pressure and a lower temperature than a steam reformer.

For this reason the capabilities of pre-reforming at atmospheric pressure is subject of this work to investigate possibility for an efficient reforming process to supply a fuel cell system. The research is done within a project for the integration of a fuel cell on a mid-size ship and this system shall provide auxiliary electrical power and heat.

The test facility for catalyst screening and fuel variation is a tubular reactor. Furthermore, a saturated steam generator and additional supply as well as an online gas measurement system belong to the test facility.

The results for the first commercial nickel oxide catalyst showed good results. The geometry of the first catalyst was pellet-shaped and as fuel pure aliphatic compounds were used. Experiments showed a good product gas composition and small deactivation of catalyst was observed. So pre-reforming of liquid hydrocarbons could be an economic process to supply feed to a fuel cell system.

1

B1305

Pyrolysis, a Low Cost Multi-fuel Processor for Fuel Cells

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Abstract

Pyrolysis offers an alternate route for fuel processing. The main advantage of pyrolysis systems is their simple and cost effective architecture. The fuel is catalytically converted to hydrogen, methane and carbon. The resulting carbon is combusted during regeneration. The constantly changing operating conditions and the high temperatures which occur during regeneration (> 950°C) represent demanding conditions for the catalyst. At present, there are no commercially available catalysts which are suitable for pyrolysis systems.

At Fraunhofer ISE, we have developed a catalyst for this process which is thermally stable and durable. The active component of the catalyst consists of cost-effective nickel alloy which is deposited onto a suitable substrate.

Results of operating a fully automated propane pyrolysis system will be presented. It consists of two reactors in which pyrolysis and regeneration take place alternately. The product gas from the pyrolysis is supplied directly to a high-temperature polymer-electrolyte membrane fuel cell and converted to electricity and heat. The operating parameters of the pyrolysis system were optimized in order to keep the carbon monoxide concentration below 1 vol.-%, even during switching over from one reactor to the next. Therefore, no carbon monoxide removal steps were necessary. At the same time, the hydrogen concentration remained above 80 vol.-% at all times.

The pyrolysis process does not require any process water; therefore, complex water purification and recovery steps are not needed. The pyrolysis system can be operated with various fuels, such as propane, methane, biogas and liquid hydrocarbons (e.g. diesel). Finally, a cost comparison between pyrolysis systems and conventional reformer systems will be discussed.

B1306

Further development of a microchannel steam reformer for diesel fuel

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Abstract

Fuel cell systems based on liquid energy carriers have great potential to be established in the market without the necessity of a hydrogen infrastructure. Especially the usage of fuels with an existing infrastructure like diesel allows an early breakthrough of the technology.

In the framework of the development of a diesel fuel processor for PEM fuel cells, this paper presents the results from the ongoing optimisation of a microchannel heat exchanger for diesel steam reforming. Four downscaled reformers with different noble metal catalytic coatings were operated in order to identify the most favourable catalyst formulation. Diesel surrogate was processed at varying temperatures and steam-to-carbon ratios. The reformer performance was investigated considering reformate composition, fuel conversion, and deactivation from carbon formation. Complete fuel conversion was obtained with several catalysts. One catalyst in particular was less susceptible to carbon formation and showed high selectivity.

A fifth downscaled reformer was implemented with an increased channel height in order to optimise the reformer geometry. In operation the reformer showed advantages in performance and pressure loss in comparison to the original channel height.

Within the reformer optimisation, CFD modelling of the downscaled reformer is carried out. An existing CFD model was applied for the computation but showed deviation from measurements. Therefore, a new approach for CFD modelling the downscaled reformer is introduced.

B1308

Preferential CO Oxidation over Ru/ α -Al₂O₃ Catalyst Prepared by Deposition-Precipitation

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Abstract

Highly active 0.5 wt%Ru/ α -Al₂O₃ catalysts have been prepared by deposition-precipitation (DP) method for preferential CO oxidation (PrOx) to reduce the CO concentration less than 10 ppm in excess H₂ stream. Ruthenium nitrosyl nitrate (Ru(NO)(NO₃)_x(OH)_y, Aldrich) was used as a ruthenium precursor and the pH was adjusted from 5.5 to 7.5 with 5 wt% NaOH. For comparison, the 0.5 wt%Ru/ α -Al₂O₃ catalyst prepared by conventional impregnation (IMP) method was used as a reference. The prepared catalysts were characterized by BET, H₂-TPR and CO-chemisorption and TEM. It has been confirmed that Ru metal dispersion on the support surface can be controlled by the pH. 0.5 wt% Ru/ α -Al₂O₃ catalysts prepared with pH 6.5 has high metal dispersion, large surface area as well as good reducibility at low temperature. PrOx test was performed with a space velocity (SV) of 60,000ml/g·h in the temperature ranges from 100 to 200 °C. The [O₂]/[CO] was adjusted between 1 and 2 and the effect of H₂O and CO₂ was examined at [O₂]/[CO] =1. 0.5 wt%Ru/ α -Al₂O₃ (DP) shows higher CO conversion and CO₂ selectivity in the wide temperature window of 100-200 °C than 0.5 wt%Ru/ α -Al₂O₃ (IMP) due to high Ru dispersion and good reducibility at low temperature. In particular, 0.5 wt%Ru/ α -Al₂O₃ prepared with pH 6.5 exhibits good catalytic performance in the presence of CO₂ and H₂O.

B1401

Thermo-chemical H₂ production: Thermo-economic modeling and process integration

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Abstract

Within the global challenge of climate change and energy security, hydrogen is considered as a promising decarbonized energy vector to be used in electricity production and transportation. In this paper, the thermo-chemical production of hydrogen by natural gas reforming and by lignocellulosic biomass gasification are analyzed, compared and optimized by developing thermo-economic models. Combining flowsheeting with process integration techniques, thermo-economic analysis and life cycle assessment (LCA), a systematic comparison of different process options with regard to energy, economic and environmental considerations is made. The choice of the technologies is optimized together with the operating conditions using multi-objective optimization.

In both natural gas and biomass based H₂ pathways, a CO₂ removal step is included during the H₂ purification which allows for CO₂ capture and further sequestration. The potential for greenhouse gas mitigation is assessed and compared with conventional plants without capture based on the CO₂ avoidance cost and the overall CO₂ equivalent emissions computed from the life cycle chain. The system's performance is improved by introducing process integration valorizing the waste heat by the combined production of heat and power. The H₂ application purpose and the corresponding required purity are key factors defining the process performance. The trade-offs between competing thermoenvionomic (i.e. energy, economic and environmental) objectives are finally assessed using a multi-objective optimization.

For natural gas based H₂ production overall energy efficiencies up to 80% and production cost of 22-110\$/MWh_{H₂} are computed compared to around 60% efficiency and 75-263\$/MWh_{H₂} for biomass based processes having the advantage of using renewable resources. The CO_{2eq} emissions are reduced by more than 6.4kg_{CO_{2eq}}/kg_{H₂} for NG and 20kg_{CO_{2eq}}/kg_{H₂} for BM processes compared to the cases without CO₂ capture. The competitiveness on the energy market depends strongly on the resource price and on the imposed CO₂ taxes. Our study shows that the thermo-chemical hydrogen production has to be analyzed as a polygeneration unit producing not only hydrogen but also captured CO₂ and electricity.

B1402

Optimised hydrogen storage and operating pressure of electrolyzers

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Abstract

This work presents shortly different hydrogen storage technologies but focuses on pressurized hydrogen storage. Hydrogen properties are investigated; storage density and compression energy is calculated to identify best storage pressure. Costs for the pressure vessel are estimated to find the best trade of between storage density, compression energy and vessel costs.

Current density and voltage are estimated for electrolyses to minimize the hydrogen production costs. The operating pressure for electrolyses is calculated for best efficiency or low energy consumption for achieving a give hydrogen outlet pressure for storage. This storage pressure was identified in the first part of the work.

Doing this gives the best trade off in terms of operating conditions and costs for the combining electrolyses with a hydrogen storage for energy storage.

B1403

Solid Ammonia as Energy Carrier: Possibilities and Technology Development

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Abstract

Ammonia is very attractive as carrier of energy for its high energy density and potential of being a 'zero-carbon' fuel. Ammonia can be used directly as fuel for high temperature fuel cell e.g. solid oxide fuel cell(SOFC) and indirectly through intermediate step of generation hydrogen for low temperature fuel cell e.g. proton exchange membrane (PEM) fuel cells. Amminex A/S has developed a technology to store ammonia in non-pressurized vessels as metal amines. The Amminex storage technology is approved for road, ship or air transportation. The Amminex product, Hydrammine™, has an energy density similar to that of liquid ammonia (~110 kg H₂/m³). The storage technology has removed the end user safety concern related to the exposure of ammonia. Amminex has been active in integrating the solid ammonia storage technology with PEMFC, solid alkaline membrane and SOFC stacks. The presentation will focus on the potential of ammonia as 'zero-carbon' energy carrier for stationary and mobile application. Among the stationary applications, mobile telecom tower backup power will be highlighted. Among the mobile applications, electric vehicle range extender will be specifically discussed. Also, the results of operation of different type of stacks with ammonia will be presented.

B1404

Modeling of heat and mass transfer in metal hydride matrix during hydrogen absorption-desorption cycle

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Abstract

Packed bed reactors using metal hydride are attracting a lot of attention as potential hydrogen storage systems. Some operational and design variables are major constraints to obtain proper inflow/outflow of hydrogen in a metal hydride reactor. These variables include packed bed thermal conductivity, porosity, pressure and temperature distributions in reactor during absorption/desorption cycle and also induced by temperature gradient mechanical stress. In this paper, two dimensional model is implemented in COMSOL multiphysics to simulate the hydrogen flow, pressure and temperature distributions in the packed bed reactor during absorption/desorption cycle. Also, stresses in porous metal hydride induced by temperature variation in the heating/cooling cycle were evaluated. Possible effect of stress induced porosity changes on diffusion and heating of hydrogen in both radial and axial direction in packed bed is discussed. The model consists of a system of partial differential equations (PDE) describing structural mechanics of stress, heat and mass transfer of hydrogen in porous matrix of packed bed reactor.

Keywords- Packed bed, reactor, stress, metal hydride, hydrogen, structural mechanics, heat transfer, mass transfer.

B1405

Functionalized metal oxide nanoparticulate films for solar photo-electrochemical hydrogen generation

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Abstract

Solar water splitting in photoelectrochemical cells (PEC) is a very attractive concept for the sustainable generation of clean hydrogen, and suffers from the same shortcomings like many other electrochemical energy conversion systems, such as functionality parameter constraints, degradation and limited lifetime, incompatibility with other materials, costs, and so on. We demonstrate the concept of PEC solar water splitting and present pathways to increase the efficiency of simple, affordable and abundant metal oxides like hematite, such as by doping [1], nanostructuring, heterointerfaces, functionalization with enzymes. We show how structural changes depending on synthesis and processing conditions go along with functional performance.

Reference

[1] Kay, A.; Cesar, I.; Graetzel, M. J. Am. Chem. Soc. 2006, 128, 15714-15721.

B1406

Towards Solving Fundamental Issues For Alkaline Exchange Membrane Fuel Cells

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Abstract

Anion transport in polymer exchange membranes is important to fuel cells that have the potential to revolutionize energy conversion. However, anion transport is still poorly understood in terms of its relationship to water content, morphology and chemistry. While a large amount of research has been performed for proton exchange membranes, little work has been performed with anion exchange membranes. These systems are particularly interesting in that the charge carrier may be hydroxide, or carbonate. It is not sufficient, however, to simply understand anion transport in these systems, as robust thin films that have high ionic conductivity must also be fabricated for practical applications. We are synergistically developing new polymer architectures with standard and novel cations. The synthetic work is iteratively preparing stable cations, varying modes of attachment to polymer backbones, and generating controlled morphologies. Synthesis and characterization are tied closely to theory through model validation, firstly by the study of aqueous solutions of representative cations and secondly by the study of well-defined polymer architectures. We use a predictive multi-scale computational approach to probe both anion transport and its coupling to polymer morphology. At the molecular-scale a generalization of a novel reactive molecular dynamics methodology is being developed, while more statistical characterizations of ion transport is implemented on the scale of the membrane thickness. The novel films are studied in terms of the anion species present, their transport and equilibria. Water content is measured by dynamic vapor sorption. Bulk transport is studied in an accurately controlled temperature and relative humidity. This is complemented by the measurements of self diffusion coefficients and molecular scale activation energies by NMR. Extensive state of the art mechanical and rheological, testing is used to develop robust thin films. Morphology is related to film mechanical properties through state of the art measurements and film degradation will be studied in depth.

B1407

Scenarios for the Hydrogen Society

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Abstract

Hydrogen from fossil sources and projects like the U.S. Department of Energy's (DOE) Nuclear Hydrogen Initiative (NHI) [1] are linked to centralized production and capital intensive investments in building distribution infrastructures providing, beyond technical challenges, high political implications. Solar energy as a far wider available source of energy and modular concepts for hydrogen combustion, like Hydrogen II in Almeria, Spain and the DLR SSPS tower in Cologne, Germany [2], on one hand, as well as hydrogen bioreactors fermenting waste waters, as Welch's hydrogen plant in Pennsylvania, USA [3], on the other hand, promote worldwide energy independence and, besides environmentally-friendly solutions based on renewable energy sources their decentralized technology, could become a real people's energy [4]. The way energy is produced and consumed shapes human behaviour and social structures. Small scale on-site production combined with hopes for low cost energy as Blacklight proposes by mastering the hydrino [5,6] make the switch from today's "carriers-refined petroleum and electricity" to the hydrogen home feasible [7]. This study analysis the possible socio- and geopolitical scenarios that will result from the direction that further technological development in hydrogen based power and advocates for decentralized, small scale projects due to their higher security and reliability, advantages in innovation processes, total efficiency and environmental sustainability as essential factors for future stability and progress in human societies.

B1408

Hydrogen Production by Alkaline Electrolysis: Characterization of Porous Diaphragms

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Abstract

The alkaline electrolyzers industry is facing the imminent necessity to replace the traditionally used asbestos diaphragm, with a separator made of advanced environmentally friendly material.

The advanced material should fulfill multiple requirements, such as: good gas separation and fast evacuation of the bubbles from the surface, increased ionic conductivity and low cell overpotential, chemical stability in 25 wt. % KOH solution at 85°C. Also, the material should possess the mechanical strength, be cost effective and ecologically accepted.

The investigation of the influence of porosity on the ionic resistance of zirconium dioxide, which is the base compound for the synthesis of ceramic diaphragms, has been undertaken. Moreover, the tests were performed with asbestos and wollastonite samples for comparative purposes.

Ionic resistance of the material was determined by electrochemical impedance spectroscopy (EIS), using two compartments, four electrodes electrochemical cell and Zahner IM6eX potentiostat. Measurements were performed in 25 wt. % KOH solution at ambient temperature, by sweeping frequencies from 100 KHz to 100 mHz in potentiostatic mode.

EIS spectra showed the purely resistive behaviour of investigated diaphragms. Diaphragms ionic resistance was correlated to materials porosity.

B1409

Composite ceramic diaphragms for alkaline electrolysis

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Abstract

An impregnated zirconia felt (IZF) diaphragm was developed and investigated to be used as a separator in alkaline electrolyzers with focus on the purity of the produced hydrogen and oxygen as well as the voltage-drop over the cell. As a substrate a commercial zirconia felt with a porosity of 94% was used. After the impregnation with inorganic-organic slurry the porosity of the flexible diaphragm was 62%. The impregnated zirconia felt (IZF) diaphragm were characterized in respect to the porosity of the structure and electrochemical resistance and compared to currently in use asbestos-chrysotile and commercially available ceramic matrix composites (CMC). In the electrolysis test cell setup at ambient conditions, the IZF diaphragm showed a lower voltage drop compared to asbestos and the CMC diaphragm, while the hydrogen and oxygen purity is greater than 99.8 %.

B1410

HT-PEM Electrolysis

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Abstract

Hydrogen can be used as a secondary energy carrier and can be generated by means of various primary energy sources, like fossil or bio fuels but also electricity from renewable energies. Three methods for the production of hydrogen by electrolysis of water exist today:

- The alkaline water electrolysis using a liquid electrolyte containing a caustic potash solution;
- The PEM-electrolysis with a proton exchange membrane operating under acidic conditions at about 50 to 80 °C, which is comparable to PEM fuel cells;
- The high temperature water vapour electrolysis at temperatures up to 1000 °C.

The operation of a PEM-electrolysis at elevated temperatures in the range between about 160 to 180 °C is a possible approach to increase the efficiency of the process. State of the art systems are not able to work in this temperature range caused by the instability of the used membranes and the materials for the current distributor and the bipolar plates.

The project described here deals with the following four main topics:

- Development of new proton exchange membranes based on polybenzimidazole (PBI) which is ionically cross-linked with a macromolecular sulfonated cross-linker having the aim to inhibit the leaching of the phosphoric acid and to mechanically enforce the membrane material.
- Choice and modification of materials for current distributor and bipolar plates which is necessary to avoid corrosion caused by the acidic environment, the high anodic potential and the elevated temperatures, as well as the coating of current distributors with appropriate catalysts for the hydrogen and oxygen evolution.
- Layout and set up of electrolysis test cells ready for the operation with new / modified materials. That includes the construction of bipolar plates and end plates and also the development of media supply and a concept for sealing the cell.
- Testing and improvement of developed components.

B1411

Protic ionic liquid and ionic melts prepared from imidazole and methanesulfonic acid as non-aqueous electrolytes

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Abstract

Recent years have witnessed the active exploration of protic ionic liquids (PILs), which are formed by proton transfer from a Brønsted acid to a Brønsted base, as promising non-aqueous electrolytes for anhydrous proton conductors at elevated temperatures [1-3].

Here, we studied the physico-chemical properties of protic ionic liquid and ionic melts prepared from the combination of imidazole ($C_3H_4N_2$) and methanesulfonic acid (CH_3SO_3H) at various molar ratios.

The equimolar composition, imidazolium methanesulfonate ($C_3H_5N_2^+ \cdot CH_3SO_3^-$ (**1**)), was a proton transfer salt with a melting point around 189 °C. Impurities of **1** were determined by ion chromatography. No halide ions were detected. In addition, the pH value of the aqueous solution of **1** with a mass fraction of 0.10 % was 4.80 at room temperature, indicating that **1** has a high ionicity even in aqueous solution. Thermogravimetric analysis showed that **1** has a relatively high thermal stability with a one-step weight loss process and a decomposition onset temperature of 347 °C. X-ray thermo-diffraction together with DSC and DTA showed that **1** undergoes a solid-solid phase transition at about 174 °C.

Single crystal and powder XRD data, as well as TGA and FT-IR analysis, revealed that the base-rich region was a mixture of **1** and imidazole. FT-IR analysis and single crystal data also suggested that the $C_3H_4N_2$ - CH_3SO_3H system exists in a strongly hydrogen-bonded network.

Ionic conductivity was measured by impedance spectroscopy. Maximum ionic conductivity of 0.20 S cm^{-1} at 220 °C was obtained for the $n(C_3H_4N_2)/n(CH_3SO_3H) = 85/15$ composition. The composition dependence of the ionic conductivity in $C_3H_4N_2$ - CH_3SO_3H system is quite similar to the whole $C_3H_4N_2$ - H_2SO_4 [1] and 1,2,4-triazole- CH_3SO_3H systems [3], the $C_3H_4N_2$ - $(CF_3SO_2)_2NH$ system in the base-rich region [2], and the *N*-methylpyrrolidine-acetic acid system in the acid-rich region [4]. For the

$n(C_3H_4N_2)/n(CH_3SO_3H) = 85/15$ composition, contribution of protons to the ionic conductivity was confirmed by chrono-amperometry and impedance spectroscopy under H_2 atmosphere. Obviously, the ionic conductivity is due not only to ionic species (vehicle mechanism), but also to intermolecular proton transfer via the Grotthuss mechanism [2].

Furthermore, the proton redox behavior of the base-rich region was investigated at 80 °C by employing a three-electrode system with Pt disk, Pt plate and Pt wire (in H_2 bubbling atmosphere) as working, counter and reference electrodes, respectively. It was found that the $n(C_3H_4N_2)/n(CH_3SO_3H) = 85/15$ composition exhibited activity with a Pt electrode under H_2 atmosphere. In accordance with the finding of Watanabe et al. [2], imidazolium cation (protonated imidazole) was also found to be active for the oxygen reduction, although the overpotential of the oxygen reduction was rather large.

Finally, composite membranes were prepared by soaking a Nafion[®] 212 membrane in the $n(C_3H_4N_2)/n(CH_3SO_3H) = 85/15$ composition at 80 °C for 60 h and then heating it in a vacuum oven (ultimate pressure: 2×10^{-3} mbar) at 60 °C overnight to remove excess imidazole. FT-IR analysis demonstrated that Nafion[®] 212 membrane was successfully doped with **1** without imidazole. Using the conductivity cell MK3 from FuMA-Tech, the four-electrode in-plane conductivity measurement showed that Nafion[®] 212 membrane doped with **1** exhibited a proton conductivity nearly 3 magnitudes higher than that of undoped Nafion[®] 212 membrane at 120 °C and around 0% relative humidity.

In conclusion, good thermal stability, high ionic conductivity and simple synthesis as well as the technical availability and well documented toxicology of the starting materials make the $C_3H_4N_2$ - CH_3SO_3H system a highly interesting candidate for non-aqueous electrolytes.

B1412

Sizing of photovoltaic system coupled with hydrogen storage based on the ORIENTE model

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Abstract

PEPITE (study and experimentation of intermittent energy management using electrochemical technologies) is a project endorsed by the French PAN-H research program (action plan on hydrogen and fuel cell) supported by ANR (French Research National Agency). This project started in January 2008 for three-year duration. The aim of the project is to evaluate different system architectures and energy management strategies for hybrid systems based on renewable energy sources coupled with hydrogen for different applications. Determination of a “sustainable” point for such system in terms of sizing is possible. Moreover ORIENTE makes it possible to describe in details the energy exchanges within such a complex system. A 24/24 hours system needs huge components, so an economic study will be necessary in order to know if the system cost and if such a configuration are economically acceptable.

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by 16th of June 2011

EUROPEAN FUEL CELL FORUM 2011

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Chen, Xinbing - B0407
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El Hannach, Mohamed - A1302
Engelhardt, Philip - A1202, A1208
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Erat, S. - B0506
Escribano, Sylvie - A1001
Esposito, Angelo - A1402
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Faidel, Dietrich - B1011
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Ferluga, Matteo - B0502
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Friedrich, Andreas - A0102, A0510, A0710, A1501, A1504
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 Song, Rak-Hyun - B1004, B1009
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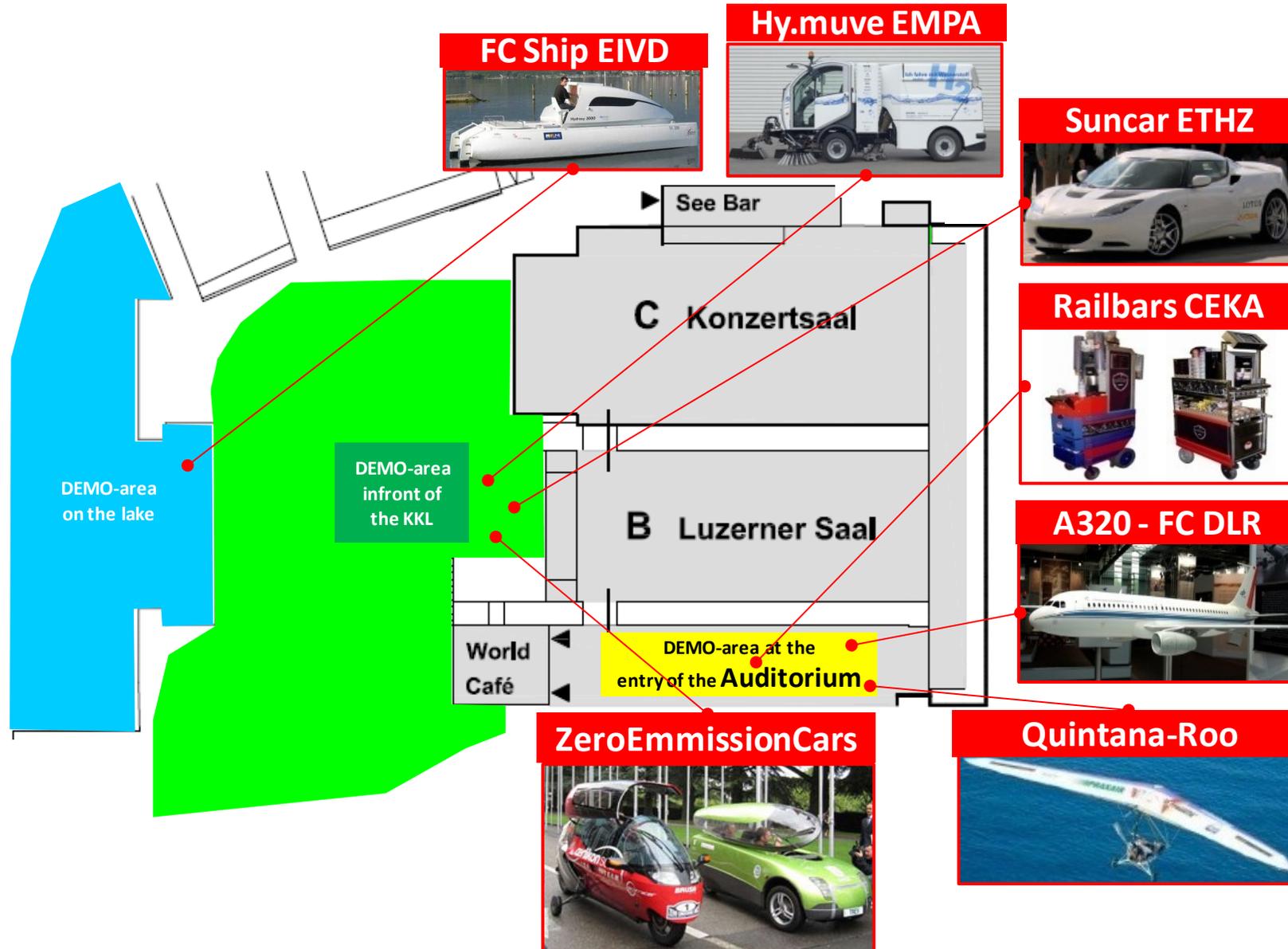
Demonstrators

Announced by 10th of June 2011

EUROPEAN FUEL CELL FORUM 2011

28 June – 1 July 2011

Kultur- und Kongresszentrum Luzern (KKL) Lucerne / Switzerland



Outlook 2012

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 the EUROPEAN FUEL CELL FORUM 2011. However, looking a little bit beyond these intensive days, we see another important event emerging at a not too far horizon in 2012:

The 10th European SOFC Forum Science, Technology and Application of Solid Oxide Fuel Cells and Electrolysers

In the traditional alternation with the other bi-annual SOFC conference series organised by the Electrochemical Society, the 10th EUROPEAN SOFC FORUM will be THE major event of the year 2012 for SOFC scientists, experts, engineers, but also increasingly business developers and managers.

Already now, many people have expressed their strong interest to participate and contribute to this event as scientists, engineers or exhibitors. On the one hand, the technical focus lies on specific engineering and design approaches and solutions for materials, processes and components of the first real applications and products. On the other hand, the technological potential of high temperature ceramics opens the horizon from pure fuel cells towards generic ceramic membrane reactors. Solid Oxide Electrolysers will be an important part of the official program with dedicated sessions. Given the potential of proton and mixed conducting ceramics in energy and gas processing applications, specific sessions are also under consideration.

The forum comprises a scientific conference, an exhibition and a tutorial. The Scientific Conference will address issues of science, engineering, materials, systems and applications / markets for all types of Solid Oxide Fuel Cells (SOFC) and Solid Oxide Electrolysers (SOE). In its traditional manner, the meeting aims at a fruitful dialogue between researchers, engineers and manufacturers, hardware developers and users, academia, industry and utilities. Business opportunities will be identified for manufacturers, commerce, consultants, utilities and investors. Although a Europe-bound event, participation is invited from all continents. About 500 participants and 30 exhibitors are expected from more than 30 nations.

For 2012, the EFCF's International Board of Advisors has **elected**

Dr. Florence Lefebvre-Joud as Chairwoman

of the next conference. She is Senior Scientist and Program Manager in the field of Materials for Energy at **CEA-LITEN in Grenoble, France**, has supervised many PhD theses and authored more than 50 publications in refereed scientific journals. A Scientific Advisory Committee has been formed to structure the technical programme in an independent and neutral manner and will exercise full scientific independence in all technical matters.

For everybody interested in SOFC and SOE, please take note in your agenda of the next opportunity to enjoy Lucerne as scientific and technical exchange platform. The 10th EUROPEAN SOFC FORUM will take place from 26 to 29 June 2012, in the KKL of Lucerne, Switzerland.

We look forward to welcoming you 2012 again in Lucerne.



The organisers Olivier Bucheli & Michael Spirig





EUROPEAN FUEL CELL FORUM 2011

28 June – 1 July 2011

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Schedule of Events

Tuesday – 28 June 2011	10:00 - 16:00	Exhibition set-up
	10:00 - 16:00	Tutorial by Dr. Günther Scherer & Dr. Jan Van herle
	10:00 - 16:00	International Project and Set-up Meetings
	14:00 - 18:00	Poster pin-up
	16:00	Official opening of the exhibition
	16:00 - 18:00	Registration (continued on following days)
	18:00 - 19:00 from 19:00	Welcome gathering on terrace above registration area Thank-You Dinner according to special invitation and networking meeting in individual groups
Wednesday – 29 June 2011	08:00 - 09:00	Speakers Breakfast
	09:00 - 18:00	Conference Sessions 1-5 including worldwide FCH program overview, poster presentation by authors, networking and demonstrator show
	12:30	Press Conference (by invitation only)
	18:30 - 23:00	Swiss Surprise Event (optional)
Thursday – 30 June 2011	08:00 - 09:00	Speakers Breakfast
	09:00 - 18:00	Conference Sessions 6-10 including common session on demonstration projects in transportation, poster presentation by authors and networking
	19:30 - 23:00	Great Dinner on the Lake
Friday – 1 July 2011	08:00 - 09:00	Speakers Breakfast
	09:00 - 17:00	Conference sessions 11-15 including common session on demonstration projects in the stationary field and networking
	17:00 – 17:45	Award Ceremony for best paper, speaker, presentation and poster: Christian Friedrich Schoenbein and Hermann Göhr Award
	17:45 – 18:00	Closing Ceremony

**EFCF 2011: The future with Fuel Cells & Hydrogen:
International Research - Programs - Realization**