

# Conference Agenda

19<sup>th</sup> conference in series of the European Fuel Cell Forum in Lucerne

## 5<sup>th</sup> EUROPEAN PEFC AND H<sub>2</sub> FORUM 2015

30 June – 3 July 2015

Kultur- und Kongresszentrum  
Luzern (KKL) Lucerne / Switzerland  
Chaired by Prof. Dr. Frano Barbir



International FUEL CELL and HYDROGEN  
Conference with Exhibition and Green Salon  
including All Hydrogen Fuel Cells (PEFC, HTPEM, AFC, PAFC)  
Direct Alcohol Fuel Cells (DMFC) & H<sub>2</sub> production, storage,  
infrastructure

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



Name:

Adress:

Phone:

E-Mail:

International FUEL CELL and HYDROGEN Conference including  
All Hydrogen Fuel Cells (PEFC, HTPEM, AFC, PAFC) Direct Alcohol Fuel Cells (DMFC) & H<sub>2</sub> production, storage, infrastructure

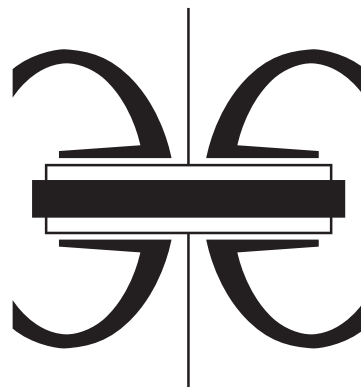
# 5<sup>th</sup> EUROPEAN PEFC & H<sub>2</sub> FORUM 2015

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**Chaired by Prof. Dr. Frano Barbir**

FESB University of Split, Fellow IAHE



## **Tutorial**

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

## **Exhibition & Green Salon**

Event organized by European Fuel Cell Forum

Olivier Bucheli & Michael Spirig

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# 5<sup>th</sup> European PEFC & H<sub>2</sub> Forum 2015

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Official Carrier

The event is endorsed by:

<b>ALPHEA</b> Rue Jacques Callot FR-57600 Forbach/France	<b>SIA (Berufsgruppe Technik und Industrie)</b> Selnastr. 16 8039 Zürich / Switzerland	<b>UK HFC Association</b> c/o Synnogy, Church Barn Fullers Close Aldwincle Northants NN14 3UU United Kingdom
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# Welcome by the Organisers

## Olivier Bucheli & Michael Spirig

European Fuel Cell Forum  
Obgardihalde 2  
6043 LUZERN / Switzerland

Welcome to the 5<sup>th</sup> European PEFC & H<sub>2</sub> Forum 2015. As from the year 2000, this 19<sup>th</sup> 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, Switzerland. Competent staff, smooth technical services and excellent food allow the participants to focus on science, technology and networking in a creative and productive work atmosphere.

In alliance with the International Board of Advisory IBoA, this year's event focuses on polymer electrolyte fuel cells and hydrogen production and storage, but also other fuel cell types like alkaline, direct alcohol, formic acid and microbial fuel cells as well as other fuels will be represented. The topics range from materials to systems and FC&H demonstrations. 250 participants are expected, opening many opportunities of top level technical exchange and networking. We keep one thing constant: The focus on facts and physics. This is granted by the autonomy of the organisation that does not depend on public or private financial sponsors but is fully based on the participants and exhibitors. Your participation has made possible this event, please take those following days as your personal reward!

Suppliers exhibit their products and services to developers and the FCH Industry. Among others, materials, components like sensors, pumps, valves, tubes, filters etc., control devices, diagnosis tools, test benches, manufacturing technologies, qualification & purification systems are exhibited in the interesting "Luzerner Saal", where the

refreshments are served during the breaks and networking activities take place directly in front of the 17 booths of the 26 exhibiting firms.

EFCF organizes also a Sustainable Energy & Mobility Solutions focused event to increase the political and public awareness. In continuation to 2013 a B2B Market Place called "Green Salon takes place on 1 - 2 July. It is a show from more 17 OEMs and operators visualizing from well to wheel the readiness and availability of the technical elements. 31 H<sub>2</sub> and FC applications together and in interaction with complementary technologies illustrate the future energy mobility world.

We would like to thank the conference chair Prof. Dr. Frano Barbir from FESB University of Split, Croatia, the Scientific Organising Committee and the Scientific Advisory Committee for their excellent work. Based on more than 180 submitted contributions, they have composed a sound scientific program picturing the recent progress in the technologies from about 30 countries and 5 continents – we look forward to seeing this exciting program of the EUROPEAN PEFC and H<sub>2</sub> FORUM 2015. 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 IBoA, the media, the KKL staff and our co-workers. We thank all of you for your coming and support. May we all have a wonderful week in Lucerne with fruitful technical debates and personal exchanges!

Yours sincerely



Olivier Bucheli & Michael Spirig

We are looking optimistic on the 2015 event and the future with:

- ▶ 12<sup>th</sup> EUROPEAN SOFC & SOE FORUM 30 June - 3 July 2016
- ▶ 6<sup>th</sup> EUROPEAN PEFC & H<sub>2</sub> FORUM 4 July - 7 July 2017



# Conference Session Overview

see also: Booklet with full Program & Memory Stick with all Proceedings

Auditorium		Kongressfoyer	
<b>A01</b>	P1: Opening Session: International Overview - EU, US and South Africa (HySA)		
<b>A02</b>	P2: Automotive FC Development in China		
<b>A03</b>	Durability stress test results	<b>B03</b>	H2-production: Alkaline electrolyzers
<b>A04</b>	in the Luzerner Saal Poster Session I covering All Oral Session Topics		
<b>A05</b>	Characterization of FC materials	<b>B05</b>	H2-storage: Material and systems
<b>A06</b>	Non-precious metal FC catalysts	<b>B06</b>	FC membranes & other components
<b>A07</b>	Keynote: Electrocatalysis of oxygen reduction reaction	<b>B07</b>	Keynote: Status and future of hydrogen technologies
<b>A08</b>	FC monitoring & diagnostics	<b>B08</b>	H2 storage in metal hydrides
<b>A09</b>	New Pt-alloy FC catalysts	<b>B09</b>	Fuel processing and hydrogen purification
<b>A10</b>	in the Luzerner Saal Poster Session II covering All Oral Session Topics		
<b>A11</b>	Degradation studies and modelling	<b>B11</b>	Membranes for IT & HT PEMFC
<b>A12</b>	FC fault and degradation modelling	<b>B12</b>	Industrial applications/Microbial fuel cell/Assessments
<b>A13</b>	New catalyst structures and manufacturing processes	<b>B13</b>	H2 production
<b>A14</b>	FC modelling and simulations	<b>B14</b>	FC Mobility applications / Stack and system integration
<b>A15</b>	Stack and system integration, operation strategies	<b>B15</b>	Portable/Back-up/Renewable
<b>A16</b>	P3: FC-H2 Mobility System		
<b>A17</b>	P4: Closing Ceremony		Legend: Px: = Plenary;

# Chair's Welcome to the 5<sup>th</sup> European PEFC & H<sub>2</sub> Forum 2015

**Prof. Dr. Frano Barbir**

FESB University of Split  
Fellow IHAЕ

Dear EFCF Attendee,

It is my great pleasure and honour to welcome you to the 5<sup>th</sup> European Polymer Electrolyte Fuel Cell and Hydrogen Forum, which is the 19<sup>th</sup> in the illustrious series of European Fuel Cell Forums to be held here in the beautiful Swiss city of Lucerne.

At the 5th European PEFC and H<sub>2</sub> Forum 2015 the focus is on polymer electrolyte fuel cells and hydrogen production and storage, but other fuel cell types and fuels will be represented as well such as alkaline, direct alcohol, formic acid and microbial fuel cells. The topics range from materials to systems and FC&H demonstrations.

Addressing issues of science, engineering, applications, market possibilities and future trends, the 5th European PEFC and H<sub>2</sub> Forum 2015 is aiming at a fruitful dialogue between researchers, engineers, and manufactures, between hardware developers and potential users, between academia and industry. The technical program comprises current results, challenges and trends in the above given fields. Business opportunities will be identified for manufacturers, suppliers and investors. The event is a unique opportunity for networking within and across different disciplines.

Aiming at high quality and relevance, the technical program has been set up by the Scientific Advisory Committee [www.EFCF.com/SAC](http://www.EFCF.com/SAC). The Committee has the task of ensuring full independence in all scientific and technical manners. All papers presented as lectures or posters will be collated in the electronic proceedings, which will be distributed to all participants at the time of registration and later distributed to libraries, research institutions and universities. In a special edition of the international Journal of Fuel Cells, some selected contributions will be published.

For a fascinating conference under the motto:

**Bringing Hydrogen Fuel Cells & Hydrogen,  
as part of our energy future, closer to deployment.**

Frano Barbir

## Conference Schedule & Program

see: Last Page, Booklet, Memory Stick with  
Proceedings and [www.EFCF.com](http://www.EFCF.com)

**FINAL ANNOUNCEMENT**

19<sup>th</sup> conference in series of the European Fuel Cell Forum in Lucerne

**5<sup>th</sup> EUROPEAN PEFC AND H<sub>2</sub> FORUM 2015**

**30 June – 3 July 2015**

Kultur- und Kongresszentrum  
Luzern (KKL) Lucerne / Switzerland  
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International FUEL CELL and HYDROGEN  
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Direct Alcohol Fuel Cells (DMFC) & H<sub>2</sub> production, storage, infrastructure

**REGISTER now on [www.EFCF.com](http://www.EFCF.com)**

Convenient hotel rooms are blocked until 30 April 2015

**SWISS**  
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Newly Optimized:  
Late Registration  
Dates p. 32

**FUEL CELL TUTORIAL**  
30 June 2015  
by Dr. Günther G. Scherer, ex PSI Villigen  
Dr. Jan Van Herle, EPFL Lausanne

## Next EFCF conferences:

↘ **12<sup>th</sup> European SOFC and SOE Forum** 2016 5 – 8 July

↘ **6<sup>th</sup> European PEFC and H<sub>2</sub> Forum** 2017 4 – 7 July

[www.EFCF.com](http://www.EFCF.com)

**in Lucerne, Switzerland**

# Session Programme Wednesday, July 1, 2015

Morning

Auditorium

<b>09:00</b>	<b>P1: Opening Session</b> <b>International Overview - EU, US and South Africa (HySA)</b> Frano Barbir, M. Spirig, O. Bucheli	<b>A01</b>
09:00	<b>Welcome by the Organizers</b> Michael Spirig, Olivier Bucheli European Fuel Cell Forum, Lucerne/Switzerland	A0101
09:05	<b>Welcome by the Chair</b> Frano Barbir FESB University of Split, Split/Croatia	A0102
09:15	<b>Welcome to Switzerland the Smart Research Place</b> Stefan Oberholzer, Rolf Schmitz, Walter Steinmann Swiss Federal Office of Energy, Bern/Switzerland	A0103
09:30	<b>The Status of Hydrogen Fuel Cells and H2 R&amp;D in the Fuel Cell and Hydrogen Joint Undertaking Program</b> Joao Serrano Gomes Fuel Cells and Hydrogen Joint Undertaking, Brussels/Belgium	A0104
09:50	<b>DOE Hydrogen and Fuel Cells Program</b> Nancy Garland, U.S. Department of Energy, Washington DC/USA	A0105
10:10	<b>Electrochemical Hydrogen Compression and Separation (EHC&amp;S): Demonstrator Developed by HySA Infrastructure</b> Dmitri Bessarabov HySA Infrastructure Center (Hydrogen South Africa), North-West University Faculty of Engineering, Potchefstroom/South Africa	A0106
10:30	<b>Break - Luzerner Saal in the Exhibition</b>	
<b>11:00</b>	<b>P2: Automotive FC Development in China</b> Frano Barbir, André Martin	<b>A02</b>
11:00	<b>Overview of automotive FC development in China</b> Jianbo Zhang Dep. of Automotive Engineering, Tsinghua University, Beijing/China	A0201
11:25	<b>5 Min to change to Kongressfoyer for B03 Session</b>	

## International Board of Advisors

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 Prof. Frano Barbir, Chair, Unido/Croatia  
 Dr. Ulf Bossel, ALMUS AG/Switzerland  
 Dr. Niels Christiansen, NCCI innovation/Danmark  
 Dr. Olaf Conrad, University of Cape Town/South Africa  
 Dr. Karl Föger, Ceramic Fuel Cells/Australia  
 Dr. Nancy L. Garland, Department of Energy, USA  
 Prof. Hubert A. Gasteiger, TU München/Germany  
 John Bøgild Hansen, Haldor Topsøe A/S, Denmark  
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 Dr. Günther G. Scherer, ex PSI, Villigen/Switzerland  
 Dr. Günter Schiller, DLR Stuttgart/Germany  
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 Prof. Robert Steinberger-Wilckens, Chair; Uni Birmingham/UK  
 Prof. Constantinos Vayenas, University of Patras/Greece  
 Prof. Wei Guo Wang NIMTE/PR, China  
 Dr. Christian Wunderlich, IKTS/Germany



## Auditorium

## Kongressfoyer

11:30	<b>Durability stress test results</b> Georgios Tsotridis (tbc)	<b>A03</b>	<b>H2-production: Alkaline electrolyzers</b> Mogens Mogensen, Trent Molter	<b>B03</b>
11:30	<b>Start-up/shut-down effect on PEMFC stack durability</b>	A0301	<b>Pressurized alkaline electrolyser with high efficiency and wide operating range – the project RESelyser</b>	B0301
	Sébastien Rosini, Fabrice Micoud, Yannick Fourneron, Hortense Laforet CEA-LITEN, Grenoble/France		Regine Reissner (1), G. Schiller (1), E. Guelzow (1), Y. Alvarez-Gallego (2), W. Doyen (2), B. van Craenendonck (3), J. Vaes (3), J.R. Bowen (4) (1) DLR German Aerospace Center, Institute of Engineering Thermodynamics, Stuttgart/Germany, (2) VITO NV, Mol/Belgium, (3) Hydrogenics Europe NV, Oevel/Belgium, (4) Technical University of Denmark (DTU), Department of Energy conversion and Storage, Roskilde/Denmark	
11:45	<b>Start/Stop Cycling Test in a PBI-based High Temperature Polymer Electrolyte Membrane Fuel Cell</b> F. Javier Pinar (1), Amanda Schlüterbusch(1,2), Peter Wagner (1), Michael Wark (2), Alexander Dyck (1) (1) NEXT ENERGY • EWE Research Centre for Energy Technology, Oldenburg/Germany, (2) Carl von Ossietzky University of Oldenburg, Oldenburg/Germany	A0302	<b>Phase inversion process of novel membranes for alkaline electrolysis</b> Dariusz Burnat (1), Meike V. F. Schlupp (1), Alexander Bonk (1), Corsin Battaglia (1), Ulrich F. Vogt (1,2) (1) Materials for Energy Conversion, Swiss Federal Laboratories for Material Science and Technology (EMPA), Dübendorf/Switzerland, (2) Faculty of Environment and Natural Resources, Crystallography, Albert-Ludwigs-Uni Freiburg/Germany	B0302
12:00	<b>Impact of Accelerated Stress Tests on High Temperature PEMFC Degradation</b> Dana Schonvogel (1), Maren Rastedt (1), Peter Wagner (1), Michael Wark (2), Alexander Dyck (1) (1) NEXT ENERGY • EWE Research Centre for Energy Technology at the University of Oldenburg, Oldenburg/Germany, (2) Institute for Chemistry, Carl von Ossietzky University, Oldenburg/Germany	A0303	<b>Novel gas separation membranes for alkaline water electrolysis</b> Ulrich F. Vogt (1,2), Dariusz Burnat (1), Meike V. F. Schlupp (1), Corsin Battaglia (1) (1) Materials for Energy Conversion & Swiss Federal Laboratories for Material Science and Technology (EMPA), Dübendorf/Switzerland, (2) EPFL SB ISIC PH A2 354 (Bâtiment PH), Station 3, Lausanne/Switzerland, (3) Faculty of Environment and Natural Resources, Crystallography, Freiburg/Germany	B0303
12:15	<b>Accelerated stress testing of HT-PEFC: the effect of electrolyte loss on cell performance</b> S. H. Eberhardt, F. N. Büchi, T. J. Schmidt Paul Scherrer Institut, Electrochemistry Laboratory, Villigen/Switzerland	A0304	<b>Pressure and Temperature Influence on Alkaline Electrolysis Performance</b> Ulrich R. Fischer, André Voigt, Daniel Tannert, Christian Ziems, Hans-Joachim Krautz Brandenburg University of Technology Cottbus-Senftenberg, Department of Power Plant Technology, Hydrogen Research Center, Cottbus/Germany	B0304
12:30	<b>Lunch &amp; Coffee - Luzerner Saal in the Exhibition &amp; in the Poster Session</b>			

# Wednesday, July 1, 2015

## Luzerner Saal

### Afternoon

### Afternoon

13:15

**Poster Session I** covering All Oral Session Topics  
Frano Barbir, Joachim Scholta

**A04**

### Auditorium

### Kongressfoyer

14:30

**Characterization of FC materials**

Andreas Friedrich, Pierre Boillat (tbc)

**A05**

**H2-storage: Material and systems**

Andreas Zuettel (tbc), Agata Godula (tbc)

**B05**

14:30

**Vizualization of GDL Liquid Water Invasion below Channel and Rib by X-ray Tomographic Microscopy**

A0501

Adrien Lamibrac (1), Federica Marone (2), Felix Büchi (1)  
(1) Electrochemistry Laboratory, Paul Scherrer Institut (PSI), Villigen/Switzerland, (2) Swiss Light Source, Paul Scherrer Institut (PSI), Villigen/Switzerland

14:45

**Uptake of protic electrolytes by polybenzimidazole-type polymers – Model for the adsorption isotherm and electrolyte/polymer interactions**

A0502

Carsten Korte (1), Fosca Conti (2), Jürgen Wackerl (1), Werner Lehnert (1,3)  
(1) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research – Electrochemical Process Engineering, Jülich/Germany, (2) Department of Chemical Sciences, University of Padova, Padova/Italy, (3) Modeling in Electrochemical Process Engineering, RWTH Aachen University, Aachen/Germany

15:00

**Critical Parameters and Control Strategies for Comparable PEFC Stack Characterization**

A0503

Jens Mitzel, Erich Guelzow, K. Andreas Friedrich  
German Aerospace Center (DLR), Stuttgart/Germany

**Keynote:**

**Power 2 Gas**

**Enabler for renewable energy sources (tbc)**

Phil Doran

ITM Power GmbH Germany, Sheffield(UK)

B0501  
(B0502)

**Borohydride based Ionic Liquids as novel Hydrogen Storage Technology**

Christoph Grimmer (1), Jan Senn (1), Theo Friedrich (1), Dieter Woisetschlager (2), Nicole Mayer (2), Roland Kalb (2), Michael Koncar (2), Julian Wagner (3), Viktor Hacker (1)

B0503

15:15	<b>The development of multi-layered coating and method for the aluminum bipolar plates of a direct methanol fuel cell</b> Stanislav Gorelkov (1), Thomas-Maik John (2), Georg Dura (1), Jens Wartmann (1), Angelika Heinzl (1) (1) The Fuel Cell Research Center, Duisburg/Germany, (2) PT&B SILCOR GmbH, Barleben/Germany	A0504	(1) Graz University of Technology, Institute of Chemical Engineering and Environmental Technology, Graz/Austria, (2) proionic GmbH, Grambach/Austria, (3) Graz University of Technology, Institute for Electron Microscopy and Nanoanalysis, Graz/Austria <b>Hydrogen Storage on Graphene Foam</b>	B0504 (B0501)
15:30	<b>Calculation of effective transport properties of partially saturated gas diffusion layer</b> Tomasz Bednarek, Georgios Tsotridis European Commission, Directorate-General Joint Research Centre, Petten/The Netherlands	A0505	Stephen M. Lyth (1), Huaiyu Shao (1), Masamichi Nishihara (1), Takeshi Daio (2), Ben V. Cunnig (1), Kazunari Sasaki (1,2,3,4), Etsuo Akiba (1,3) (1) International Institute for Carbon-Neutral Energy Research (I2CNER), Fukuoka/Japan, (2) International Research Center for Hydrogen Energy, Fukuoka/Japan, (3) Department of Mechanical Engineering, Kyushu University, Fukuoka/Japan, (4) Next Generation Fuel Cell Research Center (NEXT-FC), Kyushu University, Fukuoka/Japan <b>Hydrogen storage and delivery: the formic acid - carbon dioxide couple</b>	B0505
15:45	<b>“Pressed onto” 3Omega method for measuring the thermal properties of gas diffusion layers of fuel cells and the like</b> Alexandre Jacquot (1), Yannick Barb (1), Martin Jaegle (1), Evren Firat (2) (1) Fraunhofer-Institute for Physical Measurement Techniques, Freiburg/Germany, (2) Zentrum für BrennstoffzellenTechnik ZBT GmbH, Duisburg/Germany	A0506	Gábor Laurenczy EPFL, École Polytechnique Fédérale de Lausanne, Lausanne/Switzerland <b>Hydrogen Production by Dehydrogenation of Formic Acid using Iridium Catalysts</b>	B0506
16:00	<b>Break - Luzerner Saal in the Exhibition &amp; in the Poster Session</b>			

# Wednesday, July 1, 2015

Auditorium

Kongressfoyer

Afternoon

Afternoon

16:30	<b>Non-precious metal FC catalysts</b> Piotr Zelenay, Silvie Escribano (tbc)	<b>A06</b>	<b>FC membranes &amp; other components</b> Brian C. Benicewicz	<b>B06</b>
16:30	<b>Non-Precious Metal Fuel Cell Catalysts Prepared By Rationally Designed Porous Materials</b> Di-Jia Liu Argonne National Laboratory, Argonne (IL)/United States	A0601	<b>Graphene Oxide Membrane Fuel Cells</b> Stephen M. Lyth (1), Thomas Bayer (2), Takeshi Daio (3), Sean R. Bishop (1,5), Kazunari Sasaki (1,2,3,4) (1) International Institute for Carbon-Neutral Energy Research (I2CNER), Fukuoka/Japan, (2) Department of Mechanical Engineering, Kyushu University, Fukuoka/Japan, (3) International Research Center for Hydrogen Energy, Fukuoka/Japan, (4) Next Generation Fuel Cell Research Center (NEXT-FC), Kyushu University, Fukuoka/Japan, (5) Dept. of Materials Science and Engineering, Massachusetts Institute of Technology, Fukuoka/Japan	B0601
16:45	<b>Assessment of potential Co/Fe-N-C active sites arising from heat treated carbon-supported porphyrins</b> Andrew John Dixon University of Leeds, Leeds/United Kingdom	A0602	<b>A Novel Composite Nafion/Anodized Aluminum Oxide Proton Exchange Membrane</b> Robert Gloukhovski, Viatcheslav Freger, Yoed Tsur Technion – The Israel Institute of Technology, Faculty of Chemical Engineering, Haifa/Israel	B0602
17:00	<b>Transition metal ion-chelating ordered mesoporous carbons as non-noble metal PEMFC catalysts</b> Johanna K. Dombrovskis, Anders E.C. Palmqvist Chalmers University of Technology, Department of Chemical and Biological Engineering, Göteborg/Sweden	A0603	<b>Composite sPEEK-porphyrin membranes development for PEFC applications</b> Alessandra Carbone (1), A. Saccà (1), R. Pedicini (1), I. Gatto (1), A. Romeo (2), L. Monsù Scolaro (2), M. A. Castriciano (3) (1) Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano", Messina/Italy, (2) Dipartimento di Scienze Chimiche, University of Messina, Messina/Italy, (3) Istituto per lo Studio dei Materiali Nanostrutturati, c/o Dipartimento di Scienze Chimiche, Messina/Italy	B0603



17:15	<b>Synthesis of nanofibrous Co-CNF catalysts with high oxygen reduction reaction activity in alkaline media - invited talk</b>  MinJoong Kim, DoHwan Nam, SungJong Yoo, JongHyun Jang, Hyoung-Juhn Kim, EunAe Cho, HyukSang Kwon Dept. of Materials Science and Engineering, Korea Advanced Institute of Science and Technology (KAIST), Daejeon/Republic of Korea	A0604	<b>Investigating Electrodes for Intermediate Temperature Polymer Electrolyte Fuel Cell (IT-PEFC): GDL Material Properties and their Influence</b>  Amrit Chandan (1), Neil Rees (1), Robert Steinberger-Wilckens(1), Valerie Self (2), John Richmond (2) (1) University of Birmingham, Centre for Hydrogen & Fuel Cell Research, Birmingham/United Kingdom, (2) Tata Motors European Technical Centre (TMETC), International Automotive Research Centre, Coventry/United Kingdom	B0604
17:30	<b>Facile Graphene based Materials and its Application as Low Cost Hydrogen Fuel Cell Catalyst</b>  Adriana Marinou, Elena Carcadea, Mircea Raceanu, Constantin Teodorescu, Mihai Varlam National Research and Development Institute for Cryogenics and Isotopic Technologies - ICIT Rm. Valcea, Râmnicu Vâlcea/Romania	A0605	<b>High-Velocity and High-Speed Manufacturing Method and Manufacturing Cost Analysis for PEM Fuel Cell Applications</b>  Mats Wallin (1), Per Cider (1), Martin Skrikerud (2), Christian Koroschetz (2) (1) Cell Impact, Karlskoga/Sweden, (2) AP&T, Ulricehamn/Sweden	B0605
17:45	<b>Progress in High-Temperature PEM Fuel Cells</b>  Robert Kerr, Silvia M. Alfaro, Hector R. Garcia, Thomas Steenberg, Carina Terkelsen, Hans Aage Hjuler Danish Power Systems, Kvistgaard/Denmark	A0606	<b>PANI-Metallic Nanoparticles Double Layer Coating for Bipolar Plates in Polymer Electrolyte Fuel Cells</b>  Ahmad El-kharouf(1), Gaurav Gupta (1), Surbhi Sharma (1), Ole Edward (2), Michael Goetz (2), Anders Ødegard (3) (1) Centre for Fuel Cells and their Fuels, Chemical Engineering, University of Birmingham, Birmingham/United Kingdom, (2) ErlingKlinger, Dettingen&Erms/Germany, (3) SINTEF Materials and Chemistry, Trondheim/Norway	B0606
18:00	<b>End of Sessions</b>			
18:30	<b>Swiss Surprise Registered participants meet between KKL and railway station</b>			

# Thursday, July 2, 2015

## Auditorium

## Kongressfoyer

Morning

Morning

09:00	<b>Keynote: Electrocatalysis of oxygen reduction reaction</b> Frano Barbir, Günther Scherer	<b>A07</b>	<b>Keynote: Status and future of hydrogen technologies</b> Huamin Zhang (tbc)	<b>B07</b>
09:00	<b>Electrocatalysis of Oxygen Reduction Reaction: Catalyst Development, Theory and Model Systems</b> Piotr Zelenay Los Alamos National Laboratory, Los Alamos/New Mexico/United States	A0701	<b>Status and future of hydrogen technologies: Production, purification and storage</b> Trent Molter Sustainable Innovations Inc., East Hartford/(CT)/US	B0701
09:25	5 Min to change to Auditorium for B08 Session			
09:30	<b>FC monitoring &amp; diagnostics</b> Daniel Hissel (tbc), Werner Lehnert	<b>A08</b>	<b>H2 storage in metal hydrides</b> Ulrich F. Vogt	<b>B08</b>
09:30	<b>PEMFC Stack Monitoring with Advanced Total Harmonic Distortion Analysis</b>  Dipl. Ing. Katharina Renner (1), Dipl. Ing. Jürgen Rechberger (2) AVL List GmbH, Graz/Austria	A0801	<b>Nanostructured hydrogen storage materials prepared by high-energy reactive ball milling (HRBM) of magnesium and ferrovandium</b> Jonathan Goh (1), Bulelwa Ntsendwana (1), Mykhaylo Lototsky (1), Roman Denys (2), Volodymyr Yartys (3), Bruno Pollet (1) (1) HySA Systems Competence Centre, SAIAMC, University of the Western Cape, Bellville/South Africa, (2) HYSTORSYS AS, Kjeller/Norway, (3) Institute for Energy Technology, Kjeller/Norway	B0801
09:45	<b>PEM fuel cell operation under air and O2 feed: analysis of cell performance and liquid water distributions</b> Alfredo Iranzo (1), Pierre Boillat (2), Antonio Salva (1), Johannes Biesdorf (2) (1) AICIA-School of Engineering, Thermal Engineering Group, Sevilla/Spain, (2) Electrochemistry Laboratory (LEC) and Neutron Imaging and Activation Group (NIAG), Paul Scherrer Institut (PSI), Villigen/Switzerland	A0802	<b>Nanoconfinement of hydride materials into carbon hosts for reversible hydrogen storages in PEMFCs</b> Rapee Goslawit-Utke School of Chemistry, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima/Thailand	B0802

10:00	<b>Effect of PEM flow field channels orientation in the liquid water distributions and cell performance</b> Alfredo Iranzo (1), Johannes Biesdorf (2), Magali Cochet (2), Antonio Salva (1), Pierre Boillat (2), Felipe Rosa (3) (1) AICIA-School of Engineering, Thermal Engineering Group, Sevilla/Spain, (2) Electrochemistry Laboratory (LEC) and Neutron Imaging and Activation Group (NIAG), Paul Scherrer Institut (PSI), Villigen/Switzerland, (3) Thermal Engineering Group, Energy Engineering Department, University of Sevilla, Sevilla/Spain	A0803	<b>To be announced</b>	B0803
10:15	<b>In situ Diagnostic Tools for Characterization of Pinholes in PEM Fuel Cell Stacks</b> Amir Niroumand (1,2), Mark Olfert (1), Michael Eikerling (2) (1) Greenlight Innovation Corp., Burnaby (BC)/Canada	A0804	<b>Solid State Approaches for Portable H2 Applications</b> James M. Hanlon (1), Laura Bravo Diaz (2), Marek Bielewski (2), Aleksandra Milewska (3), Cédric Dupuis (4), Duncan H. Gregory (1) (1) School of Chemistry, University of Glasgow, Glasgow/United Kingdom, (2) European Commission, DG-JRC, Institute for Energy and Transport, Petten/Netherlands, (3) Institute of Power Engineering, Department of Thermal Processes, Warsaw/Poland, (4) McPhy Energy, La Motte-Fanjas/France	B0804
10:30	<b>Break - Luzerner Saal in the Exhibition &amp; in the Poster Session</b>			
11:00	<b>New Pt-alloy FC catalysts</b> Corsin Battaglia (tbc)	<b>A09</b>	<b>Fuel processing and hydrogen purification</b> Kazunari Sasaki (tbc)	<b>B09</b>
11:00	<b>Opportunities to Improve the Stability and Activity of Electrocatalysts Based on Cu-Core – Pt-Shell Nanoparticles</b> Vladimir Guterman (1), Sergey Belenov (1), Natalya Tabachkova (2) (1) Southern Federal University, Rostov-on-Don/Russia, (2) National Research Technological Univ. "MISIS", Moscow/Russia	A0901	<b>Improved PBI Membranes for High Temperature Electrochemical Hydrogen Purification</b> Kayley Fishel, Yating Mao, Xiaoming Chen, Max Molle, Harry Ploehn, Brian C. Benicewicz University of South Carolina, Columbia (SC)/USA	B0901
11:15	<b>Effect of heat treatment atmospheres of PtNi nanoparticles as an oxygen reduction electrocatalyst</b> Young-Hoon Chung, In Young Cha, Hee Young Park, Soo Jin Kim, Dong Young Chung, Yung-Eun Sung, Sung Jong Yoo, Jin Young Kim, Hyoung-Juhn Kim, Jong Hyun Jang	A0902	<b>On-site hydrogen generation from biodiesel and diesel</b> Stefan Martin (1), Pieter van der Veer (2), David Wails (3), George Karagiannakis (4), Mario Costa (5), José Luis Marcos (6), Ana Casado (7)	B0902

	Fuel Cell Research Center, Korea Institute of Science and Technology (KIST), Seoul/Republic of Korea		(1) German Aerospace Center (DLR), Stuttgart/Germany, (2) HyGear B.V. (HYG), Arnhem/Netherlands, (3) Johnson Matthey PLC. (JM), London/United Kingdom, (4) Centre for Research and Technology Hellas (APTL), Thessaloniki/Greece, (5) Instituto Superior Técnico (IST), Lisbon/Portugal, (6) Abengoa Bioenergía San Roque, S.A. (ABSR), San Roque/Spain, (7) Abengoa Hidrógeno, S.A. (AH), Sevilla/Spain	
11:30	To be announced	A0903	CO free reformat for stationary LT-PEM fuel cells - technical and commercial aspects of selective methanation	B0903
			Lutz Schilling WS Reformer GmbH, Renningen/Germany	
11:45	In-situ X-ray Absorption Spectroscopy Investigations of Cubic Pt Nanoparticles as Cathode Catalyst in PEMFCs	A0904	HIL simulations of a Real-Time Fuel Processor Model	B0904
	Julia Melke, Ditty Dixon, Christina Roth, Helmut Ehrenberg Freie Universität Berlin, Berlin/Germany		Erik Åberg (1), Jens Pålsson (1), Karin Fröjd (1), Karin Axelsson (2), Gregor Dolanc (3), Bostjan Pregelj (3) (1) Modelon AB, Ideon Science Park, Lund/Sweden, (2) PowerCell AB, Göteborg/Sweden, (3) J. Stefan Institute, Ljubljana/Slovenia	
12:00	Improved Oxygen Reduction Activity of Pt-alloys Supported on carbon via formation of Heterogeneous Superhydrophobic Structure	A0905	Study on on-board fuel reforming for hydrogen production using exhaust gas	B0905
	Mahmoud Reda CanadElectrochim, Calgary (AB)/Canada		Seunghyeon Choi (1), Joongmyeon Bae (1), Juheon Lee (2), Jeonghwa Cha (2) (1) Korea Advanced Institute of Science and Technology, Daejeon/Korea, (2) Hyundai Motors, Gyeonggi-do/Korea	
12:15	Development and Scale Up of Enhanced ORR Pt-based Catalysts for PEMFCs	A0906	Operating Strategies for Fuel Processing Systems with Focus on Water-Gas Shift Reactor Stability	B0906
	Francois van Schalkwyk, Gary Pattrick HySA/Catalsis - MINTEK, Randburg/South Africa		Daniel Krekel, Remzi Can Samsun, Joachim Pasel, Matthias Prawitz, Ralf Peters, Detlef Stolten Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research: IEK-3, Electrochemical Process Engineering, Jülich/Germany	
12:30	Lunch & Coffee - Luzerner Saal in the Exhibition & in the Poster Session			
Morning	Auditorium		Kongressfoyer	
	Morning			

**Thursday, July 2, 2015**



# Thursday, July 2, 2015

Luzerner Saal

Afternoon

Afternoon

13:15	<b>Poster Session II</b> covering All Oral Session Topics Frano Barbir,	<b>A10</b>	
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Auditorium

Kongressfoyer

14:30	<b>Degradation studies and modelling</b> Amir Niroumand, Felix Buechi	<b>A11</b>	<b>Membranes for IT &amp; HT PEMFC</b> Hans Aage Hjuler, Stylianos Neophytides (tbc)	<b>B11</b>
14:30	<b>A preliminary study on potential analogies between mechanical fatigue theory and electrochemical PEM Fuel Cells aging induced by load cycling</b> Raffaele Petrone, Daniel Hissel, Marie-Cécile Péra, Didier Chamagne FCLAB Research Federation (FR CNRS 3539), FEMTO-ST / Energy Department (UMR CNRS 6174), University of Franche-Comte , Belfort/France	A1101	<b>Synthesis and characterization of cubic mesoporous silica as additives for proton conducting membranes</b> Christopher. F. Seidler (1), Cedric Müller (1), Dieter Freude (2), Jürgen Haase (2), Michael Wark (1) (1) Institute for Chemistry, Carl-von-Ossietzky University, Oldenburg/Germany, (2) Institute for Experimental Physics, Leipzig University, Leipzig/Germany	B1101
14:45	<b>Sensitivity analysis on the impact of air contaminants on automotive fuel cells</b> Anja Talke (1), Ulrich Misz (2), Gerhard Konrad (1), Angelika Heinzel (2) (1) Daimler AG, Kirchheim/Germany, (2) ZBT GmbH, Duisburg/Germany	A1102	<b>Development of Charge-Transfer Complex Hybrid Films As Alternative PEM For High-Temp PEFC</b> Masamichi Nishihara (1,2), Liana Christiani (3), Feng Shiyan (3), Kazunari Sasaki (1,2,3) (1) International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Fukuoka/Japan, (2) Next-generation Fuel Cell Research Center (NEXT-FC), Fukuoka/Japan, (3) Graduate School of Engineering, Kyushu University, Fukuoka/Japan	B1102
15:00	<b>Mathematical description of voltage decay rates in PEM fuel cells</b> Pawel Gazdzicki, Mathias Schulze, K. Andreas Friedrich German Aerospace Center (DLR), Stuttgart/Germany	A1103	<b>Influence of Temperature Related Operation Faults on HT-PEMFC MEA Performance and Durability</b> Piotr Bujlo, Emmanuel Unathi March, Nkcubeko Mkruqulwa, Sivakumar Pasupathi, Bruno G. Pollet Hydrogen South Africa (HySA) Systems and Validation Centre, University of the Western Cape, Cape Town/South Africa	B1103

15:15	<b>Analysis of the heterogeneities in a PEMFC stack operated with reformat</b> S. Escribano, L. Jacqmin, H. Laforêt, C. Robin, F. Nandjou, L. Guétaz Fuel Cells Forever, Inc CEA-Liten, Grenoble/France	A1104	<b>Multilayer membrane for IT-PEFC</b> Carolina Musse Branco, Kun Zhang, Surbhi Sharma, Robert Steinberger-Wilckens The Centre for Hydrogen and Fuel Cell Research, Birmingham/United Kingdom	B1104
15:30	<b>Local CO Poisoning Modelling for PEM Fuel Cell with Spatial Segmentation</b> Jiayi Gu (1), Rob Thring (1), Gregory Offer (2) (1) Loughborough University, Loughborough/UK, (2) Imperial College, London/UK	A1105	<b>Proton Conductivity of Porous Zirconium-Organic Frameworks with Protic Ionic Liquids</b> Michael Wark (1), Christopher F. Seidler (1), Madita Einermann (1), Mahdi S. Bazarjani (1), Jann Lippke (2), Peter Behrens (2), Tobias von Zons (3), Adelheid Godt (3) (1) Institute for Chemistry, Carl-von-Ossietzky University, Oldenburg/Germany, (2) Institute for Inorganic Chemistry, Leibniz University Hannover, Hannover/Germany, (3) Faculty of Chemistry, Bielefeld University, Bielefeld/Germany	B1105
15:45	<b>Experimental and Modelling Analyses of DMFC Temporary Degradation</b> Matteo Zago, Claudio Rabissi, Andrea Baricci, Andrea Casalegno Politecnico di Milano, Department of Energy, Milano/Italy	A1106	<b>Analysis of crack structures of HT-PEFC electrodes from in-situ synchrotron radiographs</b> Dieter Froning (1), Wiebke Maier (1), Tobias Arlt (2), Ingo Manke (2), Werner Lehnert (1,3) (1) Forschungszentrum Jülich GmbH, Jülich/Germany, (2) Helmholtz-Zentrum Berlin GmbH, Institute of Applied Materials, Berlin/Germany, (3) Modeling in Electrochemical Process Engineering, RWTH Aachen University, Aachen/Germany	B1106
16:00	<b>Break - Luzerner Saal in the Exhibition &amp; in the Poster Session</b>			
16:30	<b>FC fault and degradation modelling</b> Angelo Esposito (tbc), Andrei Kulikovsky	<b>A12</b>	<b>Industrial applications/Microbial fuel cell/Assessments</b>	<b>B12</b>
16:30	<b>Fault Detection and Isolation of Polymer Electrolyte Membrane Fuel Cells Using Bond Graphs</b> Andrey Vasilyev, Dr Sarah Dunnett, Dr Lisa Jackson, Dr Lei Mao Loughborough University, Department of Aeronautical and Automotive Engineering, Loughborough/United Kingdom	A1201	<b>Sustainability assessment of alkaline fuel cells – what can we learn?</b> Brian Cox, Karin Treyer Paul Scherrer Institute (PSI), Villigen/Switzerland	B1201

16:45	<b>Fault Diagnostic Modelling for Polymer Electrolyte Fuel Cells</b> Ben Davies, Lisa Jackson, Sarah Dunnett Loughborough University, Department of Aeronautical and Automotive Engineering, Loughborough/United Kingdom	A1202	<b>Stack Development at AFC Energy- Aiming towards the Deployment of World's Largest Alkaline Fuel Cell System</b> Naveed Akhtar AFC Energy plc., Cranleigh/United Kingdom	B1202
17:00	<b>Evaluation of Performance and Chemical Degradation Phenomena in Reinforced PFSA Membranes: A Theoretical Study</b> Georg Futter (1), Thomas Jahnke (1), Arnulf Latz (1,2) (1) German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Stuttgart/Germany, (2) Helmholtz Institute Ulm for Electrochemical Energy Storage (HIU), Ulm/Germany	A1203	<b>A 50kW PEMFC system durability study at industrial site operated with industry grade hydrogen</b> Jari Ihonen, Timo Keränen, Henri Karimäki, Pauli Koski, Jaana Viitakangas, Heidi Tuiskula, Sonja Auvinen VTT Technical Research Centre of Finland, VTT/Finland	B1203
17:15	<b>Modeling reversible and irreversible degradation in direct methanol fuel cells</b> Thomas Jahnke (1), Arnulf Latz (1,2) (1) German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Stuttgart/Germany, (2) Helmholtz Institute Ulm for Electrochemical Energy Storage (HIU), Ulm/Germany	A1204	<b>High Platinum Cost: Obstacle or Blessing for Commercialization of Fuel Cell Technology</b> Prakash C Ghosh Indian Institute of Technology Bombay, Department of Energy Science and Engineering, Mumbai/India	B1204
17:30	<b>Investigation of PEMFC parameter effects on practical fuel cell system performance</b> Lei Mao, Lisa Jackson, Sarah Dunnett Loughborough University, Department of Aeronautical and Automotive Engineering, Loughborough/United Kingdom	A1205	<b>Booster Technology for Hydrogen Compression – Challenges and Solutions</b> Matthias Blome MAXIMATOR GmbH, Nordhausen/Germany	B1205
17:45	<b>To be announced</b>	A1206	<b>To be announced</b>	B1206
18:00	<b>End of Sessions</b>			
19:30	<b>Dinner on the Lake: Boarding 19.20 Lake side of KKL pier 5/6 , back 23.15 (short stop in Brunnen 22.30, early return by train)</b>			

Afternoon

Auditorium

Kongressfoyer

Afternoon

**Thursday, July 2, 2015**

# Friday, July 3, 2015

Auditorium

Kongressfoyer

Morning

Morning

09:00	<b>New catalyst structures and manufacturing processes</b> Thomas Schmidt (tbc), Francois van Schalkwyk (tbc)	<b>A13</b>	<b>H2 production</b> Naveed Akhtar	<b>B13</b>
09:00	<b>Developing Novel, Near-Optimal Pt Electrodes for Hydrogen Fuel Cells via Theoretical Simulations</b> Alessandro Fortunelli (1,2), William A. Goddard (2), Luca Sementa (1), Giovanni Barcaro (1), Fabio R. Negreiros (1), Andrés Jaramillo-Botero (2) (1) Consiglio Nazionale delle Ricerche (CNR), Pisa/Italy, (2) California Institute of Technology, Pasadena (CA)/USA	A1301	<b>Development and testing of a pressurized PEM electrolyser</b> E. Varkarakis, D. Shapiro, R. Gashi, D. Corson, A. Closset Belenos Clean Power Holding, Marin-Epagnier/Switzerland	B1301
09:15	<b>Three-dimensional catalyst electrodes with PdPt nanodendrites for PEFC applications</b> Yaxiang Lu, Shangfeng Du, Robert Steinberger-Wilckens University of Birmingham, School of Chemical Engineering, Birmingham/United Kingdom	A1302	<b>Degradation of a single cell PEM water electrolyser</b> Jan van der Merwe, Dmitri Bessarabov DST HySA Infrastructure Center of Competence, Faculty of Engineering, North-West University, Potchefstroom/South Africa	B1302
09:30	<b>Study of Pt electrocatalysts for the oxygen reduction reaction fabricated by pulsed laser deposition</b> S. E. Temmel (1), E. Fabbri (1), R. Kötz (1), D. Pergolesi (1), T. Lippert (1), T.J. Schmidt (1,2) (1) General Energy Department, Paul Scherrer Institut, Villigen-PSI/Switzerland, (2) Laboratory of Physical Chemistry, ETH Zürich, Zürich/Switzerland	A1303	<b>High Temperature Alkaline Electrolysis</b> Frank Allebrod, Christodoulos Chatzichristodoulou, Karsten Agersted, Mogens B. Mogensen Technical University of Denmark, Department of Energy Conversion and Storage, Roskilde/Denmark	B1303
09:45	<b>New Physical Technologies for Catalyst Synthesis and Anticorrosion Protection</b> Vladimir Fateev, Anton Glukhov, Sergey Nikitin, Vladimir Markelov, Olga Alekseeva, Sergey Grigoriev NRC Kurchatov Institute, Moscow/Russia	A1304	<b>Water Splitting Using GaN Based Working Electrodes for Hydrogen Generation without Applying Bias</b> Yen Yu Chen (1), Jinn Kong Sheu (1), Ming Lun Lee(2), Wei Chi Lai (1) (1) Department of Photonics, National Cheng Kung University, Tainan City/Taiwan, (2) Department of Electro-Optical Engineering, Southern Taiwan University of Science and Technology, Tainan City/Taiwan	B1304



10:00	<b>Effect of Structure of Nafion and Hydrocarbon Ionomer on Oxygen Solubility</b> Yuya Kurihara (1), Takuya Mabuchi (1), Takashi Tokumasu (2) (1) Graduate School of Engineering, Tohoku University, Miyagi/Japan, (2) Institute of Fluid Science, Tohoku University, Miyagi/Japan	A1305	<b>Demonstration of Novel Platforms for Hydrogen Generation</b> Mohammad H. Hashemi (1), Miguel A. Modestino (1,2), C. Moser (2), D. Psaltis (1) (1) EPFL, Optics Laboratory, School of Engineering, Lausanne/Switzerland, (2) EPFL, Laboratory of Applied Photonic Devices, School of Engineering, Lausanne/Switzerland	B1305
10:15	<b>Oleylamine adsorbed Pt nanoparticles as an anion-adsorption-tolerant electrocatalysts towards oxygen reduction reaction</b> Young-Hoon Chung, In Young Cha, Hee Young Park, Soo Jin Kim, Dong Young Chung, Yung-Eun Sung, Sung Jong Yoo, Jin Young Kim, Hyoung-Juhn Kim, Jong Hyun Jang Fuel Cell Research Center, Korea Institute of Science and Technology (KIST), Seoul/Republic of Korea	A1306	<b>Effective High Pressure Hydrogen Evolution from Formic Acid without any Compressing</b> Hajime Kawanami (1,3), Masatoshi Iguchi (1,3) Yuichi Manaka (2,3), Yuichiro Himeda (2,3) (1) National Institute of Advanced Science and Technology, Research Center for Compact Chemical System, Sendai/Japan, (2) National Institute of Advanced Science and Technology, Energy Technology Research Institute, Ibaraki/Japan, (3) CREST, Japan Science and Technology Agency, Saitama/Japan	B1306
10:30	<b>Break - Ground + First Floor in the Exhibition</b>			
11:00	<b>FC modelling and simulations</b> Andrei Kulikovskiy, Anthony Kucernak (tbc)	<b>A14</b>	<b>FC Mobility applications / Stack and system integration</b> Isotta Cerri, Jianbo Zhang	<b>B14</b>
11:00	<b>Pore network modelling of compressed fuel cell components with OpenPNM</b> Thomas Tranter Energy Research Institute, University of Leeds, Leeds/United Kingdom	A1401	<b>AutoStack – Core – Industry led European consortium to develop next generation automotive stack hardware</b> André Martin (1), Ludwig Jörissen (2) (1) AMC, Idstein/Germany, (2) Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg, Ulm/Germany	B1401
11:15	<b>A comparison between X-ray tomography images of water distribution in a gas diffusion layer and pore network simulations</b> Tristan Agaesse (1), Adrien Lamibrac (3), Felix Buechi (3), Joel Pauchet (1), Manuel Marcoux (2), Marc Prat (2) (1) CEA, LITEN, LCPEM, Grenoble/France, (2) Institut de Mécanique des Fluides de Toulouse, Toulouse/France, (3) Paul Scherrer Institut, Electrochemistry Laboratory Fuel Cell Systems, Villigen/Switzerland	A1402	<b>Characterization of a Fuel Cell Stack for Use in Material Handling Applications</b> Stefan Keller (1), Carsten Cremers (2), André Niedergesäß (2), Tansu Özel (1) (1) Fraunhofer Institute for Solar Energy Systems ISE, Freiburg/Germany, (2) Fraunhofer Institute for Chemical Technology ICT, Pfinztal/Germany	B1402
11:30	<b>Analytical Solutions for PEM Fuel Cell Impedance</b>	A1403	<b>Fuel Cell Applications for Range Extending and HVAC in Future Vehicle Concepts</b>	B1403



11:45	<p>Andrei Kulikovsky Research Centre Juelich, Juelich/Germany</p> <p><b>Advanced CFD Analysis of an Air-cooled PEM Fuel Cell Stack Predicting the Loss of Performance with Time</b></p> <p>Clemens Fink (1), Larisa Karpenko-Jereb (2), Sean Ashton (3) (1) AVL List GmbH, Graz/Austria, (2) Graz University of Technology, Graz/Austria, (3) Intelligent Energy, Loughborough/United Kingdom</p>	A1404	<p>Franz Philipps, Christoph Fischer, Michael Schier German Aerospace Center (DLR), Stuttgart/Germany</p> <p><b>Aircraft APUs: An Economically Viable Niche Market for Fuel Cells?</b></p>	B1404
12:00	<p><b>A computationally efficient hybrid 3D analytic-numerical approach for system level modelling of PEM fuel cells</b></p> <p>Gregor Tavčar, Tomaž Katrašnik</p> <p>Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana/Slovenia</p>	A1405	<p>Lois Milner, Scott Hardman and Robert Steinberger-Wilckens Centre for Hydrogen and Fuel Cell Research, School of Chemical Engineering, The University of Birmingham, Birmingham/United Kingdom</p> <p><b>Changing the Fate of Fuel Cell Vehicles: Lessons from Tesla Motors</b></p>	B1405
12:15	<p><b>Investigation of energy flow rates in Proton Exchange Membrane Fuel Cells using numerical model</b></p> <p>Domenico De Luca, Petronilla Fragiaco, Giuseppe De Lorenzo University of Calabria, Department of Mechanical, Energy and Management Engineering, Rende/Italy</p>	A1406	<p>Scott Hardman, Robert Steinberger-Wilckens, Eric Shiu University of Birmingham, Chemical Engineering, Birmingham/United Kingdom</p> <p><b>Future Mobility Demonstrator: Utilizing renewable excess electricity in the mobility sector</b></p> <p>Urs Cabalzar (1), Marco Brügger (1), Christian Bach (1), Brigitte Buchmann (2) (1) Empa Duebendorf, Automotive Powertrain Technologies Laboratory, Duebendorf/Switzerland, (2) Empa Duebendorf, Department for Mobility, Energy and Environment, Duebendorf/Switzerland</p>	B1406
12:30	<b>Lunch &amp; Coffee - 2nd Floor on the picturesque Terrace of the KKL</b>			

Morning

Morning

Auditorium

Friday, July 3, 2015

Kongressfoyer

Afternoon

Afternoon

13:30	<b>Stack &amp; system integration, operation strategies</b> Bruno Pollet (tbc),	<b>A15</b>	<b>Portable/Back-up/Renewable</b>	<b>B15</b>
13:30	<p><b>Novel Integrated Flow Field (IFF) Design for Higher Performance in Fuel Cell and Electrolyzer</b></p> <p>Michael Pien, Steven Lis, Marvin Warshay, Radha Jalan, Suresh Pahwa ElectroChem Inc., Woburn (MA)/USA</p>	A1501	<p><b>FCH JU HYPER – results from the 100 We HYPER system field testing and risk assessment analysis</b></p> <p>Renaut Mosdale (1), David Milverton (2), Agata Godula-Jopek (3), Cedric Dupuis (4) (1) PaxiTech SAS, Munich/Germany, (2) Institute of Chemical Engineering, PAS, Gliwice/Poland</p>	B1501

13:45	<b>Development of fuel recirculation systems at single cell and stack level for hydrogen fuel impurity studies</b> Pauli Koski, Jari Ihonen, Henri Karimäki, Sonja Auvinen VTT Technical Research Centre of Finland, VTT/Finland	A1502	<b>CFD Modelling of a New PEM Fuel Cell Configuration for Portable Applications</b> Elena Carcadea (1), Derek B Ingham (2), Adriana Marinoiu (1), Mircea Raceanu (1), Mihai Varlam (1), Dorin Schitea (1), Laurentiu Patularu (1) (1) National Research and Development Institute for Cryogenics and Isotopic Technologies - ICIT Rm. Valcea, Râmnicu Vâlcea/Romania, (2) Energy Research Institute (ERI), School of Chemical and Process Engineering, University of Leeds, Leeds/United Kingdom	B1502
14:00	<b>Development of a Fuel Cell System with an Internal Reforming Methanol Fuel Cell</b> Michael Steffen, George Bandlamudi, Frank Filusch, Tobias Meijer, Angelika Heinzel Zentrum für BrennstoffzellenTechnik GmbH, Duisburg/Germany	A1503	<b>PEM Fuel Cell Systems as Backup Solution for POLYCOM Applications</b> Ulrike Trachte, Peter Sollberger, Beat Wellig Lucerne School of Engineering and Architecture, CC Thermal Energy Systems & Process Engineering, Horw/Switzerland	B1503
14:15	<b>Design and Demonstration of an Internal Reforming Methanol Fuel Cell System for Portable Applications</b> George Avgouropoulos (1,2), Sebastian Schlicker (3), Gunther Kolb (3), Stylianos Neophytides (1) (1) Foundation for Research and Technology-Hellas (FORTH), Institute of Chemical Engineering Sciences (ICE-HT), Patras/Greece, (2) Department of Materials Science, University of Patras, Patras/Greece, (3) Fraunhofer ICT-IMM, Fraunhofer Institut für Chemische Technologie Institutsteil IMM, Mainz/Germany	A1504	<b>Hour by hour simulation of solar hydrogen energy system in conjunction with renewable energy sources</b> J. Simunovic, D. Bagaric, N. Goles, D. Bezmalinovic, I. Tolj, G. Radica, F. Barbir FESB University of Split, Split/Croatia	B1504
14:30	<b>Development of bioethanol fuelled fuel cell system for backup applications – PEMBeyond project</b> Henri Karimäki, Jari Ihonen, Pauli Koski VTT Centre Technical Research of Finland, VTT/Finland	A1505	<b>Hybrid Plant Aarmatt – a novel renewable energy concept applying PEM electrolysis</b> Marcel Rindlisbacher Regio Energie Solothurn, Solothurn/Switzerland	B1505
14:45	<b>Efficient H<sub>2</sub>/O<sub>2</sub> polymer electrolyte fuel cells for Re-electrification of Hydrogen Obtained from the Power-to-Gas Process</b> F. N. Büchi (1), C. Peter (1), M. Hofer (1), U. Hannesen (2), T. J. Schmidt (1) (1) Paul Scherrer Institut (PSI), Electrochemistry Laboratory, Villigen/Switzerland, (2) Belenos Clean Power Holding, Marin-Epagnier/Switzerland	A1506	<b>Stand-alone PEMFC system based on solar hydrogen</b> Kréhi Serge AGBLI (1), Daniel HISSEL(1), Marie-Cécile PERA (1), Issa DOUMBIA (2) FCLAB Institute/FEMTO-ST laboratory, Belfort/France, (1) University of Franche-Comte, FEMTO-ST/FCLAB, Belfort/France, (2) University of Felix Houphouët Boigny, Signals and Systems laboratory, Abidjan/Ivory Coast	B1506
15:00	<b>5 Min to change from B15 Session to Auditorium for A16 Session</b>			

# Friday, July 3, 2015

## Auditorium

### Afternoon

15:05	<b>P3: FC-H2 Mobility System</b> Frano Barbir, Thomas Schmidt (tbc)	<b>A16</b>
15:05	<b>Toyota's Next Generation Vehicle Strategy &amp; FCV Development</b> Isotta Cerri Advanced Technology Division, Production Engineering Group, Toyota Motor Europe, Zaventem/Belgium	A1601
15:30	<b>P4: Closing Ceremony</b> O. Bucheli, M. Spirig, Frano Barbir	<b>A17</b>
15:30	<b>Summary by the Chair</b> Frano Barbir FESB University of Split, Split/Croatia	A1701
15:41	<b>Information on Next EFCF: 12th European SOFC &amp; SOE Forum 2016 6th PEFC &amp; H2 Forum 2017</b> Olivier Bucheli, Michael Spirig European Fuel Cell Forum, Lucerne/Switzerland	A1702
15:52	<b>Friedrich Schönbein Award for the Best Poster, Best Science Contribution, Medal of Honour</b> Frano Barbir FESB University of Split, Split/Croatia	A1703
16:03	<b>Thank you and Closing by the Organizers</b> Michael Spirig, Olivier Bucheli European Fuel Cell Forum, Lucerne/Switzerland	A1704
16:15	<b>End of Sessions - End of Conference</b> <b>Good by coffee and travel refreshment in front of the Auditorium</b>	

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 Dr. Joachim Scholta, ZWS, Germany

**A04 Poster Session I** with all Session Topics **Wednesday, 1st July 20 15** **13.15 - 14:30**  
**A10 Poster Session II** with all Session Topics **Thursday, 2nd July 2015** **13.15 - 14:30**

Poster Session	Characterization of FC materials	A05	H2-storage: Material and systems	B05
	<b>Identification and quantification of Pt surface sites and of performance losses for PEM fuel cells by selective chemisorption measurement</b> K. Punyawudho (1), K. Wuttikit (1), Y. Zhang (2), J. R. Monnier (2) (1) Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai/Thailand, (2) Department of Chemical Engineering, School of Engineering and Computing, University of South Carolina, Columbia (SC)/United State	A0507	<b>Rod-like FeOOH Catalyst for Ortho-Para Conversion of Hydrogen</b> Jung Hyun Kim, In Wook Nah, Sarng Woo Karng, Kang-Bong Lee, In Hwan Oh Center for Energy Convergence, Korea Institute of Science and Technology, Seoul/Republic of Korea	B0507
	<b>Comparison of hydrocarbon-type Block and Random copolymer for Polymer Electrolyte Fuel Cells</b> M. A. Barique (1), Akihiro Ohira (1,2), Tatsuya Oshima (3), Masahiro Rikukawa (3) (1) Fuel Cell Cutting-Edge Research Center (FC-Cubic) TRA, Tokyo/Japan, (2) Research Institute for Ubiquitous Energy Devices, AIST, Ikeda/Osaka, (3) Department of Materials and Life Sciences, Sophia University, Tokyo/Japan	A0508	<b>CO2 Methanation Under Atmospheric Pressure Conditions on a Ni catalyst: Experiments and Kinetic Modelling</b> Magda Katoufa (1), Emanuele Giglio (2), Dimitris Katsourinis (1), George Vourliotakis (1), Samir Bensaid (2), Fabio Deorsola (2), Raffaele Pirone (2), Guido Saracco (2), Maria Founti (1) (1) National Technical University of Athens, Athens/Greece, (2) Politecnico di Torino, Torino/Italy	B0508
	<b>La2TiO5-based Solid Oxides for SOFC Applications. Characterisation and Processing</b> Nicoleta Cioatera (1), Elena-Adriana Voinea (1), Aurelie Rolle (2), Cezar-Ionut Spinu (1), Rose-Noelle Vannier (2) (1) University of Craiova, Department of Chemistry, Craiova/Romania, (2) Unité de Catalyse et de Chimie du Solide, Equipe de Chimie du Solide, UMR CNRS 8181, ENSCL/UST, Lille/France	A0509	<b>Measurement of hydrogen quantity adsorbed in carbon nanostructures using volumetric method</b> Salim Daoudi (1,2), Nadjima Benkara Mohammed (1,3), Bouzid Chebbah (1) (1) Faculty of Sciences and Technology, Bordj Bou Arréridj University, El Anasser/Algeria, (2) LPMRN laboratory, Bordj-Bou-Arreridj University, El Anasser/Algeria, (3) SISM Laboratry, Setif University, Setif/Algeria	B0509
	<b>Effect of Sr Addition on Electrical Conduction Behavior of RE-doped Ceria</b> Elena-Adriana Voinea, Nicoleta Cioatera, Mariana Osiac, Cezar-Ionut Spinu University of Craiova, Craiova/Romania	A0511		



Poster Session	Non-precious metal FC catalysts	A06	FC membranes & other components	B06
	<b>Ultralow Platinum Decorated Self-active Ordered Mesoporous Carbon for Oxygen Reduction Reaction</b> Sun-Mi Hwang (1), Sang Hoon Joo (2), Gu-Gon Park (1), Sung-Dae Yim (1) (1) Korea Institute of Energy Research, Daejeon/Republic of Korea, (2) School of Nano-Bioscience and Chemical Engineering, Ulsan National Institute of Science and Technology, Ulsan/Republic of Korea	A0607	<b>Optimization of Pack Chromising Process Parameters for Proton Exchange Membrane Fuel Cells Bipolar plates using Box–Behnken Experimental Design</b> A. Oladoye, K. Benyounis, J. Stokes (1), A. Olabi School of Mechanical and Manufacturing Engineering, Dublin City University, Dublin/Ireland, (2) University of the West of Scotland, Paisley/United Kingdom	B0607
			<b>Proton exchange membranes prepared from multi-block copolymers based on poly(arylene ether ketone)</b> Kyuhyun Kang, Dukjoon Kim School of Chemical Engineering, Sungkyunkwan University, Kyunggi/Republic of Korea	B0608
	FC monitoring & diagnostics	A08		
	<b>Frequency dependent perturbation amplitude EIS measurement optimization for impedance measurements in a commercial PEM fuel cell</b> J. J. Giner-Sanz, E. M. Ortega, V. Pérez-Herranz IEC group, Depto. Ingeniería Química y Nuclear, Universitat Politècnica de Valencia, Valencia/Spain	A0807	<b>Development of new hybrid membranes for DMFC</b> Rubén Beneito (1), Agustín Merlos (1), Mayte Gil (2), Inés Monfort (2) (1) Technological Institute of children's products & leisure (AIJU), Alicante/Spain, (2) Technological Institute of Energy (ITE), Valencia/Spain	B0609
	<b>FFT based linearity study of a commercial PEM fuel cell</b> J. J. Giner-Sanz, E. M. Ortega, V. Pérez-Herranz IEC group, Depto. Ingeniería Química y Nuclear, Universitat Politècnica de Valencia, Valencia/Spain	A0808	<b>Silica-sulfonic acid-functionalized hybrid membranes synthesized by sol-gel for direct methanol fuel cells</b> Jadra Mosa, Alicia Durán, Mario Aparicio Instituto de Cerámica y Vidrio (CSIC), Madrid/Spain	B0610
	<b>Comment on the Application of Cyclic Voltammetry for the Determination of Specific Activity of Oxygen Reduction at the Cathode of Fuel Cell</b> M. Reda (1,2) (1) CanadElectrochim, Calgary (AB)/Canada, (2) Department of Chemical Engineering, Kuwait University, Kuwait-City/Kuwait	A0809	<b>Polysulfone based Nanocomposite Membranes for Alkaline Fuel Cell Applications</b> Nomthandazo Mutangwa (1), Patrick Nonjola (1), Jaqueline Tembu (2), Thabani Mhlongo (2), Kenneth Oezomena (1) (1) CSIR, Material Science and Manufacturing, Pretoria/South Africa, (2) Tshwane University of Technology, Pretoria/South Africa	B0611
	<b>Inductance at Low Frequencies in Electrochemical Impedance Spectroscopy of PEM Fuel Cells</b> I. Pivac, B. Simic, D. Bezmalinovic, I. Tolj, G. Radica, F. Barbir FESB University of Split, Split/Croatia	A0810		

<b>New Pt-alloy FC catalysts</b>	<b>A09</b>	<b>H2 storage in metal hydrides</b>	<b>B08</b>
<b>SnO<sub>2</sub>-modified Pt electrocatalyst for ammonia-fueled anion exchange membrane fuel cell</b> Takeou Okanishi, Yu Katayama, Hiroki Muroyama, Toshiaki Matsui, Koichi Eguchi Graduate School of Engineering, Kyoto University, Kyoto/Japan	A0907	<b>Effect of Ni addition on hydrogen storage capacity of beryllium intermetallic compound</b> Jae-Hwan Kim (1), Hirotomo Iwakiri (2), Masaru Nakamichi (1); (1) Fusion Research & Development Directorate, Japan Atomic Energy Agency, Aomori/Japan, (2) Faculty of Education Elementary and Secondary School Teacher Training Program, University of the Ryukyus, Okinawa/Japan	B0807
<b>Pd<sub>x</sub>Ir<sub>y</sub>/C for Hydrogen Oxidation Reaction</b> Fotini Tzorbatzoglou (1), Angeliki Brouzgou (1), Panagiotis Tsiakaras (1,2); (1) Laboratory of Alternative Energy Conversion Systems, Department of Mechanical Engineering/University of Thessaly, Volos/Greece, (2) Laboratory of Electrochemical Devices based on Solid Oxide Proton Electrolytes/Institute of High Temperature Electrochemistry, Yekaterinburg/Russia	A0908	<b>Fuel processing and hydrogen purification</b>	<b>B09</b>
<b>Highly Durable Non-Precious Nitrogen-doped Graphene Electrocatalysts for Alkaline Fuel Cells</b> Stephen M. Lyth (1), Jianfeng Liu (2), Takeshi Daio (3), Kazunari Sasaki (1,2,3,5); (1) International Institute for Carbon-Neutral Energy Research (I2CNER), Fukuoka/Japan, (2) Department of Mechanical Engineering, Fukuoka/Japan, (3) International Research Center for Hydrogen Energy, Fukuoka/Japan, (4) Next Generation Fuel Cell Research Center (NEXT-FC), Fukuoka/Japan, (5) Kyushu University, Fukuoka/Japan	A0909	<b>Low Temperature Methanol Steam Reformer with Heat Exchanger Structure Thermally Integrated with a HT-PEMFC</b> Sonja Auvinen, Francisco Vidal Vazquez, Jari Pennanen VTT Technical Research Centre of Finland, VTT/Finland	B0907
<b>Hydrogen Polymer Electrolyte Fuel Cell performance on Low Platinum PdPt Anode</b> Angeliki Brouzgou (1,2), Fotini Tzorbatzoglou (1), Panagiotis Tsiakaras (1,2); (1) Laboratory of Alternative Energy Conversion Systems, Department of Mechanical Engineering/University of Thessaly, Volos/Greece, (2) Laboratory of Electrochemical Devices based on Solid Oxide Proton Electrolytes/Institute of High Temperature Electrochemistry, Yekaterinburg/Russia	A0910	<b>Hydrogen Gas Purifiers for Fuel Cells</b> Marco Succi, Giorgio Macchi, Simona Pirola, Cristian Landoni Saes Getters Spa, Milan/Italy	B0908
<b>Development of a PtCo/C catalyst manufacturing and stabilization method</b> Christoph Grimmer, Alexander Schenk, Birgit Pichler, Markus Perchthaler, Viktor Hacker; Graz University of Technology, Institute of Chemical Engineering and Environmental Technology, NAWI, Graz/Austria	A0911	<b>Experimental study on diesel reforming with hydrogen peroxide</b> Gwangwoo Han, Minseok Bae, Joongmyeon Bae Department of Mechanical Engineering, KAIST, Daejeon/Republic of Korea	B0909
		<b>A 1kW Gasoline Fuel Processors for Mobile PEMFCs</b> Inyong Kang, Woojin Kang, Byounggwon Gwak, Younggil Choi; H&power, Inc., Daejeon/Republic of Korea	B0910

<b>Degradation studies and modelling</b>	<b>A11</b>	<b>Membranes for IT &amp; HT PEMFC</b>	<b>B11</b>
<b>Siloxane effects on proton exchange membrane fuel cell</b> Da-Yeong Kim, Ji-Sung Seo, Yong-Min Jung, Young-Gi Yoon, Tae-Young Kim Hydrogen and Fuel Cell Center for Industry, Academy, and Laboratories, Korea Institute of Energy Research (KIER), Jellabuk-do/Republic of Korea	A1107	<b>Optimization of Poly2,5 benzimidazole(ABPBI) membrane for high temperature fuel cell application</b> Ratikanta Nayak, Prakash C. Ghosh Fuel Cell Research Facility, Department of Energy Science and Engineering, Indian Institute of Technology Bombay, Mumbai/India	B1107
		<b>Investigations on the H<sub>3</sub>PO<sub>4</sub>-Uptake of Polybenz-imidazole type Polymers using RAMAN Spectroscopy</b> Carsten Korte, Fosca Conti, Jürgen Wackerl, Susanne Kuhri, Werner Lehnert Forschungszentrum Jülich GmbH, Jülich/Germany	B1108
<b>FC fault and degradation modelling</b>	<b>A12</b>		
<b>New catalyst structures and manufacturing processes</b>	<b>A13</b>	<b>Industrial applications/Microbial fuel cell/Assessments</b>	<b>B12</b>
<b>Structure and proton dynamics in catalytic layer for HT-PEFC</b> Marina Khanefit (1), Olaf Holderer (1), Oxana Ivanova (1) Reiner Zorn (2), Wiebke Lüke (3), Werner Lehnert (3,4), Emmanuel Kentzinger (2) (1) FZ Jülich, JCNS at MLZ, Garching/Germany, (2) FZ Jülich, IEK-3, Jülich/Germany, (3) Institute of energy and climate research, Forschungszentrum Jülich GmbH, Jülich, Germany, (4) RWTH Aachen University, Faculty of Mechanical Engineering Aachen/Germany	A1307	<b>Start-up approach based on hybrid system emulator for a pressurized Solid Oxide Fuel Cell Gas Turbine</b> U.M. Damo (1), M.L. Ferrari (2), A. Turan (1), A.F. Massardo (2) (1) School of Mechanical, Aerospace and Civil Engineering, The University of Manchester, Manchester/UK, (2) Thermochemical power group, University of Genoa, Genoa/Italy	B1207
<b>Fibrous and tubular structures for PEMFC catalyst supports combining electrospinning, heat treatments and atomic layer deposition (ALD)</b> Antti T. Pasanen (1), Pirjo Heikkilä (1), Matti Putkonen (1), Elina Yli-Rantala (1), Markus Bosund (2), Mika Vähä-Nissi (1) (1) VTT Technical Research Centre of Finland, Tampere/Finland, (2) Beneq Oy, Espoo/Finland	A1308	<b>Eco-friendly textile dye degradation coupled to bioelectricity generation using Microbial Fuel Cell (MFC) technology</b> Hilor Pathak, Dhatri Chaudhari Department of Microbiology, P.D. Patel Institute of Applied Sciences, Charotar University of Science and Technology (CHARUSAT), Gujarat/India	B1208
<b>Synthesis of Carbon Supported Platinum Nanoparticles via Sputtering onto Liquid and their Oxygen Reduction Activities</b> In Young Cha (1,2), Minjeh Ahn (1), Young-Hoon Chung (2), Hee-Young Park (2), Sung Jong Yoo (2), Jong Hyun Jang (2,3), Yung-Eun Sung (1)	A1309	<b>Landfill Leachate: A Promising Substrate for Microbial Fuel Cells</b> Jayesh M. Sonawane, Prakash C. Ghosh Fuel Cell Research Facility, Department of Energy Science and Engineering, Indian Institute of Technology Bombay, Mumbai/India	B1209

(1) Seoul National University, School of Chemical and Biological Engineering, Seoul/Republic of Korea, (2) Fuel Cell Research Center, Korea Institute of Science and Technology (KIST), Seoul/Republic of Korea, (3) Green School, Korea University, Seoul/Republic of Korea

## FC modelling and simulations

A14

## Accessing Fuel Cell opportunities in European Research and Innovation

B1210

### 2D modeling of two-phase multicomponent transport in direct methanol fuel cells

A1408

Nicole Wyss, Julian Randall  
Euresearch, Bern/Switzerland

Marie-Dominique Baum (1), Thomas Jahnke (1), Arnulf Latz (1,2); (1) German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Stuttgart/Germany, (2) Helmholtz Institute Ulm for Electrochemical Energy Storage (HIU), Ulm/Germany

### Enhanced Electron Transfer by a Magnetic Self-assembled Conductive Fe<sub>3</sub>O<sub>4</sub>/Carbon Nanocomposites in E. coli-Catalyzed Mediator-less Microbial Fuel Cells

B1211

### Dynamic and multiphysic modelisation of a PEM electrolyser using the Bond Graph modelling tool

A1409

Pierre Olivier, Cyril Bourasseau  
CEA Grenoble (DRT/LITEN/DTBH/SCSH/L2ED), Grenoble/France

Hyo Seok Park, Kwang Uk Moon, Jong Ju Lee, Yong Bin Kim, Kee Suk Nahm  
Department of Energy Conversion and Storage Engineering, School of Chemical Engineering, Chobnuk National University, Jeonju/Republic of Korea

## Stack and system integration, operation strategies

A15

## H<sub>2</sub> production

B13

### Development and Characterization of a LT-PEFC Stack with an Extended Temperature Range up to 120 °C

A1507

Andreas Dreizler, Tiziana Ruiu, Jens Mitzel, Erich Gültow  
German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Stuttgart/Germany

### Catalytic Dehydrogenation of NaBH<sub>4</sub> Solution across Pin Fin Structures in a Microchannel Reactor

B1307

Ki Moon Jung (1), Seok Hyun Choi (1), Moon-Sun Chung (2), Hee Joon Lee (1)  
(1) School of Mechanical Engineering, Kookmin University, Seoul/Republic of Korea, (2) Hydrogen Energy R&D Center, Korea Institute of Energy Research, Daejeon/South Korea

### Development of an electrical backup power supply based on a novel hybrid fuel cell system

A1508

V. Lukassek (4), M. Metzen (1), T. Hickmann (2), W. Möring (3), A. Heinzl (4); (1) University Duisburg-Essen, Duisburg/Germany, (2) Eisenhuth GmbH, Osterode am Harz/Germany, (3) ehb GmbH, Langenhagen/Germany, (4) The Fuel Cell Research Center (ZBT), Duisburg/Germany

### Effect of Iron Oxide Nanoparticles on Dark Fermentative Hydrogen Production from Molasses based Distillery Wastewater

B1308

Sameena. N. Malik (1), Kodhaiyolii Shanmugam (2), Atul. N. Vaidya (1), Prakash C. Ghosh (3), Gajanan. S. Kannade (1), Pugalanthi Velan (2), Sandeep. N. Mudliar (1)  
(1) CSIR – National Environmental Engineering Research Institute, Maharashtra/India, (2) Department of Biotechnology, Bharathidasan Institute of Technology, Anna University, Tiruchirappalli/India, (3) Department of Energy Science & Engineering, Indian Institute of Technology, Bombay/India



Hydrogen recovery and electricity production from an electrocoagulation process using a PEMFC

E. Torralba-Calleja, A. Serra, D. Galí, M. Della Pirriera, J. García-Montaña

LEITAT Technological Center, Barcelona/Spain

A1509

**In-situ O3 rejuvenation of SO2 contaminated Polymer Electrolyte Fuel Cell: Electrochemistry, single cell and 5-cells stack studies**

Biraj Kumar Kakati (1,2), Anthony RJ Kucernak (1)

(1) Department of Chemistry, London/United Kingdom, (2) Department of Energy, Tezpur/India

B1309

**Design, modelling and simulation of a 1kW fuel cell power generator system**

Makani Mwinga\*, Ben Groenewald, Michael McPherson  
Cape Peninsula University of Technology, Cape Town/South Africa

A1510

**FC Mobility applications / Stack and system integration**

B14

**New direct alcohol and hydrogen fuel cells for naval and aeronautical applications (PILCONAER)**

B1407

Carmen del Río (1), Enrique Morales (1), Miguel A. Raso (2), Isabel Carrillo (3), Eleuterio Mora (3), Emilio Navarro (3), Teresa J. Leo (3), Eduardo Lopez (4), María Carmen García (4), Jesús Maellas (4), Berta Moreno (5), Eva Chinarro (5), Jadra Mosa (5), Mario Aparicio (5)

(1) Institute of Polymer Science and Technology (ICTP-CSIC), Madrid/Spain, (2) Fac. CC. Químicas – Universidad Complutense de Madrid, Madrid/Spain, (3) ETSI Navales – Universidad Politécnica de Madrid, Madrid/Spain, (4) Dep. Renew. Energy, National Institute for Aerospace Technology (INTA), Madrid/Spain, (5) Institute of Ceramic and Glass, (ICV-CSIC), Madrid/Spain

**Portable/Back-up/Renewable**

B15

**Hour by hour simulation of solar hydrogen energy system in conjunction with renewable energy sources**

J. Simunovic, D. Bagaric, N. Goles, D. Bezmalinovic, I. Tolj, G. Radica, F. Barbir

FESB University of Split, Split/Croatia

B1507

**Development of a Reliable Hydrogen Gas Sensor for Leak Detection in Fuel Cell Vehicles**

B1408

Hiroki Yamamoto, Nobuaki Murakami, Yuri Kuwahara, Saori Yamashita, Takashi Matsumoto, Mitsuharu Kira, Hiroshi Koda, Kiyonori Ono FIS Inc., Itami Hyogo/Japan

**Optimization of diesel powered FC-based APU power and battery capacity for specified load demand**

B1409

Bostjan Pregelj (1), Daniel T. McGuniness (2), Janko Petrovcic (1), Gregor Dolanc (1), Vladimir Jovan (1)

(1) J. Stefan Institute, Ljubljana/Slovenia, (2) Istanbul Technical University, Electrical & Electronics Faculty, Istanbul/Turkey

**Virtualisation of Fuel Cell Hybrid Electric Vehicle Powertrains in a RTD Laboratory Environment**

B1410

Dr.-Ing. Bruno Gnörich; RWTH Aachen University, Institute of Automobile Engineering (ika), Aachen/Germany



International FUEL CELL and HYDROGEN Conference

# 5<sup>th</sup> EUROPEAN PEFC & H<sub>2</sub> FORUM 2015

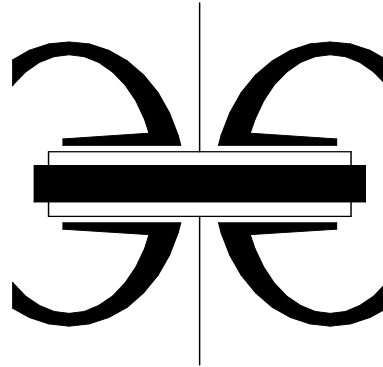
30 June – 3 July 2015

Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

Chaired by

**Prof. Dr. Frano Barbir**

FESB University of Split, Fellow IHAE



## Abstracts of all Oral and Poster Contributions

### Legend:

- The program includes three **major thematic blocks** with keynotes:
  1. International (USA, SA, China, ..) and EU Overviews of Strategies, Programs; R&D and Commercialisation Activities
  2. FC Material, Catalysis, Membranes, Advanced Diagnostic, Characterisation, Modelling and Stack-System Integration and mobile applications with an outlook from Toyota
  3. H<sub>2</sub> production (electrolysis, with renewable power) and H<sub>2</sub> storage as well as microbial and other fuel cell technologies
- **Abstracts** are identified and preliminarily sorted by presentation number (= EFCF-ID) e.g. A0504, B1205, etc. first all A and then all B. However some very similar session topics like A08-A11-A12-A14 (diagnostics, monitoring, degradation, ..) were grouped to chapters, which correspond to the chapters of the proceedings (see stick and [www.EFCF.com/Lib](http://www.EFCF.com/Lib))
  - Oral abstracts consist of numbers where last two digits are lower than 07
  - Poster abstracts are linked to related sessions by letter and first two digits: e.g. A05.., B10, ...etc
  - Due to late changes some numbers (second two digits) are missing or changed

## Chapter-Session-Overview

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A0101

## Welcome by the Organizers

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A0102

## Welcome by the Chairs

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A0103

## Welcome to Switzerland the Smart Research Place

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contact the authors directly for further information.

A0104 (Plenary)

## The Status of Hydrogen Fuel Cells and H<sub>2</sub> R&D in the Fuel Cell and Hydrogen Joint Undertaking Program

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### Abstract

The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) was set up in 2008 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, to match RTD activities to industry's needs and expectations and to scale-up and intensify links between the Industry Community and the Research Community.

Projects under FCH aim to improve performance and reduce the cost of products as well as demonstrate on a large scale the readiness of the technology to enter the market in the fields of energy (hydrogen production and distribution, energy storage and stationary power generation) and transport (cars, buses and refuelling infrastructure). Within the energy pillar the objective is to accelerate the commercialisation of FCH technologies in the fields of fuel cells for stationary applications (e.g. combined heat and power, power and portable systems) and for technologies for hydrogen production, storage and distribution. In the transport pillar the priority lays in Fuel Cell vehicle and infrastructure development and deployment, with technologies in FC vehicles, Auxiliary Power Units (APU), Hydrogen storage and supply.

Up to now a total of 155 projects with 545 different participants (28% of SMEs) from 22 EU Member States have been supported under FCH, 15 new projects are currently under Grant Agreement preparation. By supporting such a project portfolio, FCH JU is going to reach most of the objectives set-up at European level mainly in terms of potential reduction of costs through sufficient number of units demonstrated across Europe in transport and stationary applications. The EU public support will continue for the next period of 2014-2020 for activities with an advanced TRL, moving towards market penetration of the FCH technologies.

The purpose of this presentation is to address the existing portfolio of projects supported by the FCH JU and FCH 2 JU particularly in view of the 5th EUROPEAN PEFC & H<sub>2</sub> FORUM topics. Additionally an overview on the next step for funding projects in the field of fuel cells and hydrogen technologies under the Horizon 2020, the new Framework Program of the European Commission.

## A0105 (Plenary)

### DOE Hydrogen and Fuel Cells Program

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#### Abstract

Fuel cells are highly efficient energy conversion devices; they can operate on fuels such as natural gas, methane, and methanol as well as hydrogen from clean, renewable resources. The U.S. Department of Energy's Hydrogen and Fuel Cell Program, part of President Obama's all-of-the-above energy strategy, supports a broad portfolio of activities to build a competitive and sustainable clean energy economy. The focus is on the transportation sector.

Reducing cost and increasing durability remain as the major challenges in the advancement of fuel cell technology. To address these challenges, the Program maintains a portfolio of research projects aimed at meeting technical and cost targets that allow fuel cells to compete in the marketplace. These projects will be discussed in this presentation. The Program also carries out activities that support the growth of early markets such as material handling equipment and backup power and those activities will be discussed.

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## A0106 (Plenary)

### Electrochemical Hydrogen Compression and Separation (EHC&S): Demonstrator Developed by HySA Infrastructure

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#### Abstract

The Department of Science and Technology of South Africa developed the National Hydrogen and Fuel Cells Technologies (HFCT) Research, Development and Innovation (RDI) Strategy. The National Strategy was branded Hydrogen South Africa (HySA). The overall goal of HySA is to develop and guide innovation along the value chain of hydrogen and fuel cell technologies in South Africa. Allied to this one of the goals is to support developing a range of high-level skills, generally in accordance with the required human capital development strategy.

Other primary objectives of HySA include:

- (I) Wealth creation through value added manufacturing (this will be achieved by developing the platinum group metal (PGM) catalysis value chain in South Africa);
- (II) Development of hydrogen infrastructure (this will be achieved by developing local cost competitive hydrogen generation solutions based on renewable resources);
- (III) Equity and inclusion in sharing the economic benefit derived from South Africa's mineral endowment (this will be achieved through creating a viable industry for the finished products that will create jobs and boost economic growth, for the benefit of all South Africans); and
- (IV) Stimulation of PGM (in particular platinum) demand.

HySA has been established consisting of three Centres of Competence – HySA Infrastructure, HySA Catalyst and HySA Systems. The HySA Infrastructure (Hydrogen Production, Storage and Delivery) Centre of Competence, HySA Infrastructure in short, co-hosted by the North-West University (NWU) and Council for Scientific and Industrial Research (CSIR), and directed by Dr Dmitri Bessarabov

This paper will report on the general activities of HySA in South Africa as well as focus at the electrochemical technology for hydrogen compression and separation.

## A0201 (Plenary)

**The development of fuel cell for automotive application in Asia**

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**Abstract**

From a statistical analysis of the survey results of PEMFC papers and patents, the position and features of Asia in the research of fuel cell for automotive application are elucidated. The technology used in Toyota's FCV MIRAI and the underlying fundamental research are introduced. The roadmap and status of FCV commercialization of Japan, as well as the grand strategy for the hydrogen society, is described. The basic stance, major events and key players of China in the development of FCV are compared. Finally, which country and which companies are leading the world in FCV are discussed from a multitude of perspectives, including the number of papers/patents, the amount of investment, the key performance indicators of the fuel cell stack, etc.

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Please contact the authors directly for further information.

## A0701 (Keynote, Abstract only)

**Electrocatalysis of Oxygen Reduction Reaction: Catalyst Development, Theory and Model Systems**

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**Abstract**

In this presentation, we will provide an overview of the state of oxygen reduction reaction (ORR) electrocatalysis on non-precious metal catalysts (NPMCs) for polymer electrolyte fuel cells (PEFCs). In particular, we will review NPMC research at Los Alamos National Laboratory, concentrating on the development of catalysts for both acidic and alkaline fuel cell cathodes, design of model systems and theory of the active site.

Electrocatalytic activity of ORR catalysts often determines the performance of polymer electrolyte fuel cells, especially their power output, open circuit voltage, and fuel conversion efficiency. Pt-nanoparticle catalysts, supported on high surface-area carbons, represent the state of the art in ORR electrocatalysts for the polymer electrolyte fuel cell cathode, which accounts for approximately 80% of the Pt loading in a typical automotive PEFC. However, the high price, scarceness and price volatility of Pt have limited its widespread implementation in the PEFC cathode. Consequently, non-precious metal catalysts for oxygen reduction have received much attention in recent years as possible replacement of Pt-based formulations. The progress achieved since the early work of Jasinski (*Nature* **201**, 1212, 1964), mostly via broad implementation of the high-temperature synthesis approach (Lefevre *et al.*, *Science* **324**, 71, 2009; Wu *et al.*, *Science* **332**, 443, 2011), make replacement of Pt in ORR electrocatalysts with earth-abundant elements, such as Fe, Co, N, and C, a realistic possibility.

A successful ORR catalyst must combine high activity with good long-term stability – a major challenge in the strongly acidic environment of the PEFC cathode. The NPMC performance depends on the selection of precursors, synthesis chemistry and catalyst nanostructure. Apart from possible direct participation in the active site, the transition metal is crucial to *in-situ* formation of carbon nanostructures (nanotubes, onion-like structures, graphene) by catalyzing the decomposition of the nitrogen/carbon precursor(s) at high temperatures (800-1000°C).

The much needed continued progress in ORR electrocatalysis at NPMCs, especially in acid media, will likely depend on a better understanding of the origin of catalytic activity and nature of active site. Those elements of NPMC development will be addressed in this presentation, along with a summary of the progress accomplished to date and challenges still awaiting non-precious metal electrocatalysis in polymer electrolyte fuel cells.

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## B0701 (Keynote, no Abstract)

### **Status and future of hydrogen technologies: Production, purification and storage**

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Remark: Keynote presentation must not have an abstract.  
Please contact the author directly for further information.

## A1601 (Plenary, no Abstract)

### **Toyota's Next Generation Vehicle Strategy & FCV Development (A1601)**

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## Chapter 02 - Session A03

### Durability stress test results

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## A0301 (Abstract only)

### Start-up/shut-down effect on PEMFC stack durability

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#### Abstract

PEMFC systems are nowadays considered as promising energy sources for transportation and/or stationary applications. However, the durability of the PEMFC system is still the major hurdle to their commercialization because of the degradation rate of the fuel cell stack [1].

On the one hand, it is now well established that the operating conditions such as reactant humidity, stoichiometry, pressure and temperature play a major role in the durability of the stack components such as the membrane, the catalysts and the bipolar plate materials [2]. These working conditions are often imposed by the application and the system environment and cannot be softened even more without lowering the performances targets. On the other hand, stack degradation is also closely linked to the dynamic strategy chosen for transient phases such as start-up and shut-down of the system. These steps can indeed generate harsh corrosion phenomena due to internal current circulation within the cell [3, 4] due to fuel starvation and/or non-optimized reactant management (see Figure 1). On the whole, the overall stack durability can mostly be set by the system management during these transient steps.

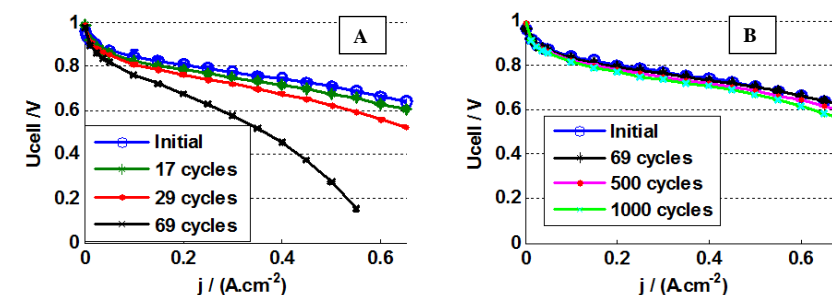


Figure 1. Evolution of performances on short stacks during start-up/shut-down cycles. Impact of air content within the stack. A) Start-up with air-filled anode before H<sub>2</sub> injection; B) Limited air content before H<sub>2</sub> injection. Polarization curves conditions: 80°C, 1.5 bar, RH 50/50%, Stoichiometry H<sub>2</sub>/Air 1.5/2.

We studied the impact of start-up and shut-down strategies on short stacks using test benches in order to i) control precisely the experimental parameters and ii) make it possible to characterize periodically the performances and electrochemical properties of the cell (H<sub>2</sub> permeation current, catalyst surface area). The influence of air content within the stack, reactant flow rate, gas injection order and reactant consumption were investigated so as to get further insights in their respective contribution on the degradation rate. This sensitivity study shall help the definition of mitigation strategies to be implemented on PEMFC system according to their architecture and environment.

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Remark: Only short abstract was available at the time of completion.  
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A0302

## Start/Stop Cycling Test in a PBI-based High Temperature Polymer Electrolyte Membrane Fuel Cell

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## Abstract

Start/stop cycling tests are designed to simulate the fuel cell system shut-down and restart that occurs in actual system operation. During start and stop procedure, localized starvation of fuel during short periods of time may induce local potentials on the cathode up to 1.8 V vs. NHE. For polybenzimidazole based HT-PEMFCs, idling temperature during shut-down can play an important role as residual product liquid water from the cell may drag phosphoric acid out of the fuel cell and consequently fuel cell performance is reduced after restarting the system. In the present work, a commercial PBI-based MEA from Danish Power Systems Ltd. has been evaluated in a start/stop cycling test. Start/stop cycling has been conducted on a daily basis until completing 60 cycles or reaching end-of-life. The fuel cell has been operated at 160 °C in operational mode and has been kept 100 °C during the idling mode. Moreover, a specific flushing strategy with N<sub>2</sub>/N<sub>2</sub> has been followed during shut-down, idle and start-up periods of time. Polarization curves, electrochemical impedance spectroscopy, cyclic and linear sweep voltammetry are utilized for characterizing the MEA. The fuel cell operating under start/stop cycling conditions has shown a voltage degradation rate of -57 µV/h or -2.4 mV/cycle. Moreover, the N<sub>2</sub> flushing strategy has allowed that the fuel cell voltage during shut-down procedure was over 0.2 V for almost 5 h during each and every one of the start/stop cycles. Thus, the fuel cell may feature both carbon catalyst support and carbon porous media structure corrosion.

## A0303 (Fuel Cells SI publication candidate)

### Impact of Accelerated Stress Tests on High Temperature PEMFC Degradation

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#### Abstract

High temperature proton exchange membrane fuel cells represent one promising fuel cell type due to the simplified fuel cell system design, attractive for portable and stationary applications. For commercialization, they require an improvement of performance and durability with regard to long-term operations. Therefore, understanding of degradation processes inside the cell is essential. Accelerated stress tests have been used to provoke and investigate degradation mechanisms inside the fuel cell. A novel load cycling test procedure using high current densities (16 min at 1.0 Acm<sup>-2</sup> / 4 min at 0.6 Acm<sup>-2</sup> / every 6 h 10 min at 0.0 Acm<sup>-2</sup>) has been developed. In comparison to this novel load cycling, a standardized test implying low currents (16 min at 0.3 Acm<sup>-2</sup> / 4 min at 0.0 Acm<sup>-2</sup>) has been performed. A high comparability between results is ensured by testing membrane electrode assemblies from the same supplier and batch under identical test conditions. Daily electrochemical characterization (polarization curves, electrochemical impedance spectroscopy, linear sweep and cyclic voltammetries), product water analysis by inductively coupled plasma mass spectrometry as well as cross sectional imaging of the used cells via micro-computed tomography has been carried out. Clear differences on degradation results have been identified between the different ageing tests. On the one hand, load cycling at low currents led to stronger decrease in electrochemically active surface area of the catalyst than operation at high cycled currents. On the other hand, load cycling at high currents resulted into comparatively high phosphoric acid leaching out of the cell. Furthermore, the performance behavior as function of time has been evaluated and discussed in the present study.

## A0304 (Abstract only, elsewhere published)

### Accelerated stress testing of HT-PEFC: the effect of electrolyte loss on cell performance

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#### Abstract

High temperature polymer electrolyte fuel cells (HT-PEFC), operating at 160-190°C, use phosphoric acid (PA) doped polybenzimidazole (PBI) membranes as the proton conducting electrolyte. The low vapor pressure of PA allows for operation at the elevated temperatures. HT-PEFCs are mainly developed for stationary combined heat and power applications where long term durability is a key element for commercialization. A major life limiting process is the loss of PA from the membrane and electrodes by evaporation due to the small, but finite vapor pressure of the electrolyte.

In this contribution a common descriptor for the PA evaporation rate as a function of operating condition for BASF Celtec<sup>®</sup> MEAs is presented. Based on these results an accelerated stress testing protocol was developed to elucidate the phosphoric acid loss induced fuel cell degradation. During a 3000h experiment, air and O<sub>2</sub> polarization curves are used as diagnostic tool to distinguish between the different efficiency loss contributions from catalysis, cell resistance and mass transport [1].

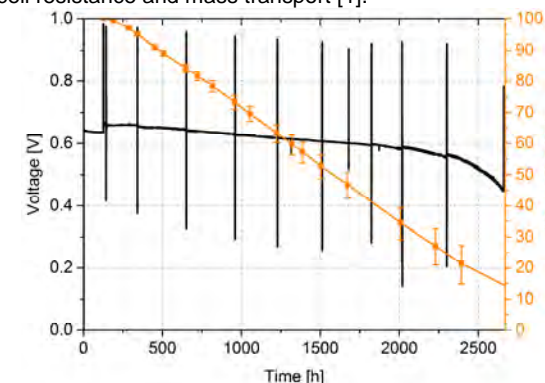


Figure 1: Measured voltage profile and PA content in the MEA during an accelerated stress test.

- [1] Schmidt, T. J. (2006a) Durability and degradation in high-temperature polymer electrolyte fuel cells. ECS Transactions 1(8), 19–31.

Remark: The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.

### Chapter 03 - Session A05

#### Characterization of FC materials

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### A0501 (Abstract only, elsewhere published)

## Vizualization of GDL Liquid Water Invasion below Channel and Rib by X-ray Tomographic Microscopy

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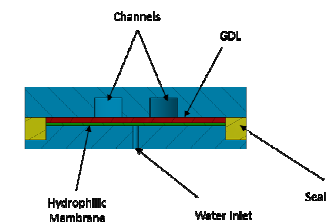
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### Abstract

Liquid water transport in GDLs is a key issue in low temperature proton exchange fuel cells (PEFC). Too much water accumulation usually results in significant performance losses due to the increased difficulty for gases to access the reaction sites in the cathode catalyst layer. In order to characterize the efficiency of a GDL to evacuate the water produced, an ex-situ experiment has been developed. A GDL is imbibed, having a homogenous boundary condition at the bottom (a hydrophilic membrane), by increasing the capillary pressure stepwise. The top boundary of the GDL is a flow field with two channels and one rib (Figure 1). For each capillary pressure X-ray tomographic microscopy imaging is performed to obtain the 3D fiber, void and water structures. This allows for quantitative image analysis of the water transport through the GDL. The set-up should deliver water distributions similar to in-operando fuel cells. Information of interest is in particular the water distribution below the rib and channels. The data is particularly suited for model validation because all boundary conditions (temperature, water and air pressure) are well defined.

Two different GDLs have been tested: SGL 24BA and Toray TGP-H060. Breakthrough is achieved at 22 mbar for the SGL while 40 mbar are necessary for water to reach the channel for the Toray.



**Figure 1:** Schematic, illustrating the GDL and hydrophilic membrane clamped between the two flow fields.

Remark: The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.



## A0502 (Fuel Cells SI publication candidate)

# Uptake of protic electrolytes by polybenzimidazole-type polymers – Model for the absorption isotherm and electrolyte/polymer interactions

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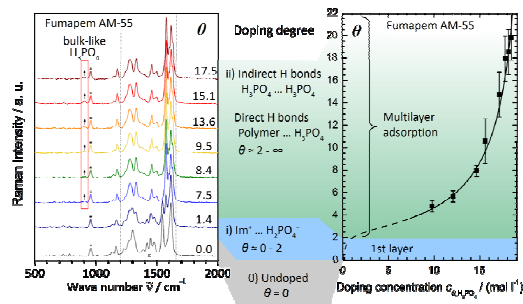
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## Abstract

Phosphoric acid doped polybenzimidazol (PBI) membranes are commonly used as proton conducting membrane in high temperature polymer electrolyte fuel cells (HT-PEFC). In this study we want to present a general (thermodynamic) model for the absorption process of protic electrolytes by PBI-type polymers, which is able to describe the whole accessible doping range. We have analysed literature and own data on the uptake of phosphoric, sulphuric and perchloric acid by non-cross-linked *m*-PBI [1, 2] and AB-PBI [3] and by a commercial cross-linked PBI derivative (Fumapem AM-55®). The uptake of protic electrolytes by PBI-type polymers can be described satisfactorily by a BET-like adsorption isotherm (GAB model), assuming a multilayer-like adsorption process.

In addition to the thermodynamic data spectroscopic data from Raman studies are taken into account [4]. It is possible to correlate domains in the adsorption isotherms to the protonation of the polymer chains, the formation of H-bonds directly to the chains and to still absorbed electrolyte molecules.



**Fig.1:** FT-Raman spectra (left) of pristine Fumapem AM-55 (bottom) and doped with H<sub>3</sub>PO<sub>4</sub> at different doping degrees  $\Theta$  (~20°C). Absorption isotherm (right) for H<sub>3</sub>PO<sub>4</sub> by Fumapem AM-55 (110°C). The coloured areas indicate different absorption stages: 0) undoped (grey,  $\Theta = 0$ ), i) adsorption of first layer (blue,  $0 < \Theta \leq 2$ ), ii) multilayer adsorption (green,  $\Theta > 2$ ).

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Remark: This contents is also shown in the poster contribution “B1108”

## A0503 (Fuel Cells SI publication candidate)

# Critical Parameters and Control Strategies for Comparable PEFC Stack Characterization

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## Abstract

The harmonization of PEFC test procedures is of significant interest for industry and academia and important to accelerate fuel cell development. Up to the present date, PEFC analysis has not been standardized for the stack level leading to non-comparable results.

The preparation of required protocols was realized in a two-step process in the EU-funded project Stack-Test. The crucial parameters were identified and the procedure for the respective parameter variation was specified. The direction of parameter adjustment, the sensor position and the parameter control are defined in order to achieve reproducible results. Thereby, the feedback from industry and academia has been considered.

For the present work, different protocols regarding stack performance were applied to different 10-cell stacks. The typical test operating parameters have been varied according to the protocols. Thereby, the impact of the protocols on the test results was examined. For industry, the test duration is a further crucial parameter and should be minimized without endanger the result accuracy and reproducibility. This aspect will be demonstrated for polarization curves, the most common tool for PEFC characterization. Our results show that the comparability of the test results carried out at different facilities across Europe is greatly influenced by the applied testing protocols. In this work, we will present the validation results, identify and highlight critical parameters and sequence of examination steps. Our work clearly demonstrates the great need for harmonized test protocols and their case-dependent choice.

All results are part of the Stack-Test project funded by the EU Seventh Framework Program (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant n° 303445. We gratefully acknowledge the members of the consortium.

A0504

## The development of multi-layered coating and method for the aluminum bipolar plates of a direct methanol fuel cell

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### Abstract

Aluminium as bipolar plate material is one of the most attractive metals among all other metallic-based alternatives due to its good machinability and low costs. However, one major drawback can be found in the low corrosion resistance of the material. Therefore a new CrN/aC-based multi-layer coating was fabricated by physical vapour deposition (PVD) and deposited onto aluminium alloy 1050A samples. The potentiodynamic test results show greatly improved corrosion resistance. The corrosion potential increased 0.37 V, whereas corrosion current decreased by two orders of magnitude at -0.13 V vs Ag/AgCl reference electrode.

In contrast to that, the interfacial contact resistances (ICR) increased significantly due to the low electrical conductivity of amorphous carbon.

Moreover, an approach to modify the surface texture of the aluminium samples using a high precision UV laser system is also presented in this study (Fig.1). As a result, significantly more hydrophilic wetting behaviour and lower contact resistances could be achieved.

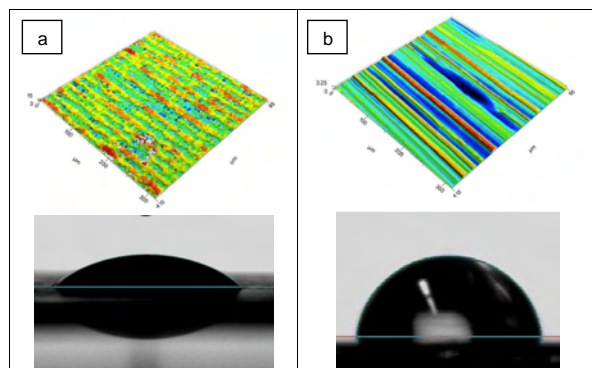


Figure 1: Contact angle and surface texture of the laser-modified uncoated (a) and untreated substrate surfaces (b)

A0505 (Abstract only)

## Calculation of effective transport properties of partially saturated gas diffusion layer

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### Abstract

Gas diffusion layers (GDLs) play an important role in proton exchange membrane fuel cells (PEMFCs) for the diffusion of reactant and the removal of product water. The water management is one of principal issues of PEMFC modelling. Current PEMFC models are usually developed on the basis of computer fluid dynamics (CFD) where porous layers are mainly developed as layer-like and homogenous. Therefore CFD models simplify the local transport properties of porous structures dependency on liquid water saturation. The current research investigates Lattice-Boltzmann method (LBM) to analyse a function of local properties of partially saturated with liquid water GDL. This is an approach to develop new tools that allow to better understanding of 2-phase transport processes and maybe propose improvements of materials.

In this study the LBM is used in two aspects. First of all the 2-phase flow model is applied to insert a liquid water into porous structure. The random Voronoi mesh (see Fig. 1) is taken as a validation example. Initially the cube is saturated by air (gas phase). The liquid water is inserted from the bottom while the top is assumed gas and liquid water outlet. The sides of the cube are taken as walls. The shape of liquid water surface inside the cube is shown in Fig. 2. In turn, the bulk transport properties (permeability, diffusivity, conductivity) of the partially saturated structure are calculated. The calculated material properties could be used as input parameters for CFD analysis of the PEMFC performance.

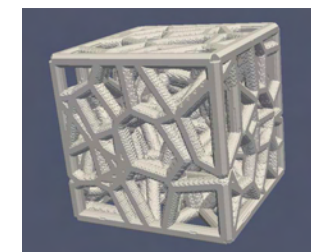


Fig. 1. Cube, random Voronoi mesh.

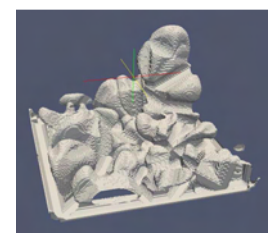


Fig. 2. Water surface inside the cube.

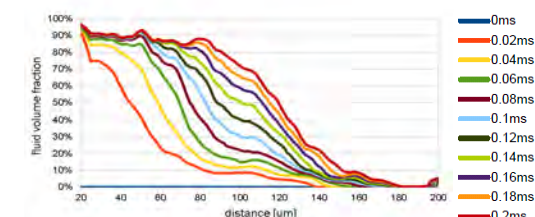


Fig. 3. Water saturation profiles, transient simulation of water intrusion.

A0506

## Pressed-onto 3Omega method for measuring the thermal properties of gas diffusion layers of fuel cells and the like

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### Abstract

3Omega measurements of the thermal conductivity often require a high preparation effort due to processing in clean-room. In this work, first results are presented of a new method which simplified the use of the 3Omega technique. The method has been tested successfully on gas diffusion layers of Polymer Electrolyte Membrane Fuel Cells as well as materials with well-known properties such as Teflon, Lithosil, Macor, iron silicide or chromel. In the “pressed onto” 3Omega method, a micro-heater is fabricated on a flexible substrate foil. The micro-heater on its substrate is pressed on the surface of the sample for measurements. The micro-heater is integrated into the sample holder and belongs to the measurement systems; no costly sample preparation is needed. The measurement is non-destructive. A thin electrical insulation of the micro-heater enables the measurement of conductive samples. The method could be potentially integrated in a fuel cell thus being suitable for in-situ measurement and feedback control loops.

A0507

## Identification and quantification of Pt surface sites and of performance losses for PEM fuel cells by selective chemisorption measurement

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### Abstract

The platinum surface sites of commercial electrocatalysts Pt/C have been determined using X-ray diffraction (XRD), high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM), selective chemisorption, and cyclic voltammetry (CV) methods. Comparison of the results shows that XRD and STEM methods give Pt surface sites much higher than for chemisorption analysis due to assumptions regarding Pt particle shapes and particle size distributions. The results from CV analysis agree reasonably well with those from chemisorption if the sample amounts and methods of sample deposition preceding CV analysis can be well-controlled and there is no loss of surface exposure by the Nafion over-layer. Because both chemisorption and CV analyses more directly measure actual sites with fewer assumptions, these methods should be considered superior to XRD and STEM analyses.

The membrane electrode assembly (MEA) was fabricated using commercial available electrocatalysts of 20wt% Pt/C. The Pt surface sites in the MEA were measured by selective H<sub>2</sub> chemisorption methods at dry conditions and by cyclic voltammetry (CV) for the electrochemical reaction. The chemisorption measurements indicate that ~52% of the active Pt surface are lost due to ionomer coverage and CV shows an additional 28% of the Pt surface are lost due to blockage by condensed water and the isolation of Pt sites from ionomer and electrical conduction. In total 80% of the Pt surface sites present on the 20 wt% Pt/C starting material are lost during preparation and at operating conditions. Thus, both mechanisms of activity loss are separately identified and quantified.

## A0508 (Abstract only)

## Comparison of hydrocarbon-type Block and Random copolymer for Polymer Electrolyte Fuel Cells

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### Abstract

A promising route to high-performance polymer electrolyte materials (PEMs) in fuel cell (FC) is the use of hydrocarbon (HC)-type ionomers. The advantages of HC ionomers are that they are cheaper than the perfluorinated ionomers currently used, have higher mechanical property, better thermal and chemical stability at high temperature which can lead to a suitable design. There is a possibility that states of waters are correlated with the proton conductivity of polymer electrolyte materials, so it is important to analyze and understand the existence of different types of waters quantitatively to choose the materials and effective operating condition for fuel cells. Molecular vibration and absorption spectroscopy of water molecules and liquid water can be effectively studied by FTIR spectroscopy. We have studied the effect of temperature and relative humidity (RH) on the changes in morphology and states of waters, and their correlation with the proton conductivity for the two HC-type ionomers.

Two types of copolymers, AB-type Block (SBu-b-H) (Mw:74-164, IEC:2.2 meq/g) and Random (SBu-r-H) (IEC:2.28 meq/g) were utilized in the present investigation.

Figure 1 shows the proton conductivity for SBu-b-H(block) and SBu-r-H(random); at 80°C and 50% RH; SBu-b-H block copolymer showed around 5 times higher conductivity than random copolymer, though at higher RH the conductivity value becomes closer.

FTIR spectra for the water Overtone ( $\nu_1 + \nu_3$ ) band at the NIR region at 80°C and varied RH for the block and random copolymers showed that, the absorbance intensity for the region with stronger H-bond was slightly stronger for the block-type copolymer than random. The Overtone bands for the copolymers at 80°C and 50% RH were deconvoluted by the software GRAMS and 3-types of waters (according to their strength of H-bonds) were found present in the ionomers. It was also found that the area of the stronger H-bonded waters in random copolymer was 13%, whereas that for the block copolymers was 30% (i.e. more than 2 times than random).

From the proton conductivity and deconvolution results, it is assumed that comparing to random structure, the block copolymer probably has some ordered structures, which can interconnect more number of stronger H-bonded waters in block copolymer.

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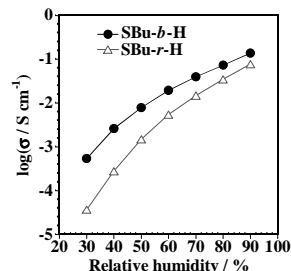


Figure 1. Proton conductivity of copolymers

## A0509 (Abstract only)

## La<sub>2</sub>TiO<sub>5</sub>-based Solid Oxides for SOFC Applications. Characterisation and Processing

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### Abstract

The development of Solid Oxide Fuel Cells is currently focused on the decrease of operating temperature, thus lowering the manufacture costs and improving the cell lifetime [1]. Therefore, there is a great interest in the identification of new compounds with improved properties in the intermediate temperature range (500-700°C). Recently, a new class of materials - oxy-cuspidines - with fast ion conduction behavior has been reported. La<sub>2</sub>TiO<sub>5</sub> compound poses an orthorhombic structure and a great flexibility for cation substitution. Our previous studies evidenced an increase in its electrical conductivity after partial substitution of Ti sites with vanadium [2].

In this work, La<sub>2-x</sub>Ca<sub>x</sub>TiO<sub>5-δ</sub> (x=0.05; 0.10; 0.15) and La<sub>2</sub>Ti<sub>1-y</sub>V<sub>y</sub>O<sub>5+δ</sub> (y=0.05; 0.10) powders have been synthesized using a sol-gel method. The thermal treatment of the precursor solid resin was adjusted in order to get dense and single phase samples for electrochemical characterization. Solid oxides have been characterized by X-ray diffraction, confocal Raman spectroscopy, SEM/EDXS. Electrical conductivity of the samples was evaluated from EIS measurements under air and 2% H<sub>2</sub>/Ar mixture in the temperature range 400-800°C. Appropriate compositions have been selected and thin films have been deposited onto YSZ substrates by deep-coating from the precursor gel. After thermal treatment, as-obtained thin films have been characterized by confocal Raman spectroscopy and SEM/EDXS. EIS measurements also have been performed on the symmetrical cells. The effect of dopants on the electrochemical performance of La<sub>2</sub>TiO<sub>5</sub> will be evidenced.

UEFISCDI financial support in the framework of research projects PN-II-PT-PCCA-2011-3.1-1423 (no 26/2012) and PN-II-CT-RO-FR-2012-1-0068 (no 27/2013) is greatly acknowledged.

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Remark: Only one page abstract was available at the time of completion.  
Please contact the authors directly for further information.

A0511 (Abstract only, elsewhere published)

## Effect of Sr Addition on Electrical Conduction Behavior of RE-doped Ceria

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### Abstract

In the past years many efforts have been devoted to the identification of new electrolytes for intermediate-temperature solid oxide fuel cells (IT-SOFCs). Among the investigated compounds, doped-ceria materials are of great interest due to their high ionic conductivity in the intermediate temperature range. However, the electrolytic domain of ceria-based materials is narrower than the one characteristic to the state-of-the-art SOFC electrolyte - yttria-stabilized zirconia (YSZ). In order to overcome this limitation, co-doping of ceria materials have been adopted [1].

Previous studies concerning RE-doped ceria evidenced a lower electrical conductivity for Dy- and Yb-doped ceria compared with Gd- or Sm-doped ceria [2]. Moreover, Sr proved to be an effective co-dopant for RE-doped ceria [3].

In this work, Ce<sub>0.85</sub>RE<sub>0.15-x</sub>Sr<sub>x</sub>O<sub>2-δ</sub> (with RE=Dy, Yb; x=0, 0.05, 0.075) powders have been synthesized using a modified Pechini method. Nanostructured solid oxides have been obtained after thermal treatment in air at 550°C. Raman spectroscopy and X-ray diffraction analyses of as-synthesized solid oxides revealed their nanostructured nature and the presence of fluorite phase. The powder sintering behavior was investigated by dilatometry. Powders were further shaped in pellets and sintered at 1200°C for 10h. Sinters were analyzed by XRD, SEM and confocal Raman spectroscopy. The electrical conductivity of all investigated samples was evaluated by EIS measurements under air in the temperature range 200-800°C evidencing the effect of Sr-co-doping on doped-ceria materials.

UEFISCDI financial support in the framework of research project PN-II-PT-PCCA-2011-3.1-1423 (no 26/2012) is greatly acknowledged.

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**Chapter 04 - Sessions A06, A09, A13****A06: Non-precious metal FC catalysts****A09: New Pt-alloy FC catalysts****A13: New catalyst structures and manufacturing processes**

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## A0601 (Fuel Cells SI publication candidate)

### Non-Precious Metal Fuel Cell Catalysts Prepared By Rationally Designed Porous Materials

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#### Abstract

Finding inexpensive and stable replacements for the platinum group metals (PGMs) has been the ultimate goal for proton exchange membrane fuel cell catalyst research. Among all the non-PGM candidates, transition metal doped nitrogen-carbon (TM-N-C) composites appear to be the most promising at present in promoting oxygen reduction reaction (ORR) at cathode. Since non-PGM catalysts are known to have lower turn-over frequency per catalytic site when compared to platinum, their active site densities must be substantially higher to deliver a comparable performance.

At Argonne National Laboratory, we developed recently several new approaches using metal-organic frameworks (MOFs) and porous organic polymers (POPs) as the precursors to generate TM-N-C type of non-PGM catalyst. For example, we demonstrated that the "support-free" non-PGM electrode catalysts can be prepared through zeolitic imidazolate framework (ZIF, a subclass of MOF), taking the advantages of its 3-dimensional metal-N<sub>4</sub> coordination structure, high volumetric active site density and high surface area. Both single and binary MOF-based catalysts have been developed in our laboratory with excellent ORR activities. More recently, we developed a method of preparing non-PGM catalyst using POPs containing high density, evenly distributed metallated N-coordination sites in the highly porous networks. POPs with both two-N coordinated and four-N coordinated transition metals were investigated which also showed excellent ORR activities after thermal activation. In this presentation, we will focus on the design, synthesis and activation strategies of ZIF-derived non-PGM catalysts and their physical/chemical properties obtained from various characterization techniques.

## A0602 (Abstract only)

### Assessment of potential Co/Fe-N-C active sites arising from heat treated carbon-supported porphyrins

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#### Abstract

Proton exchange membrane fuel cell (PEMFC) performance is hindered by the large overpotential and sluggish kinetics of the platinum cathode catalyst and as such a replacement is sought. Organic and metallo-organic catalysts that are able to compete with platinum with regards to performance are of interest due to their comparatively low cost. It has been established that pyrolysed metallo-organic systems such as carbon-supported porphyrins are active towards the oxygen reduction reaction, though the nature of the resultant active site(s) is still a matter of contention within the literature. In this work a large number of potential active sites ranging from porphyrin-like centres to nitrogen doped structures are investigated computationally, taking into account imposed potentials, proton donor structure, nitrogen content of the carbon support and water layers above the catalyst surface. It has been found that some structures are simply inactive towards oxygen reduction as a whole, while others are only catalytically active for parts of the overall four electron reaction. It is expected that the results will show that a suitable catalyst need consist of a variety of active sites, that migration of reaction intermediates between active sites occurs and that such heterogenous catalysts are not as active towards oxygen reduction as platinum.

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Non-precious metal FC catalysts  
New Pt-alloy FC catalysts  
New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 5/29

## A0603 (Elsewhere published)

### Transition metal ion-chelating ordered mesoporous carbons as non-noble metal PEMFC catalysts

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#### Abstract

Transition metal-containing cathode catalysts for PEM fuel cells have drawn much attention as promising alternatives to expensive precious metal-containing catalysts [1]. The materials presented here illustrate a new synthesis approach for non-noble metal-containing catalysts [2]. A synthesis route for ordered mesoporous carbons (OMCs) was modified to include a source of nitrogen as well as iron and/or cobalt salts. Using this approach active sites were directly incorporated inside a highly porous electron-conducting support material. This results in a material with much higher specific surface area compared to conventional Vulcan supported catalyst materials. Furthermore the synthesis method may be tuned by careful selection of a large number of synthesis variables. Thus the influence of changes in the synthesis on the mesostructure of the matrix and the atomic local structure of the active sites was studied [3]. The focus here is on correlating the local atomic structure, studied by EXAFS, and the catalytic performance of the catalyst, evaluated by measurements in a single cell fuel cell.

Non-precious metal FC catalysts  
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New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 6/29

## A0604 (Abstract only)

### Synthesis of nanofibrous Co-CNF catalysts with high oxygen reduction reaction activity in alkaline media

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#### Abstract

Polymer electrolyte membrane fuel cell (PEMFC) has been considered as one of the most promising energy conversion device for future. However, current manufacturing cost of PEMFC stack can hardly meet the demands which market allows for large-scale commercialization. Among various components of PEMFC, electrodes containing Pt based catalysts account for almost more than half of the stack cost. The development of low cost electrode with high performance for reducing Pt based catalysts usage is a key technology to overcome economic problem. The development of non-precious metal catalysts (NMPCs) is mainly focused on oxygen reduction reaction (ORR) because of its sluggish reaction kinetics. Previous reports examined that the heat treatment at 400 ~ 1000 °C derived transition metal-nitrogen bond coordinated with carbon structure (Me-N-C) exhibits ORR activity in various pH conditions. The present developed NMPCs have poor ORR activity compared to the Pt based catalysts.

Herein we report highly active NMPCs for oxygen reduction reaction with nanofiber structure. The 1-D nanofiber structure has a great potential to improve the catalytic activity due to its large surface area to volume ratio. The electrospinning technique was conducted to achieve nanofiber structure, and polyacrylonitrile (PAN) and Co acetate were used as precursors. After the pyrolysis under inert gas environment, PAN was transformed to a carbon structure. This is verified from the appearance of D and G band peaks in Raman analysis results. The prepared catalyst in this study exhibits 4-electron involved excellent ORR activity comparable with commercial 20 wt. % Pt catalyst in alkaline condition. And, the ORR activity is strongly depends on N chemical state change induced by Co phase introduction in carbon structure. These results showed a potential of nanofibrous Me-N-C catalysts to replace Pt based catalysts and catalyst design for future to achieve high performance of PEMFC.

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Non-precious metal FC catalysts

New Pt-alloy FC catalysts

New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 7/29

## A0605 (Fuel Cells SI publication candidate)

### Facile Graphene based Materials and its Application as Low Cost Hydrogen Fuel Cell Catalyst

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#### Abstract

With various technology upgrades to achieve a low cost and reliable proton exchange membrane fuel cell, there is still a pressing need for increasing the catalytic stability and durability. Among others advances, new carbon-based materials are considered to be applied within Membrane – Electrode Assembly. Due to the specific proprieties such as specific surface and potential low manufacturing cost, graphene nanosheets have been investigated as a support for low temperature fuel cell catalysts. The basic idea in these exploratory activities is the use of graphene as support material for platinum catalysts as fuel cell electrodes, with the expected effect of improving catalytic activity and decrease the platinum loading. A direct consequence will be a decrease of the cost. Within this paper, the partial results of an ongoing national project, which is intended to implement graphene-based electrodes for the PEM fuel cells manufacturing line from NCHFC Ramnicu Valcea-Romania are shown and discussed. The first stage of the project was focused onto synthesis methodology and basic characterization.

Non-precious metal FC catalysts

New Pt-alloy FC catalysts

New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 8/29

## A0606 (Fuel Cells SI publication candidate)

### Progress in High-Temperature PEM Fuel Cells

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#### Abstract

The work presented here focuses on recent results obtained by Danish Power Systems (DPS) and the current materials development challenges that are faced in the efforts to commercialize high temperature PEM fuel cell technology. The results presented here will focus on the degradation of their membrane electrode assemblies (MEAs) under various operating conditions in addition to their latest developments on achieving an increased platinum utilization. An average degradation rate of 9  $\mu\text{V/h}$  has been achieved during long-term MEA testing under dry hydrogen and air for the first 12.000 hours at 0.24  $\text{A/cm}^2$ . Long-term testing on MEAs subjected to testing using wet hydrogen (30 mol%) have shown similar rates of degradation over the first 2.600 hours. Post mortem scanning electron microscopy, transmission electron microscopy, micro-computed tomography and x-ray diffraction analyses have been used to investigate the modes of degradation occurring within the catalyst layers and membrane. Attempts to reduce the platinum loading are presented whereby the use of alternative cathode catalyst materials has shown far superior performance compared to benchmark DPS MEAs.

## A0607 (Abstract only, elsewhere published)

### Ultralow Platinum Decorated Self-active Ordered Mesoporous Carbon for Oxygen Reduction Reaction

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#### Abstract

Exploring the cost effective electrocatalyst with enhanced activity is one of the most important challenges for the commercialization of polymer electrolyte fuel cells (PEFCs). Many researches focuses on the development of non-precious metal based electrocatalysts and low platinum based Pt-M alloy, dealloy, or core-shell catalyst by morphological and structural tuning with inexpensive transition metals. Unfortunately, the performance of non-precious metal-based materials is still inferior to that of Pt-based catalysts in respect of activity and longevity in acid medium. Recently, we found that the self-supported ordered mesoporous porphyrinic carbon (M-OMPC) which have a comparable ORR catalytic activity with Pt/C under a relatively large amount of catalyst (ca.  $> 0.6 \text{ mg/cm}^2$ ) loading. However, a thick membrane electrode with a high catalyst loading is unfavorable for the cell performance in terms of cell resistance and gas diffusion resistance. In this study, we demonstrated an alternative catalyst combined with a trace of Pt active nanoparticles and M-OMPC as a substitution for the carbon supports generally being used. The ultralow platinum ( $\sim 5 \text{ wt.}\%$ ) loaded Pt/M-OMPC showed a 10 times enhanced ORR kinetic activity compared to that of M-OMPC at 0.9 V RHE. The Pt mass activity was also improved by 7 times compared to that of Pt/C at 0.85 V RHE.

**Remark:** The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.



## A0901 (Fuel Cells SI publication candidate)

## Opportunities to Improve the Stability and Activity of Electrocatalysts Based on Cu-Core – Pt-Shell Nanoparticles

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### Abstract

Reducing the cost of electricity produced in the PEMFC demands the use of electrocatalysts which would exhibit high specific activity at low platinum content.

Previously, we reported the preparation of Cu-core - Pt-shell carbon supported electrocatalysts, the platinum content of which was reduced in comparison with Pt/C catalysts. Unfortunately, the electrochemically active surface area of these materials markedly decreases during extended voltammetric cycling. The aim of this work was to obtain carbon supported electrocatalysts based on Cu-core - Pt-shell and hollow Pt nanoparticles, which could show increased stability in comparing with Pt/C materials.

Cu@Pt/C catalysts were prepared by successive chemical reduction of Cu (2+) and Pt (IV) compounds in carbon (Vulcan XC-72) suspension based on water-organic solutions. In fact, this method produces mixture of one phase- and two phases - nanoparticles. A part of the last has a perfect (continuous) Pt-shell, but some nanoparticles - unfinished, “holey” shells. The combination of the corrosion and thermo-treatment were used for the leaching of copper from nanoparticles with a defective structure and for the improvement of Pt-shell for nanoparticles, the shell of which had no defects. Study of structural characteristics, activity and stability of the catalysts was carried out by XRD, thermogravimetry, X-ray fluorescence analysis, transmission electron microscopy, and cyclic voltammetry under argon and air atmospheres.

It was shown that the correct thermo-treatment of catalysts orders the structure of core-shell nanoparticles (Fig. 1). Electrocatalysts based on Cu@Pt/C and hollow type Pt nanoparticles, which show increased stability in comparing with commercial Pt/C catalyst, have been prepared.

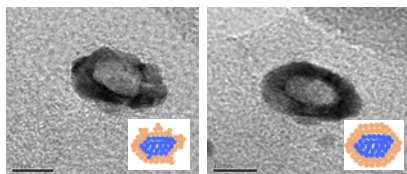


Figure 1. TEM images of Cu@Pt nanoparticle before (a) and after (b) thermo-treatment.

## A0902 (Abstract only, elsewhere published)

## Effect of heat treatment atmospheres of PtNi nanoparticles as an oxygen reduction electrocatalyst

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### Abstract

One of the most challenging problems to commercialize proton electrolyte membrane fuel cells (PEMFCs) is the sluggish kinetics of the oxygen reduction reaction (ORR). The Pt-based nanoparticle is generally used as an ORR electrocatalyst owing to its intrinsic activity. For practical preparation step, the heat treatment step is inevitably needed to remove surface contaminated species and improve crystallinity of electrocatalysts. The high temperature-PEMFC (HT-PEMFC), operating in the temperature range of 120 ~ 200 °C, conventionally used phosphoric acid doped polybenzimidazole (PBI) membrane because of its chemical and physical stability. However, the kinetics of the ORR is severely retarded by the adsorption of phosphate anions. In this study, we demonstrated the effect of heat treatment atmospheres of PtNi nanoparticles on the ORR in the presence of phosphoric acid.

For this, we prepared carbon supported Pt-Ni bimetallic (Pt<sub>2</sub>Ni<sub>1</sub>) nanoparticles via colloidal reduction method. After the reduction of metallic precursors, we carried out the heat treatments under various heat treatment atmospheres such as Ar, H<sub>2</sub>/Ar, and air. In half-cell measurements, the argon treated Pt-Ni nanoparticles (PtNi\_Ar) showed the most active ORR electrocatalysis in both the absence and the presence of the phosphoric acid. These changes are attributed to the alteration of electronic structure of Pt, in accordance with X-ray spectroscopic techniques. In real operating condition of the HT-PEMFC, the PtNi-Ar also showed excellent performance compared to the commercial Pt nanoparticles. These results suggested that a proper heat-treatment atmosphere is crucial role to prepare the electrocatalysts for the HT-PEMFC.

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## A0904 (Abstract only)

### In-situ X-ray Absorption Spectroscopy Investigations of Cubic Pt Nanoparticles as Cathode Catalyst in PEMFCs

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#### Abstract

Cubic shape selected Pt nanoparticles were produced by a synthesis route reducing the Pt precursor using NaBH<sub>4</sub> in the presence of the surfactant tetradecyltrimethylammonium bromide (TTAB) and supported in Vulcan XC72. The power density of a polymer electrolyte fuel cell with these cubic Pt nanoparticles as cathode catalysts outperforms a commercial catalyst by a factor of four, normalized to the metal weight [1]. Several factors may be responsible for the large increase in the catalyst utilization: the electrochemical surface area is increased as less particle agglomeration is found, the activities of low index facets (100) on the SS-NP is increased, or the surfactant which can be found on the catalyst surface influences the reaction. In order to improve our understanding, we investigated the oxygen reduction reaction and the water oxidation reaction on the cubic Pt-NP catalyst and on a conventional Pt/C catalyst in-situ by X-ray absorption spectroscopy during potential step measurements. For the conventional Pt/C catalyst changes in the X-ray absorption near edge structure region (XANES) can be attributed to formation of H, OH or n-fold bonded O. Surprisingly, for the SS-NPs no change in the XANES region is observed. Furthermore the time dependent current density of the Pt/C shows a current overshoot after a potential step. Such an overshoot is not observed for the cubic Pt-NP catalyst. This indicates that the species observed on the Pt/C catalyst block the surface which is prevented on the cubic Pt-NPs facilitating the ORR and water oxidation reaction.

[1] D. Dixon, J. Melke, M. Botros, J. Rathore, H. Ehrenberg, C. Roth Increase of catalyst utilization in polymer electrolyte membrane fuel cells by shape-selected Pt nanoparticles *International Journal of Hydrogen Energy* **2013** 38(30) 13393–13398.

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Non-precious metal FC catalysts

New Pt-alloy FC catalysts

New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 13/29

## A0905 (Abstract only)

### Improved Oxygen Reduction Activity of Pt-alloys Supported on carbon via formation of Heterogeneous Superhydrophobic Structure

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#### Abstract

One of the important obstacle that prevent fuel cell from replacing the internal combustion engine is the high polarization (mainly concentration polarization) and high cost of the catalyst (Platinum ) of the oxygen reduction reaction (ORR). In an effort to reduce the cost of the catalyst, many research groups alloyed Pt with transition metals such as Ni and Co and produced a catalyst that use Pt.Ni or Pt.Co alloys to replace pure Pt and found that these alloyed catalyst produced ORR rate of reaction similar or sometimes better than the more expensive pure Pt. This effect was attributed to various factors (see for example Alia (2014))It is believed that such an enhancement on the rate of ORR may be attributed to the formation of some special facet on the surface of Pt crystal that was called Pt (111) which has special catalytic activity. Her we show that transition metals like Ni and Co may act as a catalyst for the production of heterogeneous superhydrophobic surface in the carbon support (Vulcan XC72) containing Pt. This produced hierarchical surface not only expands the triple phase boundary but also reduces mass transfer resistance. On such hierarchical heterogeneous superhydrophobic surface a gas layer always separate the liquid phase from the catalyst. Thus a gas layer containing oxygen gas is exposed to the catalyst. This dramatically reduces diffusion limitation. In this publication it will be shown that the experimental procedures used by various authors in order to prepare the special facet on the Pt crystals may actually produce a hierarchical heterogeneous superhydrophobic structure (see for example Roach (2004) and Lathe (2012)).

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Non-precious metal FC catalysts

New Pt-alloy FC catalysts

New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 14/29

## A0906 (Fuel Cells SI publication candidate)

## Development and Scale Up of Enhanced ORR Pt-based Catalysts for PEMFCs

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## Abstract

As the custodians of roughly 75% of the world's platinum reserves, the South African government has embarked on an ambitious National Hydrogen and Fuel Cells Technologies Flagship project, branded as Hydrogen South Africa [HySA] in order to shift from a resource-based economy to a knowledge-based economy. Consequently, one of the major focus points of **HySA/Catalysis** is to supply 25% of the global fuel cell industry's PGM catalyst requirements by 2020. Monumental progress has been achieved in the form of the **HySA V- and K- series** of catalysts which consists of Pt-only materials supported on Vulcan and Ketjen Black, at various Pt loadings. These materials have been proven both on in-situ (single cell MEA testing) and ex-situ (TF-RDE techniques) basis to be on par with state-of-the-art commercial benchmark materials. Despite these development efforts intense research efforts have been focused on developing high-performance platinum alloy catalysts that address sluggish Oxygen Reduction Reaction (ORR) kinetics and catalyst stability issues, in an attempt to minimize the precious metal content and ultimately the cost of fuel cell catalysts. Therefore, in line with international trends, and in an attempt to diversify its portfolio of catalyst offerings, **HySA/Catalysis** has given much attention to the development of high performing and durable cathode catalysts for PEMFC applications, particularly PtMx (M – transition metals) supported catalysts. Conveyed in this work is a demonstration of **HySA/Catalysis'** competence at employing fundamental principles to engineer the composition and structure of nano-alloy catalysts both on laboratory- and pre-commercial scale. This has culminated thus far in the preparation of dealloyed PtMx (M = Co or Ni) catalyst material that exhibit improved ORR electrocatalytic activity on ex-situ-as well as in-situ basis.

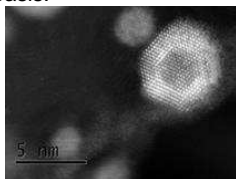


Figure 1 High-resolution Z contrast HAADF micrograph of a dealloyed PtCo<sub>3</sub> nanoparticle.

## A0907 (Elsewhere published)

SnO<sub>2</sub>-modified Pt electrocatalysts for ammonia-fueled anion exchange membrane fuel cells

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## Abstract

The electrochemical oxidation of ammonia over two types of SnO<sub>2</sub>-modified Pt (C–Pt/SnO<sub>2</sub>, SnO<sub>2</sub>–Pt/C) and Pt/C electrocatalysts was evaluated in alkaline aqueous solutions. Linear sweep voltammograms (LSVs) and chronoamperograms (CAs) were obtained in a 1 M KOH solution with 0.1 M NH<sub>3</sub>. The ammonia oxidation current achieved during the LSVs was in the order C–Pt/SnO<sub>2</sub> > SnO<sub>2</sub>–Pt/C > Pt/C. In addition, the apparent activation energies for ammonia oxidation calculated from the CAs for C–Pt/SnO<sub>2</sub>, SnO<sub>2</sub>–Pt/C, and Pt/C at various temperatures were 52, 58, and 67 kJ mol<sup>–1</sup>, respectively. These results indicated that SnO<sub>2</sub> activated the dehydrogenation of ammonia over Pt. Moreover, the *I*–*V* characteristics of an ammonia-fueled anion exchange membrane fuel cell with the SnO<sub>2</sub>–Pt/C anode clearly achieved a higher performance than with the Pt/C anode.

Remark: This paper will be published in the journal "*Electrochimica Acta*".  
DOI: 10.1016/j.electacta.2015.05.066

## A0908 (Abstract only)

**Pd<sub>x</sub>Ir<sub>y</sub>/C for Hydrogen Oxidation Reaction****Fotini Tzorbatzoglou (1), Angeliki Brouzgou (1), Panagiotis Tsiakaras (1,2)**

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**Abstract**

In the present work, Pd<sub>x</sub>Ir<sub>y</sub> supported on Vulcan XC-72 carbon (with x:y atomic ratios 3:1, 1:1, 1:3) are prepared by a modified microwave-assisted polyol method, physicochemically characterized and electrochemically studied both as anodes for Hydrogen Oxidation Reaction (HOR) and as cathodes for Oxygen Reduction Reaction (ORR) in acid media.

For comparison reasons, Pd/Vulcan XC-72 and Ir/Vulcan XC-72 are also prepared, characterized and electrochemically tested. More precisely, the as prepared catalysts are characterized structurally by X-ray diffraction (XRD), morphologically by Transmission Electron Microscopy (TEM), while their electrocatalytic properties are evaluated by cyclic voltammetry (CV) and by rotating disk electrode (RDE).

It is found that the addition of Ir to Pd enhances both HOR and ORR electrocatalytic activity. The kinetic parameters, such as the Tafel slope, and exchange current density, are calculated from the experimental results and discussed in detail.

It is also found that, among the bimetallic catalysts studied, PdIr is exhibited the highest activity toward the HOR.

Moreover, the exchange current density values for the ORR are found to be in the following order: Pd<sub>3</sub>Ir > PdIr > PdIr<sub>3</sub> > Ir > Pd. Apart the electrocatalytic activity, Pd<sub>3</sub>Ir is exhibited larger number of electrons transferred for ORR.

**Keywords:** Microwave-assisted polyol, Hydrogen oxidation reaction, Palladium, Iridium

**Acknowledgments**

The authors are grateful to the research programme "Bilateral R&D Co-operation between Greece-China 2012-2014", which is co-financed by the European Union and the Greek Ministry of Education-GSRT. The authors are also grateful to The Ministry of Education and Science of the Russian Federation (contract № 14.Z50.31.0001) for financial support.

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Please contact the authors directly for further information.

## A0909 (Abstract only)

**Highly Durable Non-Precious Nitrogen-doped Graphene Electrocatalysts for Alkaline Fuel Cells****Stephen M. Lyth (1), Jianfeng Liu (2), Takeshi Daio (3), Kazunari Sasaki (1,2,3,5)**

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**Abstract**

Platinum nanoparticles are generally used as the electrocatalyst in proton exchange membrane fuel cells (PEMFCs). However this is expensive, and has limited durability due to dissolution, agglomeration and carbon corrosion in the harsh environment of the fuel cell cathode. Alternative electrocatalysts have been proposed, one of the most popular being Fe/N/C-based electrocatalysts. However, these non-platinum group metal (non-PGM) electrocatalysts struggle to compete with platinum in terms of performance and durability in the acid environment of a PEMFC.

In alkaline media, the oxygen reduction reaction (ORR) kinetics are much faster, and this means that non-PGM electrocatalysts can compete with Pt. Until recently, anion exchange membrane fuel cells (AEMFCs) were not considered to be able to compete with PEMFCs. However, recent advances in membrane technology have made them more viable.

Here, we show that even a completely metal-free nitrogen-doped carbon can have electrochemical ORR activity comparable to that of platinum. Moreover, we perform electrochemical load-cycle durability tests and show that even after 60,000 potential cycles negligible degradation is observed for this electrocatalyst system in alkaline. In contrast, the performance of platinum is much worse after the same test. In conclusion, non-precious nitrogen-doped graphene foam is a potential electrocatalyst for the oxygen reduction reaction in alkaline anion exchange membrane fuel cells.

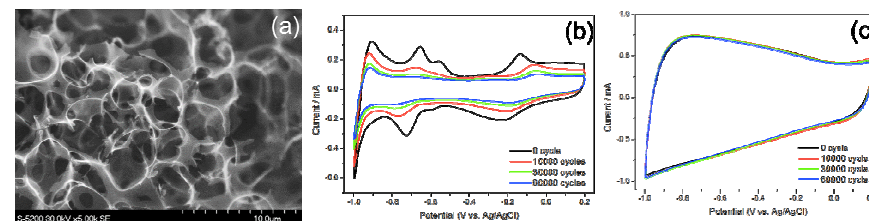


Figure 1. (a) Nitrogen-doped graphene foam electrocatalyst; (b) cyclic voltammograms of Pt/C in alkaline media up to 60,000 potential cycles; (c) negligible degradation in nitrogen-doped graphene after 60,000 potential cycles.

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## A0910 (Abstract only)

## Hydrogen Polymer Electrolyte Fuel Cell performance on Low Platinum PdPt Anode

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### Abstract

PdPt (97:3) supported on Vulcan-XC72 carbon electrocatalyst with metal loading 20 wt% was prepared by a modified pulse-microwave assisted polyol synthesis procedure and was used as anode in a H<sub>2</sub>-PEMFC. The as prepared anode was physicochemically (XRD, TEM) and electrochemically (by CV, RDE and EIS) characterized. As cathode catalyst was adopted commercial Pt (40 wt%)/C. The as-prepared MEA with total platinum loading of 657  $\mu\text{g}/\text{cm}^2$  was performed under fuel cell operation conditions (30 - 80°C and at atmospheric pressure).

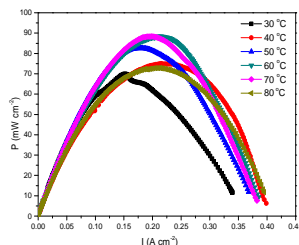


Fig. 1. H<sub>2</sub>-PEMFC polarization curves, from 30 to 80°C, with 80cc/min H<sub>2</sub> and 40cc/min O<sub>2</sub>, 1 atm and 50mV/s scan rate.

It was found that, the increment of temperature until 70°C enhances the fuel cell power up to a maximum of 90 mWcm<sup>-2</sup>, which deteriorated at ca. 70 mWcm<sup>-2</sup> when the fuel cell temperature increases more at 80°C (Fig.1). According to the electrochemical impedance results, this behaviour is attributed to not very well humidified membrane and not to mass diffusion phenomena. Moreover, most of the impedance was due to the slow oxygen reduction reaction, as it was expected according to the literature works, while the anode impedance was minimal. Additionally, the Pd<sub>97</sub>Pt<sub>3</sub>/C, was examined with the rotating disk electrode technique for the oxygen reduction reaction, in order in the future to be used as cathode electrocatalyst, instead of the commercial Pt/C.

Keywords: hydrogen fuel cell, low platinum, palladium-based

### Acknowledgments

The authors are grateful to the research programme "Bilateral R&D Co-operation between Greece-China 2012-2014", which is co-financed by the European Union and the Greek Ministry of Education-GSRT. The authors are also grateful to The Ministry of Education and Science of the Russian Federation (contract № 14.Z50.31.0001) for financial support.

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Non-precious metal FC catalysts

New Pt-alloy FC catalysts

New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 19/29

## A0911 (Abstract only)

## Development of a PtCo/C catalyst manufacturing and stabilization method

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### Abstract

The usage of platinum as electrocatalyst is responsible for approx. 30% of the manufacturing costs of the proton exchange membrane fuel cell (PEMFC) [1]. Reducing the platinum loading, especially on the cathode side, is therefore crucial for this promising technology to be commercially successful. One strategy of increasing the activity towards the oxygen reduction reaction (ORR) and reducing the platinum loading is the appropriate combination of platinum with first row transition metals such as Fe, Ti, Ni, Fe or Co [2]. In this paper we present a straightforward and scalable PtCo/C catalyst preparation method with stability increasing post-preparation treatments.

Platinum cobalt catalysts supported on high surface carbon (PtCo/C) were prepared by a modified impregnation method with thermal initiation of the reduction. Post-preparation treatments with activity and stability increasing effect were performed [3]. Accelerated stress tests (ASTs) were performed to compare the stability to standard Pt/C catalysts.

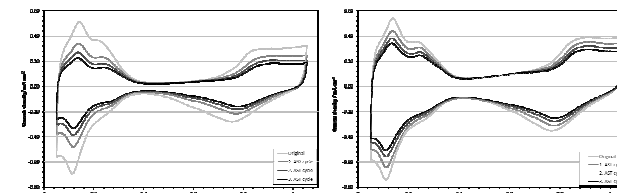


Fig. 1: Results of Pt/C standard catalyst (left) and stabilized PtCo/C catalyst (right) during AST testing

Implementing the new catalyst system to a membrane electrode assembly decreases the platinum loading by 20% on the cathode without losing performance during longterm operation over 600 hours [3]. In addition the loss of electrochemical surface area was decreased by approx. 50% by the post-preparation treatment (see diagrams below, left: Pt/C standard catalyst, right: PtCo/C catalyst after post-preparation treatment).

Financial support by the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT), the Austrian Research Promotion Agency (FFG) through the program a3plus and the IEA research cooperation and our industry partners VTU engineering and proionic GmbH is gratefully acknowledged.

[1] C. Grimmer, A. Schenk, B.E. Pichler, M. Perchthaler, V. Hacker, ECS Trans. 58 (2013) 753.

[2] V.R. Stamenkovic, B.S. Mun, M. Arenz, K.J.J. Mayrhofer, C.A. Lucas, G. Wang, P.N. Ross, N.M. Markovic, Nat. Mater. 6 (2007) 241.

[3] A. Schenk, C. Grimmer, M. Perchthaler, S. Weinberger, B. Pichler, C. Heinzl, C. Scheu, F.-A. Mautner, B. Bitschnau, V. Hacker, J. Power Sources 266 (2014) 313.

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Non-precious metal FC catalysts

New Pt-alloy FC catalysts

New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 20/29



## A1301 (Abstract only)

## Developing Novel, Near-Optimal Pt Electrodes for Hydrogen Fuel Cells via Theoretical Simulations

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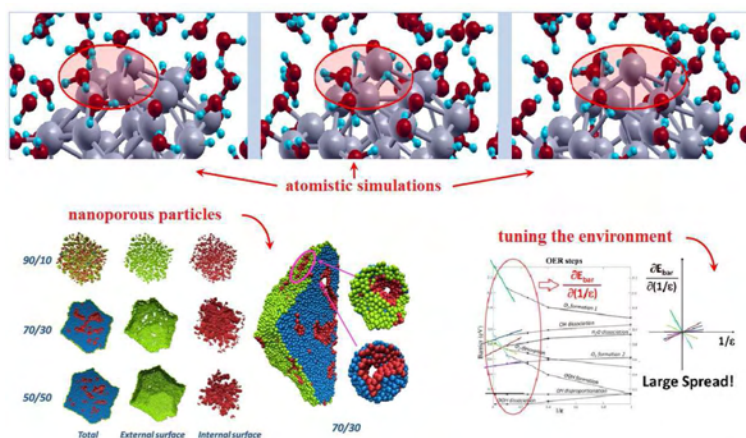
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### Abstract

A comprehensive picture of the atomistic mechanisms of the Oxygen Reduction Reaction (ORR) over Pt-based catalysts is achieved, ranging from extended surfaces to nanoporous particles and small clusters in different environments and supports (including glassy carbon) [1]. The reasons of the current kinetic limitations and catalyst degradation are singled out. It is predicted that this will allow a significant reduction of the Pt catalyst loading and extension of the catalyst life time in Polymer Electrolyte Fuel Cells (PEFC), thus accelerating the a commercial introduction of fuel cell electric cars.

[1] A. Fortunelli, et al. "Dramatic Increase in the Oxygen Reduction Reaction for Platinum Cathodes from Tuning the Solvent Dielectric Constant" *Angew. Chem. Int. Ed.* 2014, 53, 6669 –6672, DOI: 10.1002/anie.201403264; "The atomistic origin of the extraordinary Oxygen Reduction activity of Pt<sub>3</sub>Ni<sub>7</sub>" (submitted); "Optimizing the Oxygen Evolution Reaction for Electrochemical Water Oxidation by Tuning Solvent Properties" (submitted)



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Non-precious metal FC catalysts

New Pt-alloy FC catalysts

New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 21/29

## A1302 (Elsewhere published)

## Three-dimensional catalyst electrodes with PdPt nanodendrites for PEFC applications

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### Abstract

Three-dimensional (3D) catalyst electrodes by bottom-design from one-dimensional (1D) nanostructure arrays have been demonstrated as an effective approach to address some challenges faced by conventional fuel cell electrodes. 3D Pt-nanowire (PtNW) catalyst electrodes, benefiting from a significantly reduced mass transfer resistance from the extremely thin catalyst layer, the excellent catalytic abilities through the unique surface properties of single-crystal Pt NWs, together with a highly reliable fabrication approach enabled by a simple one-step reduction process, show a high potential for next-generation PEFC application developments.

Based on this 3D catalyst electrode platform, the synergistic effect between Pd and Pt is further demonstrated in this work. PdPt nanodendrites (NDs) with different compositions were in-situ grown on gas diffusion layers (GDLs) through the reported simple wet-chemical route in aqueous solution at room temperature. The GDLs with PdPt NDs are directly employed as gas diffusion electrodes (GDEs) for ORR at cathode in H<sub>2</sub>/air PEFCs. Experimental results reveal that the introducing of Pd not only manipulates the catalytic activity and durability of bimetallic PdPt NDs, its content is also an efficient tool in tuning the morphology and distribution of products through the large-area substrate. At an optimal Pd content of 5 at%, uniformly distributed PdPt NDs with a branch diameter of 4 nm and length of ca. 10 nm are achieved on a 16 cm<sup>2</sup> GDL and showed the best performance. The as-prepared PdPtND GDE with 5 at% Pd also shows a better power performance and durability compared with PtNW GDE.

Non-precious metal FC catalysts

New Pt-alloy FC catalysts

New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 22/29

## A1303 (Abstract only, elsewhere published)

**Study of Pt electrocatalysts for the oxygen reduction reaction fabricated by pulsed laser deposition**

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**Abstract**

Polymer electrolyte fuel cells (PEFCs) represent attractive and environmentally friendly candidates for transport applications due to their relatively low operating temperatures, high energy density and zero emissions. However, the slow kinetics of the oxygen reduction reaction (ORR) at the cathode leads to high overpotentials. The resulting performance loss is considered as one of the main obstacles towards their commercialization. Since state-of-the-art electrocatalysts are all Pt-based materials, increasing their activity is of great interest. A very promising approach is to induce a variation of inter-atomic distance of Pt atoms to influence the oxygen-platinum-bonding on the surface and hence facilitate the ORR [1]. In this context, epitaxial thin Pt films in different stress states were grown on single crystalline (100) and (111)-oriented strontium titanate substrates using pulsed laser deposition. Reflection high energy electron diffraction was applied to monitor in-situ the film growth mode. It was found that 3D-Volmer-Weber-Mode is dominant for as-produced Pt films. A good crystalline quality and epitaxy was confirmed for all Pt films by X-ray diffraction measurements. Scanning electron microscopy images revealed that the surface morphology of as-produced Pt films was strongly dependent on their thickness as shown in figure 1. Cyclic voltammetry measurements were carried out to investigate the electrochemical surface properties of the as-produced Pt films. The ORR activity of the as-produced Pt films of different inter-atomic distances was investigated in a specifically designed flow cell.

First results on the structural and the electrochemical analyses of the Pt films will be presented and discussed. The superior activity of strained Pt films for the ORR as compared to bulk-terminated surface structures will be demonstrated.

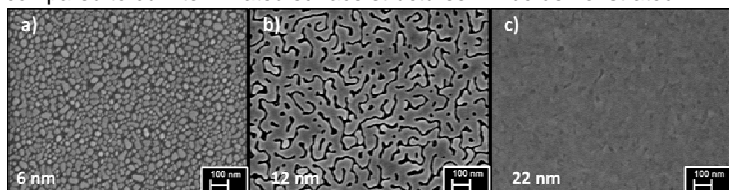


Figure 1: Scanning electron microscopy images of the surface of a) 6 nm, b) 12 nm and c) 22 nm (111)-oriented Pt film, respectively.

[1] A.Rabis, P.Rodriguez and T.J.Schmidt, ACS Catal. 2012, 2, 864–890,

Remark: The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.

Non-precious metal FC catalysts

New Pt-alloy FC catalysts

New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 23/29

## A1304 (Fuel Cells SI publication candidate)

**New Physical Technologies for Catalyst Synthesis and Anticorrosion Protection**

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**Abstract**

The problem of platinum loading reduction and increase of the catalyst lifetime is one of the key problems of PEM fuel cells. But it is worth also to stress that catalyst price due to multistage procedure using traditional methods is also very important. Development of relatively cheap and stable catalysts using magnetron sputtering and ion implantation was one of the goals of our research. It is necessary to underline that chemical liquid phase synthesis, thermal decomposition and precursor reduction by gas phase components were tested and we found out that though these methods provide production of efficient catalysts they have some limitations due to relatively high temperature (catalyst particles sintering) and/or multistage process (mainly liquid phase synthesis with rather long-time catalyst purification from impurities). Physical method (magnetron-ion sputtering, ion implantation and some others) provide low temperature synthesis of catalysts practically in any crystalline and even amorphous forms. At the same time application for implantation and/or sputtering pure metals or their "pure" alloys ensures high purity of the produced catalysts which are practically ready for further application (one stage process). Cathode and anode catalysts were synthesized using these methods. Nanostructural Pt, Pt-Ni and Pd electrocatalysts (2-10 nm) on nanostructured carbon carriers (Vulcan, graphene and graphene nanofibers) were developed for fuel cells and electrolyzer cathodes using plasma magnetron sputtering technology assisted by ion implantation. Obtained catalysts provided high fuel cell efficiency and in case of application of mixed carbon carriers (Vulcane+graphene, Vulcane+nanofibers) the efficiency was even higher in comparison with catalysts obtained by polyol method at lower Pt loading. Another important issue was application of physical methods for Ti and stainless steel protection from corrosion/oxidation and hydrogen embrittlement. It was found out that implantation of carbon ions (doses  $D=10^{16} - 10^{17}$  ion/cm<sup>2</sup>,  $E = 5-10$  keV) permitted to decrease speed of hydrogen penetration for about 50%. Implantation of Pd or Pt ions ( $D=10^{17}$  ion/cm<sup>2</sup>,  $E = 1-10$  keV) provides increase of Ti bipolar plates stability from oxidation in 2-3 times and even more in case of magnetron sputtering of Pt and Pd films assisted by ion (Ar<sup>+</sup>) implantation.

Non-precious metal FC catalysts

New Pt-alloy FC catalysts

New catalyst structures and manufacturing processes

Chapter 04 - Sessions A06, A09, A13- 24/29

## A1305 (Fuel Cells SI publication candidate)

**Effect of Structure of Nafion and Hydrocarbon Ionomer on Oxygen Solubility**

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**Abstract**

The generating efficiency of polymer electrolyte fuel cells (PEFC) is about 40% which is less than its theoretical efficiency. It is considered that one of the causes of the lower efficiency is mass diffusion losses by oxygen transportation to the catalyst surface. The ionomer contains polymer electrolytes, and not only perfluorosulfonic acid (PFSA) as typified by Nafion® but also hydrocarbon polymers (HCP) have been developed for the electrolytes, because the HCP-based membranes are lower in cost and higher in heat resistance compared with the PFSA membranes. Therefore, we analyzed the oxygen permeability in the two different types of ionomer based on Nafion and HCP by using molecular dynamics simulations.

In this study, we evaluated the dependence of the structure characteristics and the oxygen solubility on water content and the effect of the structural properties on the oxygen transport properties. We constructed two different types of ionomers based on PFSA and HCP on the Pt catalyst surface, respectively as shown in Fig. 1. From the density distributions of the Nafion-based ionomer, it is shown that the ionomer/vacuum interface and the bulk region swell with increasing water content. Generally, the oxygen permeability is evaluated by the product of the oxygen solubility and the oxygen diffusivity. Thus, the solvent molecules decrease the oxygen solubilities of those regions. Moreover, in the ionomer/Pt interface, the oxygen solubility is decreased due to the increase in the solvent molecules which fill the voids in the region. On the other hand, in the HCP-based ionomer, the ionomer/vacuum interface and the bulk region swell, which indicates the decrease of the oxygen solubility. Besides, in the ionomer/Pt interface, there is no effect of water content on the oxygen solubility, because the densities of the polymers and the solvents are constant with water content.

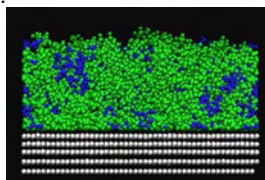


Fig. 1 Simulation system of the Nafion-based ionomer.  
(Green: Nafion, Blue: solvent, White: Pt)

## A1306 (Abstract only, elsewhere published)

**Oleylamine adsorbed Pt nanoparticles as an anion-adsorption-tolerant electrocatalysts towards oxygen reduction reaction**

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[jhiang@kist.re.kr](mailto:jhiang@kist.re.kr)**Abstract**

Due to its high activity, carbon supported Pt nanoparticles (Pt/C) are widely utilized as the electrocatalysts for the oxygen reduction reaction (ORR) in proton exchange membrane fuel cells (PEMFCs). However, when H<sub>3</sub>PO<sub>4</sub>-doped polybenzimidazole (PA-PBI) membranes are utilized at operating temperature up to 180 °C, the Pt/C is severely poisoned by the strong adsorption of phosphate anions.

In this study, in order to decrease the specific anion adsorption on Pt surface, oleylamine adsorbed Pt nanoparticles (OA-Pt/C) were synthesized, and its ORR activities under large amount of phosphoric acids were evaluated by half- and single-cell tests. When Pt nanoparticles are prepared via the colloidal reduction method, surfactant molecules, such as oleylamine (CH<sub>3</sub>(CH<sub>2</sub>)<sub>7</sub>=CH(CH<sub>2</sub>)<sub>7</sub>CH<sub>2</sub>NH<sub>2</sub>), are utilized to confine the particle size within a few nanometers. We directly utilized the synthesized Pt/C with native surfactants as ORR electrocatalysts, whereas generally the adsorbed surfactants are removed by heat or acid treatment in order to maximize the active site on Pt surface. The OA-Pt/C showed enhanced tolerance to phosphoric acid addition in half-cell tests with 0.1 M HClO<sub>4</sub> electrolyte solution. In addition, high performance and durability could be confirmed by a single-cell test with a PA-PBI membrane electrolyte at operating temperature of 160 °C. These results reveal that the native surfactant molecules can improve the catalytic activity despite loss of electrochemical active sites.

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## A1307 (Fuel Cells SI publication candidate)

### Structure and proton dynamics in catalytic layer of HT-PEFC

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#### Abstract

The present study focuses on structural and dynamical properties of the catalytic layer for high-temperature polymer electrolyte fuel cells (HT-PEFC). The catalytic layer is a composite material containing nanoporous carbon, poly(tetrafluoroethylene) (PTFE) and platinum (Pt) nanoparticles. The structure of the catalyst is investigated using small angle X-ray scattering (SAXS) following different preparation steps of the electrodes: pure carbon support, platinum/carbon (Pt/C) powder and finally complete catalytic layer. The structural properties of the Pt/C powder containing different amounts of Pt are discussed along with the size distribution of Pt particles and their arrangement on the surface of the carbon support. Following the preparation sequence of the catalytic layer based on the Pt/C powders the electrodes with different final Pt loadings are analyzed in details. Investigation of the structure of the catalytic layer is accompanied by the study of nanosecond dynamics of the phosphoric acid (PA) in the catalytic layer containing different amount of Pt by means of neutron backscattering spectroscopy. We found that the structure of the catalytic layer is mostly determined by the structure of the catalytic powder and does not vary significantly with Pt loading in the electrode. Concerning dynamic properties of the system, the behavior of the PA turned out to be sensitive to the Pt content in the electrode.

## A1308 (Abstract only, elsewhere published)

### Fibrous and tubular structures for PEMFC catalyst supports combining electrospinning, heat treatments and atomic layer deposition (ALD)

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#### Abstract

The general requirements for fuel cell catalyst support materials are high electronic conductivity; high specific surface area and high electrochemical and chemical stability. Material structure should also enable good gas and water vapor transport in it. Currently typical structures for PEM fuel cell catalysts consists Pt nano-particles on carbon black support. We are suggesting a new concept where supports consist of (nano)fibrous carbon and ceramic (nano)tubular structures providing high surface area for catalyst reaction and high porosity for good management the product water. Materials are corrosion resistant and electrically conductive.

Fibrous and tubular material structures are based on electrospinning – method leading to submicron or nanoscale fibre diameters. Our approach to produce core-shell carbon-ceramic catalyst supports includes preparation of electrospun precursor fibres, stabilization and carbonization of precursor fibres into carbon, and atomic layer deposition (ALD) coating method to produce conducting niobium doped titanium oxide layer onto carbon fibres. Our approach to produce tubular catalyst supports includes preparation of sacrificial electrospun template fibres, preparation of oxide layer on fibres by ALD and removal of polymer template from the structure by heat treatment. Oxide coating and tube structures produced by ALD are annealed to form conductive surface suitable for Pt deposition by ALD. Heat treatment processes of web samples were carried out using tubular furnace suitable for roll-to-roll operation.

In this presentation we will report production of such fibrous and tubular materials, optimization work done for improving support quality, and Pt coating of such structures, as well as discuss of use of these materials in catalyst applications. Work carried out within Catapult project; novel CATALYST structures employing Pt at Ultra Low and zero loadings for automotive MEAs; Supported by EU FCH-JU; Grant agreement no 325268.

Remark: The Authors did not wish to publish their full contribution in these proceedings.

The topic of this Abstract will be published in Journal of Power Sources 2015.

Please contact the authors directly for further information.



A1309 (Abstract only, elsewhere published)

## Synthesis of Carbon Supported Platinum Nanoparticles via Sputtering onto Liquid and their Oxygen Reduction Activities

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### Abstract

Platinum and platinum alloy nanoparticles supported on large surface area supports (Pt/C and PtM/C) are most widely utilized electrocatalysts for polymer electrolyte fuel cells, despite of their high cost and low reserves. To control the size and shape of nanoparticles, chemical reduction methods are generally utilized for the Pt/C and PtM/C synthesis. However, the chemical synthesis requires expensive and non-environmental friendly metal precursors, reducing agents and surfactants. As an alternative way, RF sputtering technique, where no chemical reagents are used, has been utilized to fabricate Pt nanoparticles dispersed in non-volatile liquids. However, practical carbon-supported electrocatalysts has not been successfully synthesized.

In this study, we synthesized Pt/C using one-step liquid sputtering technique. Dispersing carbon supports in polyethyleneglycol(PEG) by sonication was followed by direct sputtering onto carbon containing PEG. Powder Pt/C catalyst was obtained after ethanol filtration of the prepared colloidal solution. Well dispersed 2 nm Pt particles on carbon supports were observed by transmission electron microscopy (TEM) and the synthesized catalyst exhibited comparable activity to commercial Pt/C catalysts. PtCo/C and PtNi/C were also easily obtained via simple co-sputtering method and 1.9 times higher mass activity at 0.95 V for the oxygen reduction reaction relative to the conventional catalyst was confirmed.

Remark: The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.

Non-precious metal FC catalysts

New Pt-alloy FC catalysts

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Chapter 04 - Sessions A06, A09, A13- 29/29

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A11: Degradation studies and modelling  
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## A0801 (Fuel Cells SI publication candidate)

### PEMFC Stack Monitoring with Advanced Total Harmonic Distortion Analysis

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#### Abstract

For monitoring of fuel cell stacks usually single cells or cell pairs are measured individually and analyzed in relation to voltage drifts. This kind of measurement requires contacting and wiring for every single cell or cell pair separately (CVM – cell voltage monitoring). In order to avoid the complexity of individual cell voltage measurement, AVL has developed an approach that does no longer measure the voltage drift itself, but instead analyses effects which are result from voltage drifts. In parallel the approach provides additional information towards causes of voltage drops which can't be provided by CVM. These effects are detectable in the entire stack sum signal i.e. the cabling of individual cells is not necessary and the expenditure of cabling reduces to measuring stack voltage and stack current as well as superimposition of a particular signal to the stack. AVL's methodology is called THDA™ (Total Harmonic Distortion Analysis) and its theoretical background is the fact that under critical operating conditions a fuel cell distorts a superimposed signal harmonically and generates measurable spectral components. While under „normal“ operating conditions, the frequency spectrum of the superimposed current signal is identical with the spectrum of the responding voltage signal, additional spectral components (i.e. harmonics) are formed at particular frequencies during critical operating conditions. This response signals are analyzed in real time, to provide online failure identification during stack operation. The THDA method is equally suitable for monitoring stationary PEMFC applications as well as for mobile use (fuel cell vehicle, range extender). Replacing the existing, individual cell voltage measurement approach in-vehicle provides immediate and significant improvements in terms of cost and complexity. Its calibrated rapid response and dynamic failure mode detection allows immediate avoidance of potentially irreversible failures and serious lifetime consequences for fuel cell stacks. The presentation will explain the theoretical background and will show reference measurements performed in various projects.

## A0802 (Fuel Cells SI publication candidate)

### PEM fuel cell operation under air and O<sub>2</sub> feed: analysis of cell performance and liquid water distributions

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#### Abstract

A commercial 50 cm<sup>2</sup> PEM fuel cell was operated at 2.0 bara and 60 °C with two different oxidant gases, namely air and oxygen. A 3 x 3 matrix of anode and cathode reactants relative humidity was used. The cell performance and operating data including cell voltage and resistance were measured, and neutron radiographs were recorded during the entire operation to verify the liquid water distributions within the cell. A quantitative analysis of the results is presented in this work, comparing the cell operation for both gases. The gain in cell voltage observed for the operation with O<sub>2</sub>, together with the decrease in the cell resistance and the differences in the cell water content (as shown in Figure 1) are quantitatively analysed and discussed.

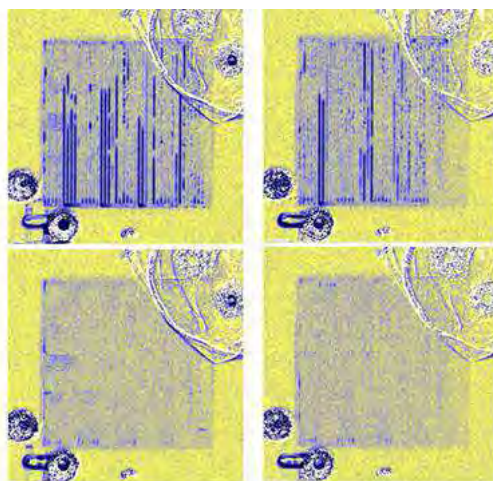


Figure 1: Liquid water content distributions in the cell (top) and in MEA/GDL (bottom) at RH<sub>a</sub> = RH<sub>c</sub> = 55% (60 °C, 2 bar, 10 A). Left: O<sub>2</sub> feed. Right: air feed.

## A0803 (Elsewhere published)

### Effect of PEM flow field channels orientation in the liquid water distributions and cell performance

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#### Abstract

A commercial 50 cm<sup>2</sup> PEM fuel cell with serpentine flow fields was operated at 2.0 bar and 60 °C with two different orientations of the flow field channels with respect to gravity (Figure 1). A 3 x 3 matrix of anode and cathode reactants relative humidity was used. The cell performance and operating data including cell voltage and resistance were measured, and neutron radiographs were recorded during the entire operation to monitor the liquid water distributions within the cell. A quantitative analysis of the results is presented in this work, comparing the cell operation for both flow field orientations. It is observed that the configuration with horizontal cathode flow field channels presents a better cell performance, and a less amount of liquid water blocking the flow field channels. The differences in the cell water content are quantitatively analysed and discussed.

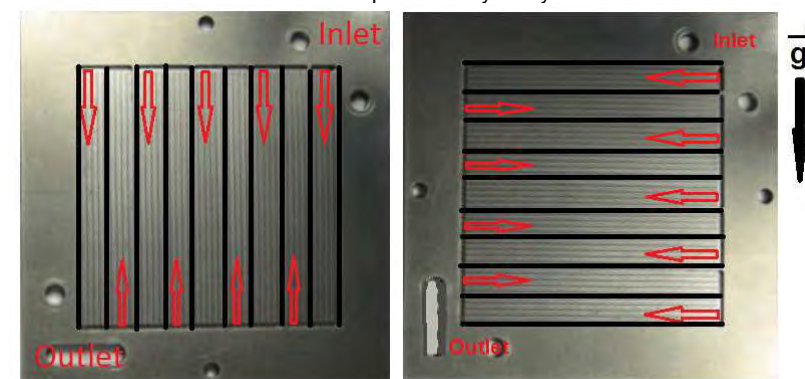


Figure 1: Flow field orientations analysed. Left: vertical cathode channels. Right: horizontal cathode channels.

A0804

## ***In situ* Diagnostic Tools for Characterization of Pinholes in PEM Fuel Cell Stacks**

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### **Abstract**

In this work, we introduce a novel diagnostic tool that allows accurate characterization of the hydrogen leak rate as well as the location of hydrogen transfer leaks, that are caused by thinning and pinhole formation in the polymer electrolyte membrane (PEM) of a single cell in a PEM fuel cell stack. The technique is accurate, non-invasive, and it can be used *in situ*. The diagnostic tool is suitable for improving the design of PEMs as well as for optimizing operating conditions to improve the performance, reliability, and lifetime of fuel cell systems.

PEMs play a key role in the operation of PEM fuel cells. They are responsible for conducting protons from anode to cathode, while prohibiting electron and reactant crossover. The highly selective transport properties of the PEM strongly affect fuel cell performance. In addition, these properties transform as the membrane ages, further affecting fuel cell performance, reliability, and lifetime. In this context, it is important to develop diagnostic tools that allow transport properties and species fluxes to be monitored during fuel cell operation. We therefore introduce a novel diagnostic tool that allows assessing the gas tightness of the membrane under operation.

Chemical degradation of PEMs results in membrane thinning, which in turn increases the rate of permeation across the membrane. In addition, various chemical, mechanical, and thermal stressors trigger formation and growth of pinholes in the membrane, further compromising its capability to separate reactant gasses between both electrodes. More specifically, the leakage of hydrogen from anode to cathode negatively affects the fuel utilization as well as the performance of the corresponding cell. Growth of pinholes eventually causes reactant starvation, indicating the end of life conditions for the fuel cell. The proposed method utilizes the Nernst potential caused by the difference in hydrogen partial pressure in anode and cathode to accurately characterize the rate and location of hydrogen transfer leaks in each individual cell. As this potential is independent of kinetic, ohmic, and mass transport losses, it can be used to accurately characterize hydrogen transfer leakage over the PEM fuel cell lifetime.

A0807 (Fuel Cells SI publication candidate)

## **Frequency dependent perturbation amplitude EIS measurement optimization for impedance measurements in a commercial PEM fuel cell**

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### **Abstract**

In current days, impedance spectroscopy has gained significant relevance in the fuel cell field, since this electrochemical measurement technique allows to obtain information on the fuel cell internal state and on its electrochemical behavior. One of the key parameters of an EIS measurement is the amplitude of the applied perturbation. A balance has to be found: The amplitude should be big enough in order to have a good signal-to-noise ratio; and at the same time, small enough in order to avoid non linear effects. Therefore, the optimum perturbation amplitude is the maximum amplitude that ensures a linear response of the system. The optimum amplitude depends on the frequency at which the impedance is measured. Consequently, using variable perturbation amplitudes leads to impedance spectra of better quality. In this work, a variable perturbation amplitude EIS measurement technique was optimized for impedance measurements in a commercial PEM fuel cell.

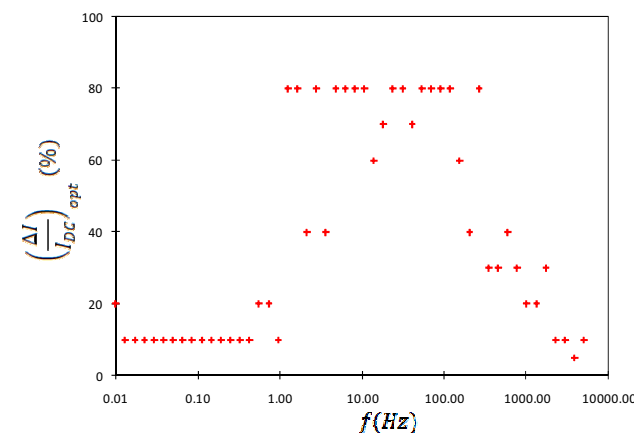


Fig. 1 Optimum perturbation amplitude for each frequency



## A0808 (Fuel Cells SI publication candidate)

## FFT based linearity study of a commercial PEM fuel cell

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## Abstract

The generalized Ohm's law, which defines the concept of impedance, is only valid if the assumptions of stability, linearity and causality are met. Fuel cells, as other electrochemical systems, are non-linear systems. Consequently, during electrochemical impedance spectroscopy (EIS) measurements involving this kind of systems, the linearity condition is achieved using low enough amplitude perturbations. Thus, a linearity study is required in order to determine the susceptibility of each system to generate non linear effects that cause EIS spectra distortions; and therefore, the maximum perturbation amplitude that can be used for EIS measurements of the system. In this work, a linearity study of a commercial fuel cell was performed. The linearity study was done using a fast Fourier transform (FFT) based method: the frequency domain response of the system was analyzed for different amplitudes of the perturbation signal. Besides the linearity of the system, the critical frequency of the system was determined: the frequency at which the nonlinear effects of the system are higher.

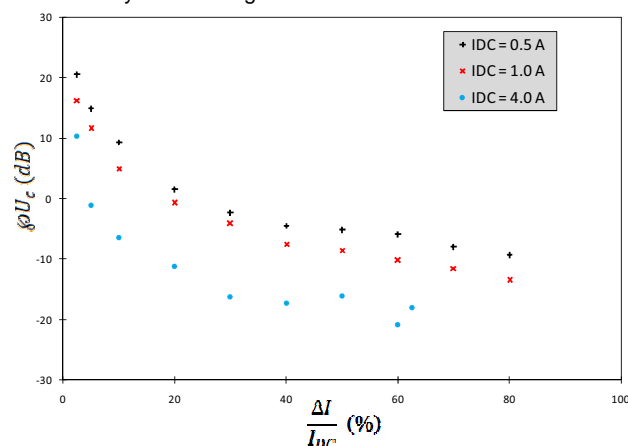


Fig. 1 Critical component to signal ratio (in decibel scale) versus the relative amplitude of the perturbation

## A0809 (Abstract only)

# Comment on the Application of Cyclic Voltammetry for the Determination of Specific Activity of Oxygen Reduction at the Cathode of Fuel Cell

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## Abstract

Cyclic voltammetry or CV is a type of potentiodynamic electrochemical measurement conducted at stagnant conditions. In a cyclic voltammetry experiment the working electrode potential is ramped linearly versus time like linear sweep voltammetry. Cyclic voltammetry takes the experiment a step further than linear sweep voltammetry which ends when it reaches a set potential. When cyclic voltammetry reaches a set potential, the working electrode's potential ramp is inverted. This inversion can happen multiple times during a single experiment. Cyclic voltammetry is generally used to study the electrochemical properties of anodic reaction ( cannot be used for cathodic reaction) [1, 2]. In an effort to determine the specific activity of oxygen reduction reaction at the cathode of

fuel cell many investigators [3-5] utilize cyclic voltammetry in dilute  $0.1 \frac{\text{mole}}{\text{liter}} \text{HClO}_2$  to determine the under-potentially deposited hydrogen  $H_{upd}$  in the potential range between 0.05 and 0.4 volts from the following cathodic reaction



This supposed to give the electrochemical active surface area (ECSAs) of the cathode electrode. It is obvious that the cathodic reaction 1 and at such low concentration of hydrogen ions (0.1 moles /liter) and at stagnant conditions is controlled by diffusion limitation. The objective of this comment is to show that misleading results may results from using cyclic voltammetry for cathodic reaction especially at low concentration of electro-active species and stagnant conditions.

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 [2] H. Jürgen. Agnew. Chem. Int. Ed. 23 831 1984  
 [3] Stamenkovic et al. Science 315, 493 January 2007.  
 [4] Yu et al. Agnew. Chem. Int. Ed. 50 2733 2011.  
 [5] Stamenkovic et al. Nature Materials 6, 241, 2007.

Remark: Only one page abstract was available at the time of completion.  
 Please contact the authors directly for further information.



A0810

## Inductance at Low Frequencies in Electrochemical Impedance Spectroscopy of PEM Fuel Cells

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### Abstract

The results of electrochemical impedance spectroscopy of PEM fuel cells may exhibit inductance at low frequencies. A standard representation of fuel cell processes by equivalent circuit models involving resistance/capacitance loops representing activation losses on both anode and cathode in series with a resistance, cannot explain inductance at low frequencies. A novel equivalent circuit model is made by adding additional resonance loops comprising of a resistance, capacitance and inductance, for both anode and cathode, representing mass transport and resistive losses within the catalyst layer. The model was used to fit the results of an accelerated stress test. The results indicate that resistance, capacitance and inductance representing the cathode catalyst layer change dramatically during the accelerated stress test, and this shows good agreement with the findings of the periodic diagnostic tests.

A1101 (Fuel Cells SI publication candidate)

## A preliminary study on potential analogies between mechanical fatigue theory and electrochemical PEM Fuel Cells aging induced by load cycling

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### Abstract

In proton exchange membrane (PEM) fuel cells domain increase system lifespan is the main objective. In this framework, studies involved in system aging and lifetime prediction usually require long-duration tests. Thus, accelerated aging procedures are introduced to reduce test duration and costs. Nevertheless, coupling natural and accelerated aging remains the main challenge. To this purpose, an additional support in accelerated stress test (AST) protocols' development is needed.

This article proposes a preliminary study on PEM fuel cells stack fatigue induced by electrical load cycling. In fact, if mechanical stress cycles can cause the system rupture (critical failure), electrical load cycles induce the system end of life (EoL) in a degradation failure mode. Considering that in fuel cells domain the effects of electrochemical degradations are usually evaluated measuring the induced cell voltage degradation, an analogy with mechanical stress and strain can be supposed. Based on this hypothesis the potential analogies between mechanical fatigue and electrochemical aging are evaluated, making the parallel between mechanical stress and electrical load cycles. The objective is raise awareness in this topic, giving the bases to conceive a new procedure aimed to analyze system durability and compare natural and accelerated aging effects. Moreover, consistently with mechanical fatigue, effects of temperature will be also considered. It is worth nothing that this procedure can be developed through in-situ cycling tests, imposing the load cycles directly at the stack terminals and measuring the single cell voltage values. The development of this approach is aimed to explain the impact of load cycling in PEM fuel cells aging, giving a valid support in AST protocol development for lifetime prediction. The fundamentals of this approach are then presented evaluating its reliability.

It is worth underlining that coupling mechanical fatigue theory with electrochemical degradations induced by load cycling is a novel approach in PEM fuel cells lifetime prediction domain. Moreover, numerous experimental results are still required to develop the methodology and then this article results in a preliminary study.

## A1102 (Fuel Cells SI publication candidate)

## Sensitivity analysis on the impact of air contaminants on automotive fuel cells

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## Abstract

In order to achieve a successful market introduction of series fuel-cell vehicles, detailed knowledge about the impact of external influences on the fuel cell, in particular the cathode catalyst must be appropriated. Common air contaminants cause power loss, decreasing lifetime or a complete MEA failure.

To get a data basis for further decisions in handling with noxious gases, the influences of air contaminants on PEMFC have been analysed extensively under automotive operating conditions systematically using a full factorial matrix test for the first time. The specific variation of temperature, voltage and harmful gas concentration resulted in 27 operating points for each used harmful gas.

First, the experiments were performed with a single cell, active area of 45.14 cm<sup>2</sup>, straight flow channels and a loading of 0.4 mg cm<sup>-2</sup> Pt/C at the cathode. Subsequently, similar experiments were carried out with a ten-cell stack. This stack was different from the single cell due to a modified flow field, larger active area of 300 cm<sup>2</sup> and the gas distribution. Hence, it is closer to the real application.

The results generated with the single cell indicated significant degradation but as well the possibility of regeneration. The degradation caused by different harmful gases is both dependent on temperature and potential. The currently performed analysis with a stack shows differences in degradation behaviour in comparison to the single cell. These outcomes reveal the necessity of stack tests to provide application-oriented reliable results. The results give an overview of the cathode harming potential of the most relevant air contaminants, including an estimation of the degradation influence depending on the harmful gas concentration. Hence, the work provides a basis for the development of cathode air filter and regeneration techniques for automotive applications.

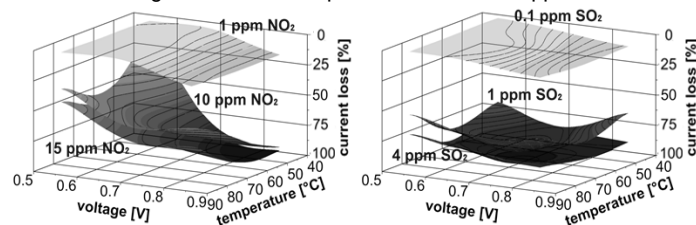


Figure 1: Current loss depending on voltage, temperature and concentration of contaminant (left: NO<sub>2</sub>; right: SO<sub>2</sub>)

## A1103 (Elsewhere published)

## Mathematical description of voltage decay rates in PEM fuel cells

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## Abstract

In the fuel cell community there is no common way to describe degradation or voltage decay rates in durability tests. This leads to a variety of possible approaches used to calculate voltage decay rates making the comparability of different tests difficult, especially when durability test are regularly interrupted by diagnostics or soak times in order to recover reversible voltage losses as shown in the left panel of the figure. Our study tries to address this issue by a mathematical description of voltage loss rates in PFSA based MEAs with Pt catalyst. In the presented approach we describe the decay rate changes by fitting an exponential and a linear decay curve to the experimental data after each refresh step, see Figure 1. The obtained fit parameters allow a clear separation and an in-depth analysis of the different contributions of the decay rate.

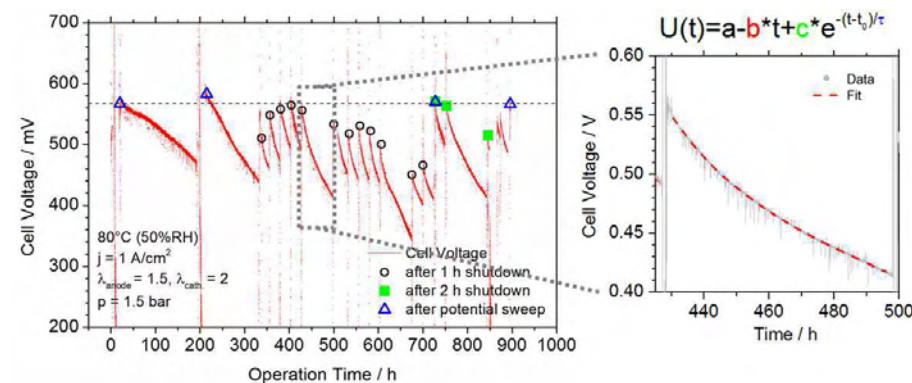


Figure 1: LEFT: Degradation test of a PEM MEA with regular interruptions of voltage recovery. Details are provided in the figure. RIGHT: Example of an exponential-linear fit of the decay rate.

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for Fuel Cell and Hydrogen Joint Technology Initiative under Grant No. 303452 (Impact).

A1104 (Abstract only, elsewhere published)

## Analysis of the heterogeneities in a PEMFC stack operated with reformat

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### Abstract

Durability of PEMFC for stationary fuel cell systems is still one of the main hurdles to overcome for large scale development and systems commercialization, when considering the required target of more than 40000 hours. These systems can operate with pure hydrogen or reformat from different fuels, thus including carbon dioxide and/or carbon monoxide, the latter being recognized as a main feature leading to a decrease in performance due first to anode catalyst poisoning and degradation due to ruthenium dissolution.

Investigations presented here are conducted in short stacks of a few cells, made with stainless steel stamped bipolar plates (surface 220 cm<sup>2</sup>) operated in different conditions with various fuel compositions, particularly with different CO contents representative of the concentrations potentially produced by reforming processes leading to more or less purified fuels. Performance and durability tests are applied with continuous registration of current density maps thanks to a S++ ® current scan line device. The work is focused on the heterogeneity of Membrane Electrodes Assemblies (MEAs) operation along the surface of a cell with the impact of the operating conditions such as temperature, relative humidity, fuel composition, with attention to non-pure H<sub>2</sub> fuels (CO, CO<sub>2</sub>, CH<sub>4</sub>) tolerance, and also to air bleeding effect; different anode catalysts can be compared to consider different tolerances. Modification of the heterogeneities induced by different reformat compositions will be addressed, both in stabilized operation but also during transients. The latter experiments allow to identify what is occurring locally within the MEA from gases inlets to outlets between two stable situations: these periods can help to interpret the impact of changing the load or the fuel on longer term operation. In addition to the impact of conditions on performance heterogeneity, results will be shown about the evolution of these heterogeneities induced by degradation: different degradation protocols are considered including cases representative of systems stationary operation but also accelerated stress tests. Electrochemical measurements are also performed cell by cell such as polarization curves, cyclic voltammetry and electrochemical impedance spectroscopy also to interpret the performance losses thanks to MEAs properties modifications. In-situ tests and analyses should be completed with local ex-situ analyses, by advanced transmission electron microscopy techniques to try determining a direct correlation between the local performance evolution obtained in-situ and the components' degradation mechanisms involved, allowing to get an ageing map as a basis for proposing further improvements of the MEAs.

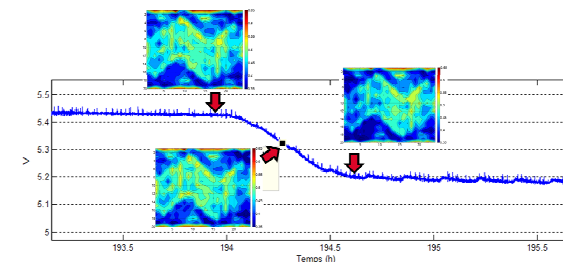


Figure: stack voltage versus time when changing the fuel by adding 10 ppm of CO in the reformat fuel (initially containing only H<sub>2</sub> and CO<sub>2</sub>) and current density maps recorded during this pollution.

Work supported by the European Union's FP7 (2007-2013) for the FCH-JU Initiative under grant agreement n°621216 (Second Act)

Remark: The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.

## A1105 (Fuel Cells SI publication candidate)

## Local CO Poisoning Modelling for PEM Fuel Cell with Spatial Segmentation

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### Abstract

Carbon monoxide poisoning can be responsible for the majority of reversible degradation of PEM fuel cells for automotive application. The degradation characteristics of PEM fuel cells are largely distributive and not uniform across the surface of the cell. Lumped single cell models are widely used to study the cell degradation under steady state operation or as a component in system-level models concerned with system control strategies. These lumped models are easily embedded into existing models and do not require excessive computational resources but they are unable to reveal the local degradation. The current study focuses on the application of a segmented single cell model to study the distributed degradation characteristics caused by carbon-monoxide poisoning in PEM fuel cells. The aim of the current study is to reveal the local contribution of different regions of a cell to the overall degradation of the cell. The developed model would form a platform for further studies on degradation mitigation strategies such as dynamic short-circuiting.

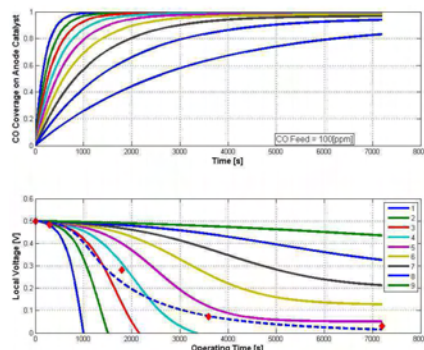


Fig. A1 Transient fractional coverage of anode catalyst site by 100ppm of CO in the anode feed (upper) and the resultant segmental cell voltage drop (lower) at 0.5V nominal cell voltage.

## A1106 (Elsewhere published)

## Experimental and Modelling Analyses of DMFC Temporary Degradation

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### Abstract

The widely use of the Direct Methanol Fuel Cell (DMFC) technology is still hindered by some technological issues, among which the severe performance degradation, that has a permanent and a temporary contribution. The latter can be partially recovered with an interruption of the operation or by applying appositely developed procedures. A systematic characterization and a complete understanding of temporary degradation phenomena are thus necessary to effectively distinguish its effects from the permanent ones. Figure 1 [1] reports the comparison of the voltage evolution of two tests where the only difference is the operating strategy structure: a reference refresh (30 seconds of OCV and 30 seconds of air-break every 20 minutes of operation) is compared with an OCV-only operating strategy (1 minute of OCV without air-break every 20 minutes of operation). Eliminating the air-break period, during which cathode potential drops to less than 0.3 V, it is possible to notice a strong increase of degradation, the most part of which is recoverable and occurs at the cathode [1]. This behavior suggests that cathode temporary degradation is most probably caused by cathode platinum oxides formation that can be removed at low cathode potential. In this work, carried out in the framework of FCH-JU FP7 project Second Act, the possible causes of cathode temporary degradation are investigated by means of dedicated OCV tests. Subsequently a preliminary DMFC model is developed to support the prosed interpretation of cathode voltage decay.

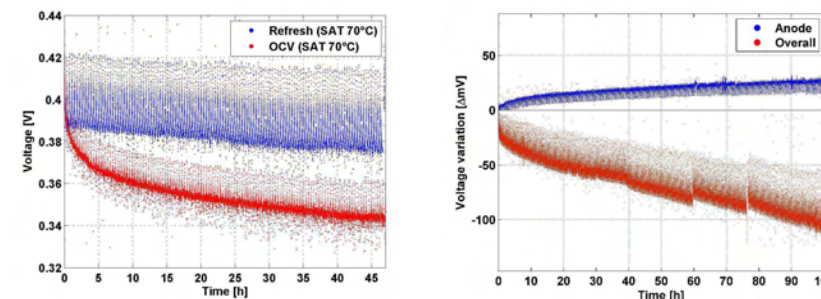


Fig.1 Voltage decay adopting different operating strategies and anode versus overall voltage variation [1].



A1107 (Abstract only, elsewhere published)

## Siloxane effects on proton exchange membrane fuel cell

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### Abstract

Due to global warming by high emissions of greenhouse gases, the world is paying attention to reduce greenhouse gases and interest in using the hydrogen gas as alternative fuel. The hydrogen gas can be also produced from biogas, which is consisted of rich CH<sub>4</sub>, CO<sub>2</sub>, CO, H<sub>2</sub>S, NH<sub>3</sub> and siloxanes. Particularly, a low concentration of siloxane can be potentially subjected to oxidized silica particles, which is extremely harmful to the durability of the internal combustion engines. Recently, the polymer electrolyte fuel cells (PEFCs) have tried to use the biogas as an alternative fuel source. However, there has been no study that tried to analyze the effects of siloxane on PEFCs during a long-term operation and establish the specific degradation mechanisms of PEFCs by siloxane. Herein, we reported the specific degradation patterns of PEFC during many specific cases and studied the specific degradation mechanisms of PEFC by siloxane.

These authors contributed equally to this work.

Remark: The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.

A1201

## Fault Detection and Isolation of Polymer Electrolyte Membrane Fuel Cells Using Bond Graphs

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### Abstract

The current generation of Polymer Electrolyte Membrane (PEM) fuel cells suffers from decreased durability characteristics compared to conventional internal combustion engines. If PEM fuel cells in automotive applications are to be competitive, it is important to minimise losses in performance (due to degradation of components) over extended periods of time.

One way to achieve this is to develop accurate Fault Detection and Isolation (FDI) techniques to ensure effective fault tolerant control and maintenance strategies, which in turn will ensure stable and prolonged operation of the system.

This ongoing research project is focused on model-based FDI. The main challenge with this approach is that fuel cell models are complex and the internal structure of a fuel cell is poorly instrumented making it impossible to measure some of the key parameters. Hence a qualitative diagnosis using Bond Graphs (BG) has been chosen here in order to investigate some major faults occurring in fuel cell systems. BG is a graphical modelling approach which represents interactions between system components as exchanges of energy. Not only does this enable the simulation and study of the dynamic performance of a system, it also enables FDI analysis by deriving Analytical Redundancy Relations (ARR) and calculating residuals.

In this work a bond graph model of a PEM fuel cell is developed using Modelica modelling language and validated against a custom built fuel cell test system. A set of faults and degradation mechanisms within PEM fuel cells will be detected using BG's. Future stages of research will use quantitative analysis of the current state of health and degradation rates of the system to extrapolate this information for prognostic studies.



A1202

## Fault Diagnostic Modelling for Polymer Electrolyte Fuel Cells

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### Abstract

Polymer Electrolyte Fuel Cells (PEFCs) offer a number of advantages over traditional power generation systems, including high efficiency, high power density and no local carbon-emissions. However, even the best demonstrator projects suffer in lifetime durability; only surviving up to half the current US Department of Energy Targets.

Prognostics and Health Management (PHM) has been identified as a methodology that can be applied to PEFCs to enhance and extend functional lifetime. PHM techniques would be applied through the control systems for the fuel cell; monitoring and managing the operational parameters, and output performance. These PHM techniques are reliant on system diagnostic models, against which state of health can be measured, and faults identified.

The approach selected in this investigation is to call upon expert knowledge and understanding of the PEFC functionality; this produces a rule-based fuzzy-logic model. With a wealth of degradation analysis and linguistic descriptions in literature, fuzzy-rules are extracted for a variety of failure modes.

This paper introduces a diagnostic-orientated fuzzy-inference model of a PEFC. This combines with existing fuel cell control and monitoring processes, to diagnose a range of commonly documented failure modes.

A1203 (Elsewhere published)

## Evaluation of Performance and Chemical Degradation Phenomena in Reinforced PFSA Membranes: A Theoretical Study

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### Abstract

For proton exchange membrane fuel cell (PEMFC) performance, electrolyte materials need to exhibit two main properties: (i) high proton conductivity and (ii) good gas separation. When it comes to durability, the latter is most important because it is the main source for chemical degradation of the membrane.

To study the cell performance and to evaluate the chemical degradation under various operating conditions, a transient, macroscopic, two-dimensional multi-physics cell model has been developed. It describes the miscible two-phase flow of liquid water and gases in the gas diffusion- (GDL) and catalyst layers (CLs). The electrochemical reactions are modeled with Butler-Volmer-equations and a physical description of Schroeder's paradox [1] is incorporated into the coupling conditions between the porous CLs and the membrane. A schematic overview of the processes of the degradation model is shown in the left hand side of Figure 1: H<sub>2</sub>O<sub>2</sub> is formed via two electron transfer reactions of O<sub>2</sub> with H<sup>+</sup> in the electrodes (see Figure 1 right) and reacts with iron impurities in the membrane forming radical species. Two possible radical attack mechanisms are considered: "unzipping" of the backbone and scission of the side chains.

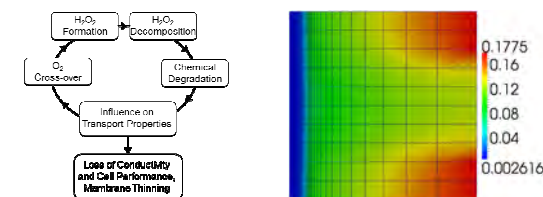


Fig. 1 Left: Processes incorporated into the chemical degradation model. Right: the mole fraction of O<sub>2</sub> in the gas phase of the cathode GDL and CL with gas channels positioned at the upper and lower part of the left boundary and a rib in the middle.

## A1204 (Elsewhere published)

### Modeling reversible and irreversible degradation in direct methanol fuel cells

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#### Abstract

Direct methanol fuel cells (DMFC) are a promising alternative to conventional energy storage systems due to the high energy density of liquid methanol. However, a remaining issue for DMFC is its severe performance degradation during operation. Most of this degradation can be attributed to the cathode. The degradation has reversible and irreversible contributions, where the reversible performance losses can be recovered by appropriate refresh procedures.

Here, we present a transient model which describes the irreversible loss of the electrochemical active surface area (ECSA) by platinum particle growth and the reversible degradation by the formation of platinum oxide. The particle growth is described by a balance equation for the particle size distribution taking into account Ostwald ripening and coalescence. The irreversible particle growth model is coupled with the reversible degradation model by taking into account that the platinum oxide forms a protective layer which reduces the platinum dissolution rates. Using the coupled model we perform transient simulations in order to investigate the effect of the refresh procedure on the reversible and irreversible degradation.

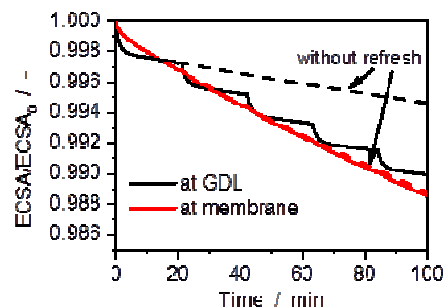


Fig. 1: Simulated irreversible loss of ECSA with/without refresh procedure

## A1205 (Fuel Cells SI publication candidate)

### Investigation of PEMFC parameter effects on practical fuel cell system performance

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#### Abstract

With the fast development of the commercialization of polymer electrolyte membrane fuel cells (PEMFC), especially for stationary power and automotive applications, the overall price of the PEMFC system must be controlled to a reasonable level, and the key is to keep the performance of the PEMFC system stable during its lifetime. Therefore, in the last few decades, the fault diagnosis of fuel cell systems and the prediction of its remaining useful lifetime (RUL) have received much more attention.

Compared to the fault diagnosis of fuel cells, where a set of studies have been devoted to investigating the diagnostic approaches to fuel cell systems under various loading conditions, only limited research has been found into the RUL prediction of these system. Among the studies performed, fuel cells faults are not considered systematically in the prediction analysis, the fault effect is expressed only with collected measurements, thus the prediction is heavily reliant on the quality of measurements. The reason for not including faults in the prediction is that the influences of fuel cell faults in the system performance are not fully understood, especially the performance decay rate due to these faults.

In this study, a parametric study will be performed to investigate the effects of fuel cell faults on the PEMFC system performance using selected parameters representing typical fuel cell faults. Two parameters related to fuel cell membrane faults, including membrane resistance and electrochemical surface area (ECSA) of the catalyst layer, are selected for the analysis. With a developed and validated PEMFC model, the relationship between fuel cell parameters and PEMFC voltage can be evaluated to study their influences on the system performance. Moreover, the evolution of these parameters with time will also be investigated using semi-empirical equations. From the results, the effect of fuel cell faults can be incorporated in the prediction analysis by updating performance decay rate, and RUL of PEMFC system can be determined with occurrence of single or multiple component faults.

## A1206 (Abstract only)

### Investigation of the effects of the water distribution in real gas diffusion structures on fuel cell performance

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#### Abstract

Polymer electrolyte membrane fuel cells (PEMFC) are a promising technology for electrochemical energy conversion. However, liquid water saturation of pores in the gas diffusion layer (GDL) inhibits the flow of reactants to the catalyst and creates an inhomogeneous current density distribution. This leads to accelerated material degradation and poor overall performance. Traditional fuel cell models, e.g. computational fluid dynamics (CFD) simulation modules, make simplifying assumptions with regards to the homogeneity of the porous GDL, which may cause current density distributions to appear more uniform than they really are. This investigation uses an integrated multi-scale approach to determine the impact of liquid water saturation in a real GDL structure on PEMFC performance.

The GDL structure inside of an assembled fuel cell is characterized using synchrotron tomography [1, 2]. This allows the different GDL structures due to flow field compression under-land and under-channel to be considered. The measurement is performed with a pixel size of 0.9 µm to account for the effects of fine pores and fiber structures in detail.

The 3D GDL structure obtained from the synchrotron tomography measurement is imported into a micro-scale CFD analysis to determine initial values for permeability and diffusivity. Mass transport through multiple samples from the GDL is simulated to reflect the distribution of these values due to compression and inhomogeneity in the GDL structure itself. A macro-scale CFD simulation using the ANSYS fuel cell module is then performed, in which the GDL is modelled as a collection of homogeneous regions based on the results of the micro-scale models. This yields a more accurate estimation of relative humidity and temperature distributions, which considers the local structure of the GDL under-land and under-channel.

A grand canonical Monte Carlo (MC) model [3] is used to calculate the water distribution within the 3D GDL structure from the synchrotron tomography measurement. The relative humidity and temperature distributions from the fuel cell CFD simulation are used as inputs in the MC model to achieve a realistic water distribution. With the calculated water distribution, the effects of pore blockage on permeability and diffusivity are then determined in a new micro-scale CFD analysis. These results are incorporated in the fuel cell simulation to reflect the influence of water saturation on overall performance.

This multi-scale approach shows that both structural effects due to GDL compression and pore-blockage due to inhomogeneous water distributions can significantly decrease GDL permeability and diffusivity and lead to non-uniform current density distributions.

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Remark: Only one page abstract was available at the time of completion. Please contact the authors directly for further information.

Monitoring, Diagnostics,  
Degradation Modelling,  
FC Fault and Simulations

Chapter 05 - Sessions A08, A11, A12, A14- 25/33

## A1401 (Fuel Cells SI publication candidate)

### Pore network modelling of compressed fuel cell components with OpenPNM

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#### Abstract

OpenPNM, an open-source pore network modelling package, was used to model the effects of compression on the porous media within PEFC, namely the gas diffusion layer. Networks were created using a Delaunay tessellation of randomly placed base-points setting the pore locations and its complement, the Voronoi diagram, was used to define the location of fibers. Realistic fibrous geometries were created and anisotropy was introduced by scaling the pore coordinates.

The modelling approach was validated with comparisons of the capillary pressure characteristic curves obtained numerically and experimentally. Primary drainage was simulated with a percolation algorithm which considers the effects of pore access limitations. Excellent agreement between model and experimental datasets was found when considering different capillary pressure relations.

Compression was simulated by scaling the through-plane coordinates in a uniform manner corresponding to a section of GDL wholly beneath the current-collector rib. It was found that the key multiphase transport properties of the porous media, namely the effective permeability and diffusivity show some dependence on compression. A power law dependence on saturation with exponent between 3 and 4 was found to describe un-compressed networks fairly well, but as compression is applied the dependence shifts depending on the phase and direction of transport. The PNM approach was demonstrated as a powerful tool for analysis of porous fuel cell components.

Monitoring, Diagnostics,  
Degradation Modelling,  
FC Fault and Simulations

Chapter 05 - Sessions A08, A11, A12, A14- 26/33

A1402 (Elsewhere published)

## A comparison between X-ray tomography images of water distribution in a gas diffusion layer and pore network simulations

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### Abstract

Understanding and modelling two-phase flows in the Gas Diffusion layer (GDL) of PEM fuel cell are technologically important in order to improve fuel cells performances and scientifically challenging because GDLs are fibrous porous media. In this context, the aim of this work is to perform comparisons between simulations at the pore network scale and images of water distributions obtained using X-rays tomography, with a very good resolution during ex-situ water invasion experiment.

Two simulation methods are tested: Pore Morphology and Pore Network Modeling. Both methods are based on geometrical analysis of the porous medium microstructure, water distribution being governed by capillary forces. The pore network is extracted from the GDL image using watershed segmentation. All algorithms were implemented using open source python libraries. The comparison between experimental and simulated microscopic water distributions will be presented and discussed.

A1403

## Analytical Solutions for PEM Fuel Cell Impedance

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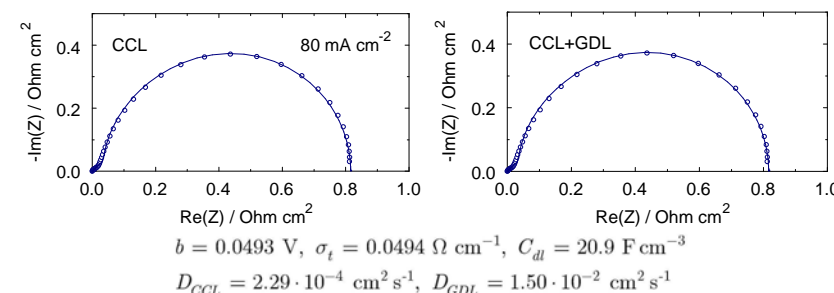
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### Abstract

Over the past decade, there has been growing interest in physical modeling of PEM fuel cell impedance. Most of the models developed are numerical. Accurate least-squares algorithms for experimental spectra fitting based on these models are usually time-consuming, as these algorithms include numerical solution of differential equations. We report explicit analytical solutions for the PEMFC impedance suitable for fast spectra fitting. The solutions are derived using the transient version of the model for the cathode catalyst layer performance [1,2]. In the first variant, we ignore the potential loss due to the oxygen transport in the GDL and solve impedance problem for the cathode catalyst layer only (CCL model) [2]. The second model includes the oxygen transport in the GDL (CCL+GDL model) [3]. Both the models lead to rather cumbersome expressions for the impedance; however, the respective least-squares fitting algorithms appear to be fast. Fitting of the HT-PEMFC experimental Nyquist spectra on a standard PC takes 15 and 120 seconds for the CCL and the CCL+GDL models, respectively (Fig.1). Fitting returns the ORR Tafel slope  $b$ , the CCL proton conductivity  $\sigma_t$ , the double layer capacitance  $C_{dl}$  and the oxygen diffusion coefficients in the CCL and GDL. The Maple worksheets with the fitting procedures based on the models discussed are available for download.



1. J. Newman, C.W.Tobias. J. Electrochem. Soc., **109** (1962) 1184.
2. A.A.Kulikovskiy. Electrochimica Acta, **147** (2014) 773.
3. A.A.Kulikovskiy. J. Electrochem. Soc., **162** (2015) F217 (free access).

## A1404 (Fuel Cells SI publication candidate)

### Advanced CFD Analysis of an Air-cooled PEM Fuel Cell Stack Predicting the Loss of Performance with Time

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#### Abstract

The PEM fuel cell simulation package developed by AVL List GmbH [1] is coupled with a semi-empirical degradation model [2,3] describing the dependency of material parameters on operating conditions. The CFD model calculates the 3D distributions of electronic/ionic potentials, velocity, pressure, phase volume fractions, gas species mass fractions, and temperature in all solids and fluids of PEM fuel cell stacks as well as water and gas species concentrations in the membrane. The degradation model modifies membrane and catalyst layer parameters according to local operating conditions and given operating time during the simulation run-time.

Calculated distributions of current density and temperature are compared to experimental data of an air-cooled PEM fuel cell stack obtained with segmented measurement plates. For the validation of the degradation model, calculated current density decay vs. operating time are compared to through-life polarization measurements. The good agreement between measurement and simulation demonstrates the ability of the model to predict the complex physical phenomena taking place in PEM fuel cells with high accuracy.

## A1405 (Fuel Cells SI publication candidate)

### A computationally efficient hybrid 3D analytic-numerical approach for system level modelling of PEM fuel cells

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#### Abstract

System level simulations, which are gaining on importance in the product design process and in the Hardware-in-the-Loop (HiL) applications, require models that feature high level of accuracy, high level of predictability and short computational times. While such system level models of e.g. internal combustion engines are commonplace, system level models of fuel cells are only slowly becoming available.

The core principle of the presented modelling approach is taking 1D numerical model for pipe gas-flow and superimposing onto it a 2D analytic solution for concentration and velocity distribution in the plane perpendicular to the gas-flow together giving a 3D information on species concentration in the fuel cell. The 2D solution is devised on a jigsaw puzzle of multiple coupled domains enabling the modelling of parallel straight channel fuel cells. Electrochemical and other nonlinear phenomena are coupled to the species transport by a routine of Newton-Raphson style. This 1D+2D approach gives the model its name: hybrid 3D analytic-numerical (HAN).

This paper summarises the key features of the HAN modelling approach and presents an innovative computationally optimized version of the HAN modelling framework denoted HAN-RT (RT standing for Real Time) that complies with the real-time constraints imposed by the HiL systems. HAN-RT shares with other HAN models the semi-analytic nature of species transport modelling and the efficient computational coupling of electrochemical kinetics to this transport, while featuring a specific computationally optimized framework for treating the governing equations.

A comparative evaluation shows very good agreement between the HAN-RT results and the CFD results. HAN-RT achieves high fidelity results at very short computational times. Accuracy of the results and computational speed thus confirm that HAN-RT efficiently combines hybrid 3D analytic-numerical mechanistic modelling basis and HiL compliant computational times.



## A1406 (Abstract only)

## Investigation of energy flow rates in Proton Exchange Membrane Fuel Cells using numerical model

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### Abstract

Proton Exchange Membrane Fuel Cells (PEMFCs) are seen as one of the most promising technologies for clean and efficient power generation for transportations in the twenty-first century. Since numerical simulation is very helpful in the improvement of this technology, in this work a Matlab/Simulink® model has been built up in order to analyze the performances of a Fuel Cell (FC) stack and to investigate the energy flow rates occurring during the process.

After a detailed explanation of the model, a parametric analysis, conducted under different conditions, is discussed. The results of simulations give indications about the behavior of PEMFCs through diagrams in which voltage, losses, power, mass flow rates and energy flow rates are plotted over current density.

A special focus is given to the energy balance, which has been set up by the equivalence between the energy content of reactants ( $\dot{h}_{inlet}$ ) and the sum of the energy content of products ( $\dot{h}_{outlet}$ ), the electricity produced ( $P_{FC}$ ) and the heat generated ( $\dot{Q}_{gen}$ ), as indicated by the equation (1).

$$\dot{h}_{H_2} + \dot{h}_{H_2O_{inlet}} + \dot{h}_{air_{inlet}} - \dot{h}_{H_2O_{outlet}} - \dot{h}_{air_{outlet}} - P_{FC} - \dot{Q}_{gen} = 0 \quad (1)$$

The results, presented in Fig. 1, show the decrement of the efficiency at higher currents due to the inverse proportionality of heat and electricity, while the energy content of reactants and products are directly proportional.

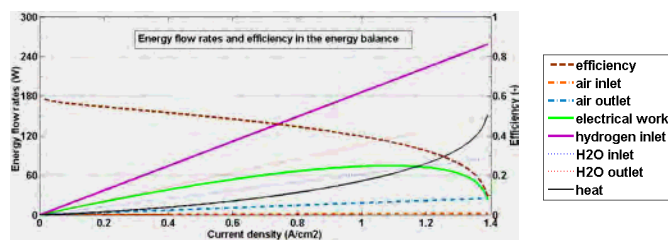


Fig. 1: Energy flow rates vs. current density

Moreover, the percentage of each flow of energy related to the total amount of energy entering or leaving the FC have been calculated.

Remark: Only one page abstract was available at the time of completion.  
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## A1408 (Elsewhere published)

## 2D modeling of two-phase multicomponent transport in direct methanol fuel cells

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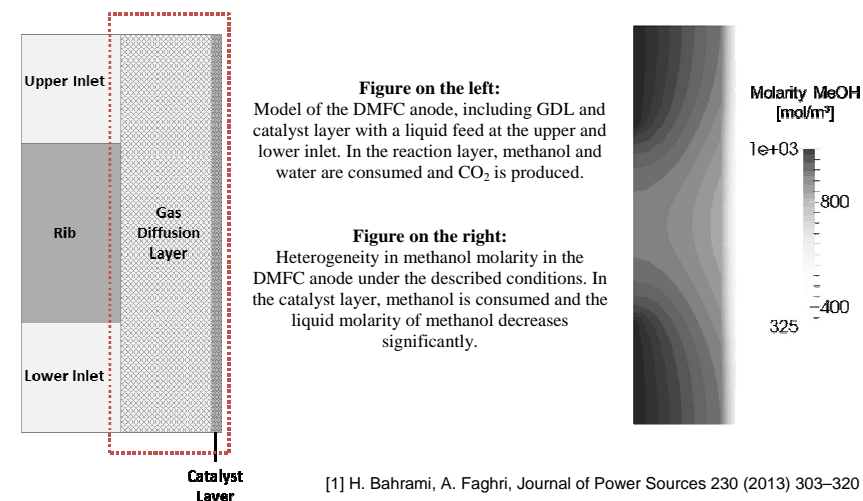
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### Abstract

**Keywords:** Modeling, Direct Methanol Fuel Cell (DMFC), two-phase flow

Direct Methanol Fuel Cells (DMFCs) are considered as a promising alternative power source for portable applications. This type of low temperature polymer electrolyte membrane fuel cells uses an aqueous methanol solution as a fuel. Methanol is oxidized in the DMFC anode under the formation of gaseous carbon dioxide. In case of a liquid feed DMFC, the formation of carbon dioxide leads to a two-phase flow [1].

In this work, we present a transient DMFC-model in 2D, which considers the two-phase flow in the porous medium and the multicomponent transport of species in the gas and the liquid phase. This model allows identifying heterogeneities, e.g. along the channel or between channel and rib. Providing such insight on the local conditions within the cell is of particular importance in order to predict local performance degradation rates. The resulting distribution of the reaction species in the porous medium is analyzed in detail.



**Figure on the left:**  
Model of the DMFC anode, including GDL and catalyst layer with a liquid feed at the upper and lower inlet. In the reaction layer, methanol and water are consumed and CO<sub>2</sub> is produced.

**Figure on the right:**  
Heterogeneity in methanol molarity in the DMFC anode under the described conditions. In the catalyst layer, methanol is consumed and the liquid molarity of methanol decreases significantly.

[1] H. Bahrami, A. Faghri, Journal of Power Sources 230 (2013) 303–320

## A1409 (Abstract only)

## Dynamic and multiphysic modelisation of a PEM electrolyser using the Bond Graph modelling tool

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### Abstract

The increasing penetration of renewable sources on the European electricity network involves the probability rise of supply and demand mismatching occurrence. Connecting an intermittent electric source to a proton exchange membrane electrolysis system seems to be a good way to convert (into hydrogen) and store the electrical energy excess (in fact, the hydrogen produced offers a wide range of potential uses). This connexion implies dynamic operating conditions. These dynamic operating conditions have a huge impact on efficiency, performance and behaviour of the system. As electrolysis systems were initially designed for grid connection – permanent operating conditions – it can be useful to perform some analysis on the behaviour of such a system under intermittent conditions. These analyses require the use of a dynamic and multiphysic (fluidic, thermal, electrical, chemical) model which represents the behaviour of each electrolysis system component. Following a literature review showing that most of electrolyser models are only focused on the stack representation, a new model was built using the Bond Graph formalism. This modelling approach is really suitable for dynamic representation of multiphysic and multicomponent systems (Figure 1).

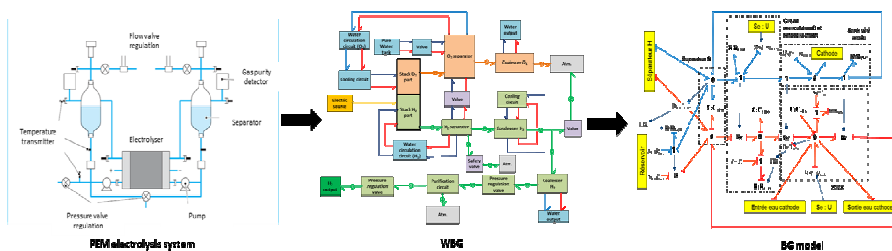


Figure 2: Word Bond Graph of a PEM electrolysis system

Then, the model was simulated and validated with a 25 kW PEM electrolysis system. The tool was proven to be very powerful and can be used both for representation and analysis. Therefore, it enables to represent our system with accuracy, analyse its comportment and achieve some general design optimizations: sizing of components, design of auxiliary's circuits, improvement of command system and control strategies.

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## Chapter 06 - Sessions A15, B14

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**Stack and system integration, operation strategies Chapter 06 - Sessions A15, B14- 2/22**

**FC Mobility applications/Stack and system integration**

## A1501 (Fuel Cells SI publication candidate)

**Novel Integrated Flow Field (IFF) Design for Higher Performance in Fuel Cell and Electrolyzer**

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**Abstract**

Higher efficiency in the operation of PEM fuel cell can be achieved through an advanced passive way to remove product water. Water droplet formation in PEM fuel cell gas channels reduces performance. This requires additional mechanical components to remove water, thus compromising the long-term reliability. This results in parasitic power loss and lowered efficiency. ElectroChem's Integrated Flow Field (IFF) design has solved these challenges with outstanding performance. In the IFF stack, reactant gas is effectively distributed to the electrode and product water is transferred separately without blocking the gas flow. Thus a water flooding condition is prevented. An effective internal humidification capability maintained the same power output at low humidity conditions in a hydrogen/air operating atmosphere. In an electrolyzer the phase-separation feature of the IFF supported the water feed to the cell and gas generation from the cell with less mass transport limitation.

## A1502 (Fuel Cells SI publication candidate)

**Development of fuel recirculation systems at single cell and stack level for hydrogen fuel impurity studies**

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**Abstract**

The European project HyCoRA (Hydrogen contaminant risk assessment, <http://hycora.eu/>) aims to develop and validate a strategy to reduce the cost of quality assurance for the hydrogen fuel of automotive grade (ISO 14687-2:2012 standard). Essential part of the HyCoRA project is to develop experimental procedures for fuel impurities research in miniature automotive polymer electrolyte membrane fuel cell systems.

Within this framework emerges the need to develop and validate testing procedures to systematically study the enrichment of impurities in the fuel recirculation loop at relevant concentrations (ISO 14687-2:2012 standard).

The first part of this work introduces various anode fuel supply configurations applied in lab scale and commercial systems, presents the mechanism of enrichment and suggest a method to approximate the magnitude of enrichment with trace impurities.

The second part presents the recirculation hardware options used for CO enrichment tests, including impurity injection and on-line gas analysis methods with discussion on possible error sources and technical problems. It is demonstrated, that a simplified recirculation system can be easily incorporated in practically any fuel cell test station with low additional cost.

The current target is to extend the work from to formic acid (HCOOH) and formaldehyde (CHOH) as impurities for the possible revision of acceptable concentrations in ISO 14687-2:2012 standard.

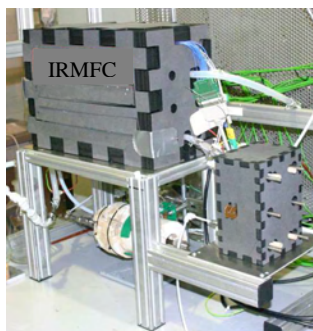
## A1503 (Fuel Cells SI publication candidate)

## Development of a Fuel Cell System with an Internal Reforming Methanol Fuel Cell

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### Abstract

Methanol is discussed as hydrogen containing energy carrier with suitable properties for fuel infrastructure and storage. Methanol fuel cell systems address large and rapidly growing markets like autonomous power supply, backup power or lightweight hybrid vehicles. Today DMFC or PEMFC with separate methanol reformers are available for the end user. An innovative approach is the integration of methanol reforming in HTPEM fuel cells to realize an IRMFC (Internal Reforming Methanol Fuel Cell). Highest efficiency potential, low complexity and modular setup for wide power range are the main advantages. In the current work, a 20 cell IRMFC stack delivering 250 W<sub>el</sub> has been developed. The evaporator is thermally integrated within the IRMFC stack. The methanol-water mixture as fuel can be fed at ambient temperature into the evaporator unit, in which it is evaporated and superheated before its entry into the reformer units. Within the reformer units the fuel is reformed and when the resulting H<sub>2</sub> rich reformat enters the HT-PEMFC unit, electrical power is generated. Aspects related to methanol evaporation, heat management, temperature control, activation of the methanol reforming catalyst and the startup behavior of the IRMFC stack have been studied and are presented. The IRMFC stack has exhibited 42,2 % efficiency at 200 °C. An anode offgas burner which can also function as startup burner using the methanol-water mixture has been developed and coupled to the IRMFC stack. The performance of the IRMFC system is presented in this work.



## A1504 (Fuel Cells SI publication candidate)

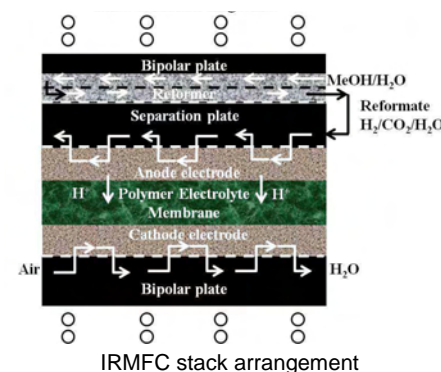
## Design and Demonstration of an Internal Reforming Methanol Fuel Cell System for Portable Applications

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### Abstract

The internal reforming methanol fuel cell (IRMFC) is a type of high temperature polymer electrolyte membrane fuel cell (HT-PEMFC) with the methanol reforming catalyst incorporated into the anode compartment (internal reforming). This configuration eliminates the need for additional heat exchangers and the HT-PEM technology applied does not require CO removal through a preferential oxidation (PrOx) reactor. Thus, the design of the fuel processor-fuel cell system offers room for simplification, increase of efficiency and minimization of system weight and volume. Increasing source runtime, speeding up the transient response while minimizing weight, volume and cost of the power supply system are key requirements for portable applications. In this work a proof-of-concept IRMFC system including Balance-of-Plant was designed, assembled and tested. The heart of the fuel cell stack was the reformer - electrode - membrane assembly. Taking



into account the requirement for a lightweight and lightvolume stack, Cu-based methanol reforming catalyst were supported on carbon papers, resulting in ultra thin reformers. Moreover, special bipolar plates were made of metal alloys, being stable at elevated temperatures and having high corrosion resistance in the strong acidic environment of the high temperature membranes. Novel flowfields design with a separation plate between the reformer and the anode electrocatalyst was applied in order to have maximum utilization of the methanol reforming catalytic bed and protection from

phosphoric acid poisoning. A proof-of-concept system of 25 W including BoP was integrated and Advent cross-linked TPS® membrane electrode assemblies were employed for fuel cell operation at 210 °C and 0.2 A cm<sup>-2</sup>, demonstrating the functionality of the unit.



## A1505 (Fuel Cells SI publication candidate)

### Development of bioethanol fuelled fuel cell system for backup applications – PEMBeyond project

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#### Abstract

In European project PEMBeyond (<http://pembeyond.eu/>) a cost-competitive, energy-efficient and durable integrated PEMFC based power system operating on low-grade bioethanol (crude BE ~80-95%) is being developed for backup and off-grid power generation (Fig. 1). The PEMBeyond system basically consists of the following functions integrated as a one complete system: a) Reforming of crude bioethanol, b) H<sub>2</sub> purification, c) Power generation in PEMFC system.

Optimizing the target hydrogen quality produced within the system is a key task with the regard to overall system cost, efficiency and durability. Experimental setup for determining suitable impurity levels (CO, CO<sub>2</sub>, CH<sub>4</sub>) at fuel cell stack and system level will be described. Achieved results together with simulation results from fuel processing stage will be analyzed, leading to optimized hydrogen quality specifications set for the developed system.

Process of defining the overall system specifications will be presented. This includes several different aspects regarding e.g. application/end-user requirements, related standards, cost, efficiency and durability targets.

The first main results from subsystems development work packages (fuel cell system, PSA, bioethanol reformer) will be presented.

## A1506 (Abstract only, elsewhere published)

### Efficient H<sub>2</sub>/O<sub>2</sub> polymer electrolyte fuel cells for Re-electrification of Hydrogen Obtained from the Power-to-Gas Process

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#### Abstract

When storing fluctuating renewable electricity in the Power-to-Gas process by water electrolysis hydrogen and oxygen are obtained. Up to a scale in the order of hundreds of Megawatt-hours the concurrent storage of oxygen and hydrogen gas is technically feasible. This opens up the possibility to use hydrogen/pure oxygen fuel cells for the efficient conversion of hydrogen back to electric power.

The oxygen reduction reaction is responsible for the largest voltage loss in the operation of polymer electrolyte fuel cells. The sluggish reaction rate of the four-electron reduction, even on the best platinum based catalysts, is aggravated by the low partial pressure of oxygen in air. When using pure oxygen the partial pressure can typically be increased by an order of magnitude.

On the cell level, not only the reduced electro catalytic loss but also voltage gain from lower transport overvoltage and reduced ohmic loss at same gas humidification as with air operation are observed. At the same time very high specific power densities of up to more than 1.5 W/cm<sup>2</sup> can be realized.

In addition to the advantages on the cell level, low parasitic power consumption in the balance of plant (no compressor/blower) also contributes to high system efficiencies of up to 69% (LHV).

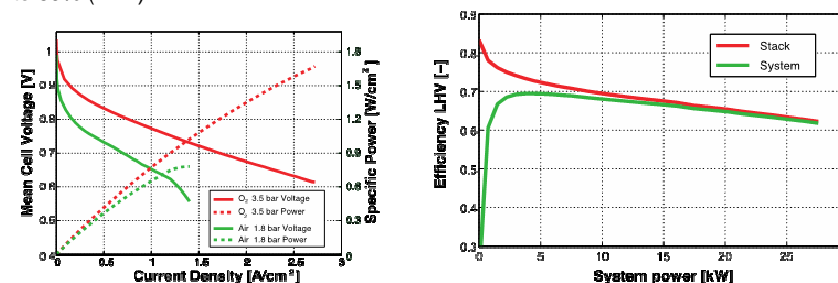


Figure 1: Current and power density and efficiency of H<sub>2</sub>/O<sub>2</sub> fuel cell systems.

Remark: The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.

A1507 (Abstract only, elsewhere published)

## Development and Characterization of a LT-PEFC Stack with an Extended Temperature Range up to 120 °C

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### Abstract

Usually, the operation temperature of a polymer electrolyte fuel cell (PEFC) stack for automotive application has its maximum at about 80 °C. The work presented here concerns the characterization of a 30-cell PEFC stack (2.5 kW<sub>el</sub>) developed at the German Aerospace Center, designed for operating temperatures up to 120 °C for a limited time. The possibility to run the stack at higher temperatures for a short time would contribute to the improvement of cooling system components with scaled-down dimensions. Those measures help to reduce the vehicle weight and thus to save fuel.

In this contribution we present the current-voltage characteristic curves and the homogeneity obtained along the cells. Moreover, in order to investigate the stack behaviour at extended operating temperatures, a series of 20 temperature cycles from 90 to 120 °C were performed at galvanostatic conditions of 70 A (approx. 0.5 A·cm<sup>-2</sup> and 1.5 kW<sub>el</sub>). The results are promising, since only a slight irreversible degradation was observed during the thermal cycling (see Figure below). Furthermore, the results of a 1200 hours long-term stability test are shown, including an end-of-life cyclovoltammetric characterization, performed on all 30 cells. The electrochemical analysis can help to find out possible causes of degradation due to catalyst or electrode degradation, and to determine hydrogen crossover rates, electrochemically active surface areas (EASAs) and electrical short-circuit resistances of each cell.

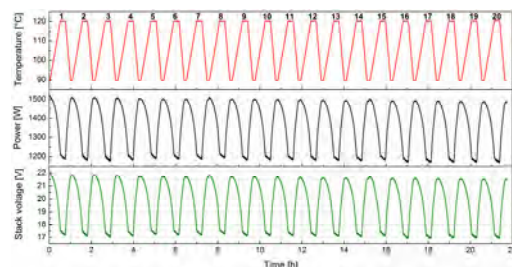


Figure: Thermal cycles between 90 and 120 °C performed on the 30-cell stack at 0.5 A·cm<sup>-2</sup>.

Remark: The Authors did not wish to publish their full contribution in these proceedings. Please contact the authors directly for further information.

A1508

## Development of an electrical backup power supply based on a novel hybrid fuel cell system

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### Abstract

Conventional electrical backup power systems like electric generators and batteries bear some problems concerning maintenance, reliability and runtime. Currently, fuel cell technology is of growing interest for electrical backup power. No other technology offers the combination of benefits fuel cells do. Among others, these include availability, minimum maintenance, long runtime and modularity.

The key benefits of Direct Methanol Fuel Cell (DMFC) systems in comparison to pure hydrogen systems are easy handling and storage of the fuel as well as high energy density and long runtime. Unfortunately, the slow start up behavior of DMFC's still hinders the use for electrical backup power.

In a new hybrid system the advantages of methanol and hydrogen fuel cell systems are combined to develop a maintenance-free emergency power supply system. Initial hydrogen operation of the cell quickly enables high power density and a rapid start up behavior.

The hybrid fuel cell system starts in hydrogen operation mode until a temperature of 60 °C is achieved (Figure 1, right). This heating time is only 4 minutes. After that the methanol operation directly starts at rated power. The combination of a hydrogen-startup and long-term operation with methanol (Figure 1 left) provides reliable operation at moderate costs.

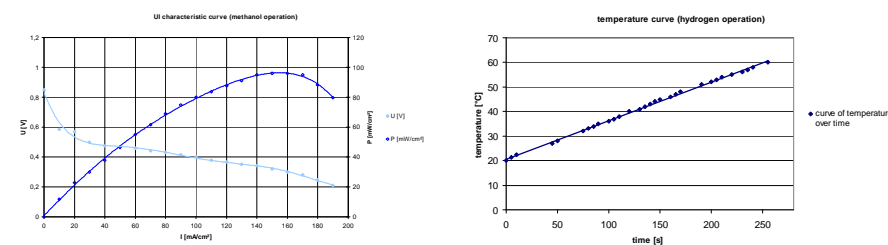


Figure 1: UI characteristic curve (methanol operation) (left); heating process over time (hydrogen operation)

A1509

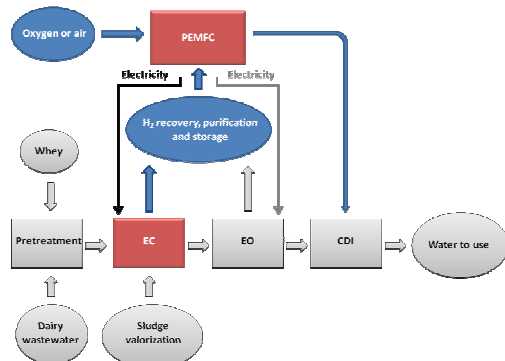
## Hydrogen recovery and electricity production from an electrocoagulation process using a PEMFC

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### Abstract

The main objective of the REWAGEN project, coordinated by IGB Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. in Germany (FRAUNHOFER) and with the participation of Acondicionamiento Tarrasense Asociacion (LEITAT), HyGear B.V. (HYG), Aqon water solutions GMBH (Aqon), Knowledge innovation market S.L. (KIM), Idropan Dell Porto Depuratori SRL (IDROPAN), Productes el Canadell SL (CTR), C-Tech Innovation Limited (C-TECH), ISA-Intelligent Sensing Anywhere S.A. (ISA) and Eilenburger Elektrolyse- und Umwelttechnik GmbH (EUT), is the research and development of a prototype for wastewater treatment in the food industry based on the sequential combination of three advanced technologies: electrocoagulation (EC), electrooxidation (EO) [1][2] and the recovery of generated hydrogen for energy saving and the reutilization of the resulting treated water for different applications - more efficient in terms of wastewater treatment and sustainable in terms of energy needs. The idea is to develop a wastewater treatment system aiming at closing the water cycle, by integrating energy and water management, where the electricity generated through the hydrogen conversion is used inside the treatment system. Additionally, the extracted residues from the waste water treatment are potentially reused inside the food and dairy industry to cover different needs.



LEITAT contributes developing, assembling and coupling two of the technologies studied inside the project, concretely EC system and Fuel Cell. The main goal is to recover the hydrogen produced during the EC process and inject the gas obtained in a PEM fuel cell. Several parameters must be taken into account, such as the gas composition or the feed rate.

Stack and system integration, operation strategies Chapter 06 - Sessions A15, B14- 11/22  
FC Mobility applications/Stack and system integration

A1510 (Abstract only)

## Design, modelling and simulation of a 1kW fuel cell power generator system

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### Abstract

This poster presents work carried out in the modelling, design and simulation of a 1 kW fuel cell (FC) power generator system, using real data collected from a PEM Horizon FC stack. The data collected represents the transient performance of the stack during load changes. The system is run for several days and its performance parameters such as the output current and the output voltage, the flow and the pressure of reactants; the temperature of the stack is measured and then logged using LabVIEW data acquisition. The experimental results are then used to determine the system behavior of a fuel cell power generator by simulation in MATLAB/Simulink software environment. Ultimately, these results are then used to design an appropriate controller, to predict a PEM FC power generator behavior and to size the load of a PEM FC stack for domestic use.

Remark: Only one page abstract was available at the time of completion.  
Please contact the authors directly for further information.

Stack and system integration, operation strategies Chapter 06 - Sessions A15, B14- 12/22  
FC Mobility applications/Stack and system integration

## B1401 (Abstract only)

**AutoStack – Core – Industry led European consortium to develop next generation automotive stack hardware****André Martin (1), Ludwig Jörissen (2)**

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[ludwig.joerissen@zsw-bw.de](mailto:ludwig.joerissen@zsw-bw.de)**Abstract**

Most of international automotive OEMs have announced plans for the commercialization of fuel cell vehicles in the next years. While this is a clear signal for the functional readiness of fuel cell technology in automotive application, durability, efficiency, power density and cost of the fuel cell stack need further advancements and in some cases substantial improvement in years to come.

“**Auto-Stack Core**” is a European funded collaborative project establishing a coalition with the objective to develop best-of-its-class automotive stack hardware with superior power density and performance while using components manufactured in an industrial scale and meeting commercial target cost. The project consortium combines the collective expertise of European automotive OEMs, component suppliers, system integrators and research institutes thus removing critical disconnects between stakeholders.

The technical concept is based on the **Auto-Stack** assessments carried out under an **FCH JU Grant Agreement from 2010 to 2012** and reflects the system requirements of major OEMs. It suggests a stack platform concept with the aim to substantially improve economies of scale and reduce critical investment cost for individual OEMs by sharing the same stack hardware for different vehicles and vehicle categories. It thus is addressing one of the most critical challenges of fuel cell commercialization. A first stack evolution has been designed, built and tested. Preliminary test results will be reported.

The project includes the benchmark of state-of-the-art stack development including innovative material and component solutions, different design options and manufacturing approaches. The technical development work will be accompanied by a detailed cost analysis using established tools of the automotive industry.

Industrial participation in the project and lead of critical work packages by industrial partners will ensure compliance of project objectives with industrial needs and allow direct implementation and utilization of the results. The project is of strategic importance for the competitiveness of the European supply industry and provides a critical contribution to supporting the commercialization of fuel cell and hydrogen technologies in Europe.

The work reported has been supported by the Fuel Cell and Hydrogen Joint Undertaking under Grant Agreement 325335.

Remark: Only one page abstract was available at the time of completion.  
Please contact the authors directly for further information.

Stack and system integration, operation strategies Chapter 06 - Sessions A15, B14- 13/22  
FC Mobility applications/Stack and system integration

## B1402 (Fuel Cells SI publication candidate)

**Characterization of a Fuel Cell Stack for Use in Material Handling Applications****Stefan Keller (1), Carsten Cremers (2), André Niedergesäß (2), Tansu Özel (1)**(1) Fraunhofer Institute for Solar Energy Systems ISE  
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[stefan.keller@ise.fraunhofer.de](mailto:stefan.keller@ise.fraunhofer.de)**Abstract**

This work investigates a fuel cell stack which is often used in material handling devices. Parametric analysis to investigate the effects of stoichiometry, temperature and pressure is carried out with the use of polarization curves and impedance spectroscopy, on both stack and single cell level. Fuel cell stacks incorporating a large number of cells, e.g. automotive fuel cells, are often reduced to short stacks for scientific characterization containing only a few cells. Therefore, we compare two stacks of the same kind, but with different cell counts. This provides information whether data derived by characterizing short stacks can be transferred to full stacks. Finally, performance data of this stack is compared to other stacks used in automotive applications. Due to the ongoing experimental work this extended abstract presents only few results but gives an overview of the scientific approach.

Stack and system integration, operation strategies Chapter 06 - Sessions A15, B14- 14/22  
FC Mobility applications/Stack and system integration

## B1403 (Abstract only, elsewhere published)

### Fuel Cell Applications for Range Extending and HVAC in Future Vehicle Concepts

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#### Abstract

Today's electrical vehicles do not offer a proper range especially if HVAC is necessary. Fuel cells are able to provide electrical and thermal power with a high efficiency. Therefore the DLR-Institute of Vehicle Concepts is investigating different fuel cell technologies for utilization in mobile applications. The power range of the applications reaches from 100 W in cargo pedelecs over 10 kW systems for passenger cars up to 200 kW systems for rail applications. To evaluate the simulated concepts there are several test benches to test individual subsystems like batteries, fuel cells, electric machines up to the complete vehicles on the roller test bench.

As one example a range extender concept with a 6 kW high temperature PEM-fuel cell as an on-board-charging unit with thermal heat coupling was proposed in [1] and [2] and simulated, using the DLR-Alternative Vehicles Library [3]. An existing electric vehicle (eSmart) with a maximum electric power of 55 kW, equipped with a 17.6 kWh Li-Ion battery, was used for model validation. The energy flow behavior between the components cabin, electric machine, power electronics, battery and HVAC has been measured to create a reliable database for further simulation of new mobile road applications. The measurements were taken on a special way from Stuttgart to Lampoldshausen and back, these are two DLR-locations in Germany which have a hydrogen filling infrastructure. On one direction the car was driven on national roads, on the other way back it was driven on highway and on national roads. It can be shown that up to 40 %, @-10°C, of the whole energy consumption in real conditions is needed for climate conditioning. Using a fuel cell the range of the vehicle can be increased up to 100 % while the heat can be used to warm up the cabin.

[1] Dickinson, D.; Nasri, M.: "Range extender vehicle concept based on high temperature polymer electrolyte membrane fuel cell", 9th International Conference of Ecological Vehicles and Renewable Energies EVER 14, Monte Carlo, Monaco

[2] Schier, M.; Kevlishvili, N.; Mayer, B.: "Thermal Management Concepts for Vehicles of Next Generation", 9th International Conference of Ecological Vehicles and Renewable Energies EVER 14, Monte Carlo, Monaco

[3] Braig, T.; Dittus, H.; Weiss-Ungethüm, J.; Engelhardt, T.: "The Modelica Library "Alternative Vehicles" for Vehicle System Simulation", SNE Simulation Notes, 2012.

**Remark:** The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.

## B1404 (Elsewhere published)

### Aircraft APUs: An Economically Viable Niche Market for Fuel Cells?

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#### Abstract

Cost is a major factor inhibiting the entry of fuel cell technology into most markets. Primarily, fuel cells are viewed as a power source and are compared with existing technologies based on this attribute alone. When used solely for power generation fuel cells cannot compete on cost due to expensive materials, manufacturing processes and lack of economies of scale.

However, clean power is not the only added value of a fuel cell. As well as being emission free at point of use, fuel cells can provide clean water, oxygen depleted air, heating and cooling. With the correct balance of plant these by-products can be utilised. There are niche market applications where these four additional features of a fuel cell are highly valued, for example; passenger aircraft. Passenger aircraft require water for lavatories and galleys, deoxygenated air for fire prevention in the fuel tanks, heating of the wings for de-icing and heating & cooling of the cabin in addition to power for electrical systems. At present all of these needs are met with independent systems.

Existing studies have proven the aforementioned issues to be technically feasible<sup>1</sup>. This paper aims to quantitatively show that by utilising all of the added value functions of a fuel cell, the initial investment cost of the fuel cell can be offset with weight, fuel and emissions capital savings. Aircrafts are used as an example market where more than just power from a fuel cell could be useful.



B1405 (Elsewhere published)

## Changing the Fate of Fuel Cell Vehicles: Lessons from Tesla Motors

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### Abstract

Fuel Cell Vehicles (FCVs) are approaching a stage where they are ready for larger scale market entries. They are currently seeing some uptake in pilot schemes, with a small number of consumers adopting early market vehicles. This manuscript uses data from early adopters of BEVs in order to understand who will adopt an FCV. This is done by presenting socio-economic and psychographic data, the results showing these adopters are atypical early adopters. Then how much early adopters are been willing to pay for a BEV is presented, the findings are that willingness to pay is high at \$37,000. Finally motivational reasons for adoption are explored and it is found that performance and environmental reasons are the most prominent reasons for adoption of a BEV. Finally all of these findings are applied to FCVs.

B1406

## Future Mobility Demonstrator: Utilizing renewable excess electricity in the mobility sector

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### Abstract

With the increasing share of renewables in the electricity production sector the supplied power becomes subject to strong fluctuations particularly stemming from unsteady solar irradiance or wind speed. In order to be able to fit production and demand and avoid wasting electricity from renewable sources, storage technologies increasingly gain significance. In this respect, the conversion of excess electricity into chemical energy carriers proves to be a promising approach which is already pursued intensively under the keyword Power-to-Gas (PtG, P2G).

The demonstration plant "Future Mobility" located on the Empa Campus aims at showing the opportunities of this technology.

Temporary electricity surpluses can be stored on a decentralized level and used in the mobility sector, namely for electric, fuel cell and gas-powered vehicles. For hydrogen production a PEM-electrolyzer capable of rapid load changes and including a remote start/stop function is employed which allows for attenuation of grid fluctuations. The gas obtained is compressed and stored in high pressure vessels for later dispensing. Apart from using hydrogen to fuel FC-vehicles it can also be added to natural gas/biogas to form the mixture HCNG (hydrogen compressed natural gas) which has proven to significantly reduce pollution and CO<sub>2</sub>-emissions in conventional internal combustion engines. Furthermore, employing a CO<sub>2</sub>-source and a methanation plant, hydrogen can be converted into synthetic methane with the strong benefit to attain the possibility of seasonal storage in the existing gas grid.

Within the scope of the project "Future Mobility Demonstrator" investigations towards optimization of a PtG-plant's operation strategy will be conducted. Alongside energetic considerations also economic aspects will be addressed. Additionally, dispensers for each abovementioned fuel type will be installed including a blending-dispenser for HCNG developed by Empa. The demonstration plant will serve as a platform for various research endeavors linking electricity to the gas market and thus securing the growth of sustainable energies.

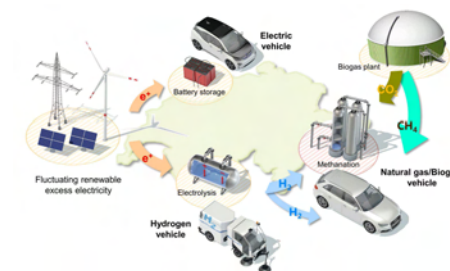


Fig. 1 Utilizing excess electricity in mobility

## B1407 (Abstract only)

### New direct alcohol and hydrogen fuel cells for naval and aeronautical applications (PILCONAER)

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#### Abstract

In the current context of demand for reliable, low cost and low environmental impact energy sources, many countries and companies are mostly focused on fuel cells (FC) in fields as transportation and stationary power generation and portable devices. Lately, FCs have begun to be applied in naval and aeronautical systems due to its high efficiency, low noise and environmental advantages. These applications could range from propulsion systems to auxiliary power units (APU). The main problems associated with the use of FCs in these areas are the current high cost due to the materials used, i.e. Nafion and Pt, the lack of durability testing in these specific conditions, security issues to flammability and high H<sub>2</sub> pressures and low availability as a fuel, or the toxicity of methanol used as a fuel, and specific parameters such as weight in aircraft applications and volume in marine applications. Currently it is working on each of these issues, and at this point the ethanol as direct fuel is considered crucial. The use of ethanol as fuel has the advantage of easy transportation, storage and refueling, and is nontoxic. Bioethanol is a promising energy source, produced from raw materials containing sugar or starch. These raw materials exists in all parts of the world and is renewable, which involves the use of local energy sources contributing to the diversification of energy supply, reducing import dependence, increasing security of supply and generating new opportunities for agriculture. The main objective of the project is the development of low power stacks (stacks) fed with methanol (DMFC) and ethanol (DEFC) based on the development of new catalysts and membranes. PILCONAER aims contributing to the development of a sustainable use technology, further commitment to the restoration of the natural environment and biodiversity conservation.

#### Acknowledgements

This project is supported by Comunidad de Madrid, Fondo Social Europeo and Fondo Europeo de Desarrollo Regional under PILCONAER S2013/MAE-2975.

Remark: Only one page abstract was available at the time of completion.  
Please contact the authors directly for further information.

## B1408 (Fuel Cells SI publication candidate)

### Development of a Reliable Hydrogen Gas Sensor for Leak Detection in Fuel Cell Vehicles

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#### Abstract

The practical application of FCV (Fuel Cell Vehicles) started in 2014 and is progressing for commercial use in 2015. In FCV, it is critical that passenger safety for usage of hydrogen is ensured with a gas leak detection and shut-off system in compliance with HFCV-GTR (Global Technical Regulation). Various hydrogen detection sensors, such as catalytic bead type or semiconductor gas sensors have been used in industrial and commercial gas leak detection systems. However, conventional gas sensors cannot be applied in FCVs as rapid startup time, extremely high durability and reliability are required. Consequently, we have developed a new catalytic combustion type hydrogen sensor using an original concept in consideration of such long life requirements in FCV-specific environments.

The following features are essential for hydrogen detection in FCV; (1) a rapid startup time: within 2 sec., (2) quick gas detection response time: within 3 sec., (3) accuracy of hydrogen detection in various operating and storage conditions: +/- 20 % in the range between -35 to 85 °C, 0 to 100 %RH (4) mechanical robustness for strong vibration and shock, (5) long life: more than 15 years. In principle, the sensing unit is composed of a pair of 30 micron diameter Pt (platinum) coil with 0.44 mm in diameter and 0.48 mm long. One element is activated for hydrogen combustion (sensing element) and the other is for compensation with no combustion (reference element). For the sensing element, we have developed a specific electroplating method of forming a three dimensional combustion layer composed of several nanometer particles of noble metal catalyst. This method provides a surface area of approx. 20,000 mm<sup>2</sup> without catalyst support. Since the whole surface area has combustion activity, the resistance against the poisoning effect has been dramatically improved. For the reference element, we have created an optimum condition of forming a mechanically, thermally and chemically stable inorganic isolation layer surrounding the Pt coil with a submicron thickness. The combination of these two miniaturized elements provides a reliable output signal according to the hydrogen concentration with rapid response. We have obtained data that the required 15 year life span is satisfied by conducting long term stability test, silicone poisoning test, HAST (Highly Accelerated temperature and humidity Stress Test) and other reliability test. With an appropriate signal processing software, optimized electronics and detector housing design, we have achieved a hydrogen detector that is capable of satisfying the required performance level listed in (1) to (5) as above.

B1409

## Optimization of diesel powered FC-based APU size and battery capacity for specified load demand

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### Abstract

In this article a power-efficiency model of a truck Auxiliary Power Unit (APU) system is used to simulate the various sizes of fuel processor and fuel cell stack and of the battery, to inspect advantages and disadvantages of the possible combinations and discuss the optimal choice. The thematic sources from the FCGEN (Fuel Cell based power GENERation), an EU project under the FP7 program FCH JU, where a truck on-board diesel powered APU is being developed. The APU consists of a PEM fuel cell stack with diesel fuel processor to enable utilization of normal truck-on-board diesel, and battery that makes the system autonomous by providing start-up and shutdown power, as well as acting as an energy buffer to extend maximal APU power and cover load transients. The system under development is a prototype, where not all components have been optimized for the specified load. Therefore, before such or similar system is redesigned for potential mass production, it is important, to find the optimal size of components to be able to exploit the technology to its best. In this work a mesh grid of experiments has been prepared using various sizes of the fuel cell with fuel processor as power generating part and batteries with various capacities as power storage unit. Upon these results the highest efficiency and lowest number start-ups are pursued.

B1410 (Fuel Cells SI publication candidate)

## Virtualisation of Fuel Cell Hybrid Electric Vehicle Powertrains in a RTD Laboratory Environment

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### Abstract

In recent years, the global RTD effort in view of market introduction of hydrogen fuel cell vehicles has increased its pace ([1]) and a few series production vehicles have been presented in 2014. The process has moved from basic and applied research to industrial-scale development with defined mass-rollout schedules in coming years. Thus, the testing and validation of full drivetrain concepts has become an essential item in the development process. The challenges that RTD stakeholders are facing in this regard are numerous and call for sound and efficient solutions. To wait for new hardware and the newest prototypes to arrive often is not an option. This paper discusses an enhanced hydrogen fuel cell hybrid laboratory that aims to address relevant aspects for successful development of drivetrains and thermal management systems. It features optional virtualisation of components and infrastructure to minimize delays in the research and development process of fuel cell vehicles [2].

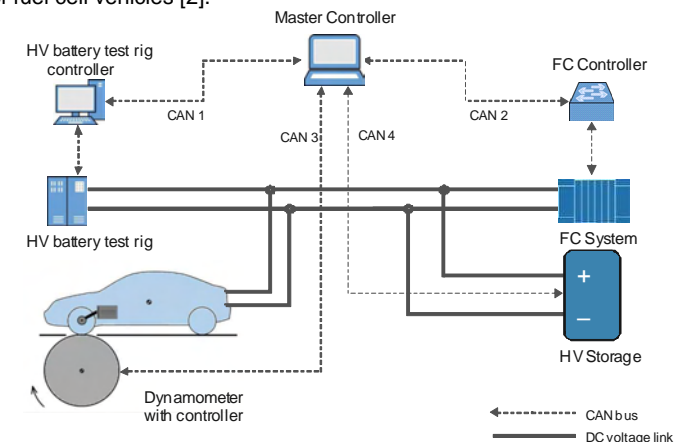


Fig. 1: Laboratory layout for RTD of xEVs [2]

As an added feature to its CAN communication, it allows to include remote testing facilities by means of standardized TCP/IP interfaces. The outcome is to identify possible usage scenarios and to quantify data throughput for remote experiments, with specific focus to their sensitivity to I/O robustness. Finally, a first estimation of cost benefits is given to evaluate the concept feasibility on a larger scale.

## Chapter 07 - Sessions B03, B13

**B03: H<sub>2</sub> production: Alkaline electrolyzers**

**B13: H<sub>2</sub> production**

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## B0301 (Elsewhere published)

**Pressurized alkaline electrolyser with high efficiency and wide operating range – the project RESelyser**

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**Abstract**

The project RESelyser has developed high pressure, highly efficient, low cost alkaline water electrolyzers that can be integrated with renewable energy power sources (RES) using an advanced membrane concept, highly efficient electrodes and a new three-compartment cell design. A new separator membrane with internal electrolyte feeding and an adapted design of the cell to improve mass transfer, especially gas evacuation has been investigated and demonstrated. Intermittent and varying load operation with RES has been addressed by improved electrode stability and a cell concept for increasing the gas purity of hydrogen and oxygen especially at partial load and high pressure operation.

The results of the project will be presented: high performance electrodes with a plasma sprayed coating layer give an overpotential reduction of 330 mV compared to uncoated electrodes thus showing high performance and stability with low cost material. Detailed investigation of the electrode pore structure and microstructure at beginning of life and after operation shows possible degradation mechanisms. It was found that by feeding KOH solution from inside the internal compartment of a double layer diaphragm towards both the anolyte and catholyte compartments improves the gas purities of the cell significantly. The novel three-compartment cell concept using this double layer diaphragm was realized in single cells of 300 cm<sup>2</sup> area and in a 10 kW stack.

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n° [278732] 10.

Details of this presentation will be published elsewhere [1].

## B0302 (Fuel Cells SI publication candidate)

**Phase inversion process of novel membranes for alkaline electrolysis**

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**Abstract**

Today, 95% of the world-wide hydrogen production is generated from hydrocarbon cracking, resulting in high CO<sub>2</sub> emissions. Alkaline electrolysis, which is an existing and mature technology, has a great potential for environmentally-friendly hydrogen production. In order to make the alkaline electrolysis more cost-effective and thus to compete with hydrogen production technologies based on hydrocarbon reforming, the energy consumption during water splitting in alkaline electrolyser must be improved. Strategies aiming at the efficiency improvement of alkaline electrolysis are higher operating temperatures and pressures as well as development of new materials, leading to lower cell resistances. Besides the electrodes contributing to the over-all voltage drop, one of the most important elements of an alkaline electrolysis cells is the membrane, which allows the transport of OH<sup>-</sup> anions and simultaneously separates the gaseous products evolving at the electrodes. The microstructure of the membrane requires a fine tuning, since it directly affects both ionic conductivity and gas separation properties. This study discusses the properties of novel alkaline electrolysis membranes prepared by a phase inversion process. The evolution of the microstructure and its influence on the membrane properties will be addressed.



## B0303 (Fuel Cells SI publication candidate)

**Novel gas separation membranes  
for alkaline water electrolysis****Ulrich F. Vogt (1,2), Dariusz Burnat (1), Meike V. F. Schlupp (1), Corsin Battaglia (1)**

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**Abstract**

Hydrogen production via water electrolysis is regaining attention in the global search for alternative energy carriers nowadays. Efficiency enhancement in alkaline electrolysis to reduce the electric power consumption is a pre-condition for a successful application of this promising technology.

Within the EU project ELYGRID, several approaches have been applied to improve the efficiency of alkaline electrolyzers. The process has been optimized to reduce the surface-specific cell resistance during operation at increased current densities (zero-gap cells, low-resistance membranes). The operating temperatures have been increased to increase the electrolyte conductivity and to decrease electrode overpotentials, and new electrocatalysts have been introduced to reduce anodic and cathodic overpotentials. The membrane, which separates hydrogen and oxygen gases during the electrolysis process, is a crucial part of the electrolyser cell. Besides that, the membrane has to ensure high ionic conductivity and feature an excellent chemical stability in 30 wt% KOH up to 120°C and 30 bar for long term operation over several years. Novel membranes with promising characteristics for low resistance diaphragms have been developed and the results will be presented below.

## B0304

**Pressure and Temperature Influence on Alkaline  
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**Abstract**

With the implementation of the German Energiewende we have an increasing share of renewable electrical energy production from wind and PV with an installed capacity of more than 70 GW (as of 2014). As a result the need for long-term storage of excess renewable electrical energy will become more important. Electrolysers producing hydrogen from electrical energy are a key technology to meet these demands. To investigate the coupling of an electrolyser with wind turbines in a more real scale a pressurised alkaline electrolyser prototype was installed at the Hydrogen Research Center Cottbus. The test station is capable of providing input power profiles similar to wind turbine profiles.

In this paper the influence of different operating parameters on the pressurised alkaline electrolyser is presented. The electrolyser is assembled of 24 single-cells in filter press design and operates at a maximum pressure of 58 bar with a nominal hydrogen production rate of 20 Nm<sup>3</sup>/h at a current density of 4.59 kA/m<sup>2</sup>. To assess the influence of both the polarisation overpotential of the electrodes and the ohmic overpotential from the resistance of the KOH-solution different test series were performed in the temperature range from 50 to 70 °C and the pressure range from 10 to 55 bar. The current density stretches from 0.18 kA/m<sup>2</sup> to 7.2 kA/m<sup>2</sup>. The qualitative and quantitative influence of pressure and temperature on the cell voltage is described in context with theoretical expectations. Due to opposite effects only a marginal pressure influence was measured. The expected theoretical increase in cell voltage due to the pressure increase is fully compensated by the decrease in cell voltage due to smaller gas bubbles. In contrast we observe a distinct temperature influence on cell voltage.

B1301

## Development and testing of a pressurized PEM electrolyser

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### Abstract

Polymer Electrolyte Membrane Electrolysers (PEME) present an interesting potential for applications in sustainable energy systems, producing clean hydrogen for energy storage and later use in fuel cells or power-to-gas systems. However, their cost remains high and their durability is still far from the 10 years generally attained by industrial alkaline electrolysers before a stack change.

At Belenos, the aim was to develop a low cost, small PEM electrolyser for residential applications, around 5 kW, producing both hydrogen and oxygen under pressure (30 bar). In order to keep the stack as simple as possible, the end-plates were also used for the current supply, the bipolar plates were simple metal sheets without flow-fields and plastic frames were used as support for the membrane-electrode-assemblies (MEAs) and current collectors, with O-ring seals.

The first electrolyser system was also designed with a minimum number of components, namely the stack, two gas separators for hydrogen and oxygen respectively, and a water pump to supply water to the system under 30 bar. The fluid movement is based on natural convection, with gases flowing out of the stack and water coming back from the separators. The performance of different stacks will be presented, and conceptual choices will be discussed based on the optimization of performance/cost criteria.

B1302

## Degradation of a single cell PEM water electrolyser

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### Abstract

Hydrogen as an energy carrier is one of the pathways to a more sustainable energy environment. There exist many ways to produce hydrogen and the proton exchange membrane (PEM) water electrolysis systems are a promising technology when linked to renewable energy sources. PEM electrolysers are robust and dynamic which offers fast response to volatile renewable energy sources like PV and wind. The cost of the PEM water electrolysis remains high and one of the ways to reduce costs is to reduce the loading of PGM-based catalysts. However, with reduced PGM catalyst loadings the durability and robustness of the systems and/or components are compromised.

The presentation will cover the progress and strategy on the development of tools for investigation of degradation in a single cell electrolyser. A single cell PEM electrolyser is operated at various stress conditions related to renewable energy sources (e.g., voltage cycling). The degradation of the electro-catalyst, membrane and current collectors is investigated using EIS, current mapping, gas crossover, fluoride release rate (FRR) and other physico-chemical characterisation methods.

B1303

## High Temperature Alkaline Electrolysis

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### Abstract

Energy storage is one of the major challenges on the way to a sustainable energy supply based on renewable energies. In the EU project "H<sub>2</sub>Ocean", it is described how a large offshore platform can convert electrical energy, produced by wind and wave energy, to hydrogen through electrolysis of water. A total of 150 units of one of the largest available low temperature alkaline electrolyzers (LT-AE) were selected to be installed on the platform. As a small part of H<sub>2</sub>Ocean, the weight and space demand, power density and efficiency was compared to an envisaged electrolysis system based on high temperature and pressure alkaline electrolysis cells (HiTAEC), which have been developed at the Department of Energy Conversion and Storage, DTU Risø Campus, Denmark. The envisioned HiTAEC system is based on a new electrolysis cell concept, which achieved record power densities and efficiencies on the lab scale, but has not been proven in large scale; tremendous research and development is necessary to demonstrate large HiTAEC systems in the coming decades. However, the space and weight demands can be reduced by approximately one order of magnitude. Neither LT-AE nor HiTAEC require any scarce and expensive noble metals or other scarce materials. Thermal desalination processes like multiple effect distillation, MED, could provide purified water direct from seawater with equal or even higher purity for the electrolysis systems than reverse osmosis systems. The required heat for MED could be used for steam generation to supply the high temperature alkaline electrolysis systems. The energy demand to produce steam for HiTAEC by commercial steam generators is around 17 % of the higher heating value for hydrogen, but this can be reduced to 2 % by proper design and installation of a heat exchange system.

In this paper only parts of the data necessary for the above summarized conclusion are described due to the space limitations, but a report with all data is available upon request, and all data will be attempted published in a later stage.

B1304 (Abstract only)

## Water Splitting Using GaN Based Working Electrodes for Hydrogen Generation without Applying Bias

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### Abstract

In this study, we demonstrated photoelectrochemical(PEC) hydrogen generation using InGa<sub>N</sub>-based semiconductors as the working electrode for water splitting under solar illumination. For a working electrode made of n-type semiconductor, the holes drive the oxidation of water on the photoelectrode, and the electrons transport within semiconductor and in turn move to the cathode electrode leading to the reduction reaction. Although GaN is potentially resistant to aqueous solution and its energy band is suitable for water photoelectrolysis, GaN only absorbs UV light which is about 5% of the solar spectrum. The bandgap energy of the In<sub>x</sub>Ga<sub>1-x</sub>N can be tuned from 0.7eV to 3.4eV by changing the Indium content to fit the most of the terrestrial solar spectrum. Therefore, InGa<sub>N</sub>-based working electrodes for water splitting are expected to be more efficient than the GaN working electrodes. The working electrodes used in this study featuring meshed metal contacts with SiO<sub>2</sub> protection layer were immersed in electrolyte to enhance the collection efficiency of photogenerated carriers. On the other hand, the generation rate of hydrogen could be improved by applying external bias onto the working electrodes to enhance the separation of photogenerated electron-hole pairs in the semiconductor and the charge transfer at the interface between semiconductor and electrolyte during the PEC water splitting process. However, the external bias on PEC water splitting requires extra input power except light illumination. In this study, InGa<sub>N</sub>-based semiconductors associated with meshed metal contacts were served as working electrodes without external bias to conduct the PEC water splitting process under the light illumination.

Instead of using an external bias provided by power supply, a solar cell was used to raise the driving force to increase the rate of hydrogen production. The solar cell was connected in series between the InGa<sub>N</sub>-based working electrode and the platinum (Pt) counterelectrode to bias the PEC cell. In principle, the water splitting for generating hydrogen involves two mechanisms during the light illumination if the solar cell supplies bias voltage larger than 1.23 V. The mechanisms are photoelectrolysis and electrolysis of water splitting. To solely evaluate the efficiency of photoelectrolysis or electrolysis of water splitting, the output voltage of solar cell was varied through changing the type of solar cell to allow the PEC cell with bias less or larger than 1.23 V. The preliminary results indicated that the hybrid working electrodes exhibited a marked improvement in the efficiency of hydrogen generation.

The detailed results will be presented in the forthcoming conference.

Remark: Only one page abstract was available at the time of completion.  
Please contact the authors directly for further information.

B1305 (Elsewhere published)

## Demonstration of Novel Platforms for Hydrogen Generation

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### Abstract

Two platforms for water splitting are reported: A membrane-less and a vapor fed device. The membrane-less electrolyzer uses laminar flow principles in microchannels to separate the product gases. Therefore, the need for an ion conductive membrane is removed. The inertial lift force due to the hyperbolic shape of the liquid electrolyte velocity profile keeps the two gas streams close to each side wall until they reach different collection outlets. These devices achieve current densities as high as 147 mA/cm<sup>2</sup> at an efficiency of 47%, and can be operated under any water-based electrolyte at different pH values. The crossover of gasses in the device is low, allowing it to continuously generate nearly-pure H<sub>2</sub> gas streams with O<sub>2</sub> concentrations below the 4% flammability limit. As the only dimension that needs to remain small is the inter-electrodes distance, it is possible to implement the same concept using high surface area electrodes as side walls of narrow electrolyte channels. The second device is a vapor-fed microelectrolyzer which absorbs water from ambient air in a Nafion® thin-film where water electrolysis takes place. The evolved gases later diffuse through the same film into the dedicated channels. The large surface to volume ratio in the microfluidic device provides efficient humidity absorption from air, and current densities above 3 mA/cm<sup>2</sup> can be reached under stable operational conditions. Effect of various parameters such as Nafion film's thickness, air flow speed, and its water content are studied, providing guidelines for the development of high-current density vapor-fed devices. The development of photoelectrodes for the fabrication of solar fuel generators will also be discussed.

Remark: The authors do not wish to publish their full contribution in these proceedings.  
The topic of this abstract is published as the references of this extended abstract.

B1306 (Elsewhere published)

## Effective High Pressure Hydrogen Evolution from Formic Acid without any Compressing

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### Abstract

High-pressure hydrogen production over the 35 MPa is one of the key technologies for the commercial use of feeding hydrogen gas especially to fuel cell vehicle, etc. to assure long term working with the fuel cell cylinder after a single charging. However to supply the high-pressure hydrogen gas over 35 MPa, specific gas compressor is necessary to pressurize hydrogen, which requires large amount of energy for proper compressing. To overcome this problem, we used Iridium (Ir) complexes as homogeneous catalysts<sup>1)</sup> which can produce hydrogen gas efficiently by the catalytic dehydrogenation of formic acid. We successfully achieved the generation of high-pressure gas over 100 MPa effectively using the catalyst without any compressing procedure. A schematic diagram of the system is shown in Figure. Furthermore, analysis of the product mixture revealed a ratio of hydrogen and carbon dioxide is 1:1 and no carbon monoxide was detected even at the high-pressure region over 10 MPa. Additionally, we can selectively separated hydrogen gas under the high-pressure conditions. In the presentation we will discuss about the high-pressure gas evolution system and the separation process.

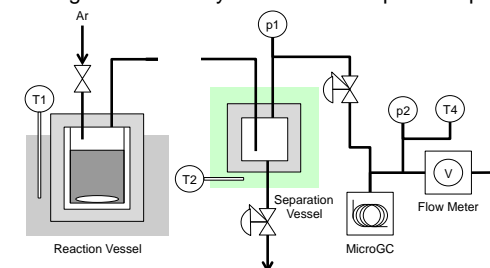


Figure: The high-pressure H<sub>2</sub> evolution system from formic acid.

References: 1) J. F. Hull, et al. Nat. Chem. 2012, 4, 383-388.

## B1307 (Fuel Cells SI publication candidate)

### Catalytic Dehydrogenation of NaBH<sub>4</sub> Solution across Pin Fin Structures in a Microchannel Reactor

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#### Abstract

Many types of hydrogen storages have been studied recently paying attention to hydrogen storage and release. Among those, dehydrogenation from the hydrolysis of a sodium borohydride (NaBH<sub>4</sub>) solution has been of much interest owing to its high theoretical hydrogen storage capacity (10.8 wt.%) and potentially safe operation.

However, most of researchers have focused on chemical characteristics such as NaBH<sub>4</sub> hydrolysis, catalysts, and synthesis, but not on the mechanical design of a chemical reactor for hydrogen generation. To design an efficient chemical reactor, size (which should be compact) and pressure drop, reaction rate are of great importance. Therefore, a microchannel is promising for the design of a dehydrogenation reactor owing to its very large reacting surface area per unit volume. Moreover, micro size pin fin structures could be manufactured on the bottom of microchannel surface for even more extended reacting surface area and contact catalytic reaction.

An experiment study has been performed on catalytic reaction rate and pressure drop of NaBH<sub>4</sub> solution over both a single microchannel with a hydraulic diameter of 300 μm and a staggered array of micro pin fins with hydraulic diameter of 50 μm in the microchannel. Catalytic reaction rates and pressure drops were obtained over Reynolds numbers from 1 to 60 and solution concentration from 5 to 20 wt.%. Moreover, reacting flows were visualized using a high-speed camera with a macro zoom lens.

As a result, both the amount of hydrogenation and pressure drop are 2.45 times and 2.26 times more in pin fin microchannel than in a single microchannel, respectively.

## B1308

### Effect of Iron Oxide Nanoparticles on Dark Fermentative Hydrogen Production from Molasses based Distillery Wastewater

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#### Abstract

The study reports the enhancement effect of iron oxide nanoparticles on dark fermentative hydrogen (H<sub>2</sub>) production from molasses-based distillery wastewater. Batch experiments with different iron oxide nanoparticle concentration (0-100 μmol L<sup>-1</sup>) of two different particle sizes (6 & 59 nm) and at different pH values (4-7) were conducted to convert soluble COD to hydrogen at 37±1°C. The 59 nm iron oxide nanoparticle was synthesized from *Murrayakoenigii* leaf extract, while the 6 nm was procured from Sigma Aldrich India. The experimental results indicated that maximum cumulative hydrogen production (433 mL), biohydrogen production rate (24.2 mL/hr), hydrogen content (65 %) and % COD reduction (72.5%) was observed at iron oxide (6 nm) nanoparticle concentration of 20 μmolL<sup>-1</sup> at pH 6; corresponding to 184%, 227%, 61.4% and 32.9% higher than that without nanoparticle supplementation respectively. The results indicated that iron oxide nanoparticles supplementation could remarkably improve the biohydrogen production from complex distillery wastewater.

**Keywords:** Distillery wastewater; Fermentative hydrogen production; Iron oxide nanoparticle; Hydrogen production; Hydrogen production rate; % COD reduction



## B1309 (Abstract only)

## In-situ O<sub>3</sub> rejuvenation of SO<sub>2</sub> contaminated Polymer Electrolyte Fuel Cell: Electrochemistry, single cell and 5-cells stack studies

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### Abstract

The performance of Polymer Electrolyte Fuel Cell (PEFC) is highly dependent on the purity of both fuel and air supplied. The airborne pollutants have a severe detrimental effect on the performance of air breathing PEFC stacks. Sulphur dioxide (SO<sub>2</sub>) is one such airborne pollutant that severely degrades the performance of the PEFC. The effects of SO<sub>2</sub> on the performance of PEFC in single cell and 5-cells stack were studied. The results show that the SO<sub>2</sub> contamination of the PEFC is highly potential dependent. Lower the output voltage of the individual fuel cell, higher the performance degradation. The contamination studies also shows that even 100ppm SO<sub>2</sub> does not affect the performance of the cell if the output voltage is around 0.65 V. However, the performance starts degrading gradually and more rapidly with decreasing output voltage. Presence of 10ppm SO<sub>2</sub> on the air stream degrades the performances of the individual unit cell, and the whole stack, by 25% within 2 h. The performance of all the cells and the stack improves slightly upon switching off the SO<sub>2</sub> on the air stream. However, it reached a plateau within 900 s, and could not be recovered further. Later, the stack was treated with 0.4% O<sub>3</sub> and purged with air to flush out the residual O<sub>3</sub> inside the cell. It was found that O<sub>3</sub> treatment can recover the performance of the stack, and all the individual cells, within 600 s. The O<sub>3</sub> rejuvenation mechanism does not discriminate among the individual cells.

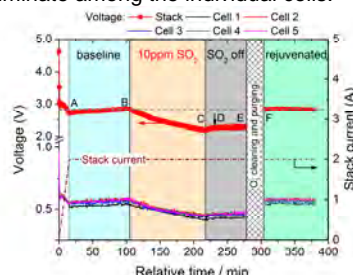


Figure 1: Effect of SO<sub>2</sub> contamination on the performance of 5-cells PEFC stack

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## Next EFCF Conferences:



**12<sup>th</sup> European SOFC and SOE Forum**  
5 July - 8 July 2016

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## Chapter 08 - Sessions B05, B08

**B05: H<sub>2</sub> storage: Material and systems**

**B08: H<sub>2</sub> storage in metal hydrides**

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## B0501 (Fuel Cells SI publication candidate)

## Hydrogen Storage on Graphene Foam

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## Abstract

Graphene has extremely high surface-area-to-weight ratio, is strong, stable, and environmentally benign. As such it may be an ideal hydrogen storage material. The theoretical maximum surface area is 2630 m<sup>2</sup>/g. However, commercially available graphene powders tend to be limited to ~600 m<sup>2</sup>/g, due to restacking of the graphene sheets. Graphene is also still prohibitively expensive. In order to solve these problems some kind of low-cost three dimensional graphene architecture is desirable.

We synthesize graphene foam via combustion of sodium ethoxide, followed by heat treatment. The process is gram-scale and low cost (<\$10), with large surface area (up to 2500 m<sup>2</sup>/g), and is template-free. The structure is highly porous with micron-scale voids encapsulated by graphene walls ~2 nm in thickness (Figure 1a, b). Hydrogen physisorption isotherms were measured at 77K up to 1 MPa. Commercially-obtained graphene powder (600m<sup>2</sup>/g) has a hydrogen capacity of 1.2 wt.%. Graphene foam with 1200 m<sup>2</sup>/g has a much higher hydrogen sorption capacity of 2.1 wt.%. Graphene foam with 1600 m<sup>2</sup>/g reaches 2.6 wt.% hydrogen capacity. At room temperature and 8 MPa, the hydrogen sorption capacity is 1.6 wt.%. Additionally, we have performed chemisorption on such samples via Birch reduction, obtaining ~4.0 wt.% chemically bound hydrogen, which can be recovered by heating.

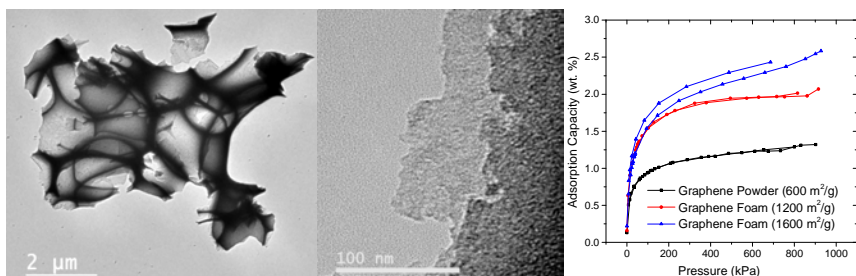


Figure 1. (a-b) Transmission electron microscopy (TEM) images of graphene foam. (c) Hydrogen sorption isotherms compared with commercially available graphene.

## B0503 (Fuel Cells SI publication candidate)

## Borohydride based Ionic Liquids as novel Hydrogen Storage

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## Abstract

Borohydride based hydrogen storage systems, especially sodium borohydride NaBH<sub>4</sub>, are well known and intensively investigated in the past decades. Research for on-board vehicular storage stopped after the U.S. DoE recommended a no-go for NaBH<sub>4</sub> due to major limitations of this system, e.g. low hydrogen storage density, the weak long-term stability and the missing recycling processes [1]. In this presentation new borohydride based ionic liquids that overcome the major drawbacks of NaBH<sub>4</sub> are developed. These new compounds show higher gravimetric and volumetric storage density and enhanced long-term stability [2,3].

The hydrogen release by catalytic hydrolysis with non-noble metal catalysts is determined by a real-time and selective electrochemical hydrogen quantification method [4]. The benefits of this storage technology are presented together with latest experimental results concerning hydrogen storage capacity and system design.

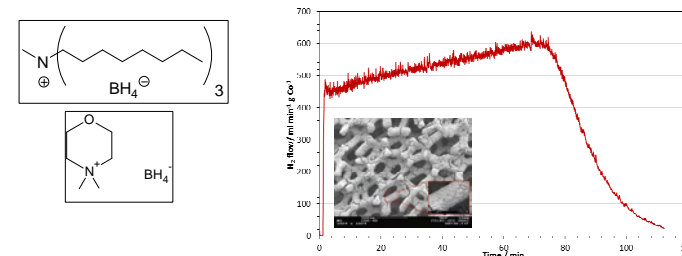


Figure 1: left: two examples of ionic liquids containing borohydride, right: hydrogen release by non-noble metal catalyst, inset: SEM image of catalyst [2,3].

B0505 (Abstract only, elsewhere published)

## Hydrogen storage and delivery: the formic acid - carbon dioxide couple

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### Abstract

Formic acid can be selectively decomposed into CO free carbon dioxide and hydrogen.<sup>[1]</sup> It has been shown, that beside the ruthenium(II)-*mtppts* systems, the iron(II) – hydrido tris[(2-diphenyl-phosphino)ethyl]-phosphine complex also catalyses formic acid cleavage with an exceptionally high rate and efficiency (turnover frequency, TOF= 9'425 h<sup>-1</sup>mol<sup>-1</sup>; turnover number, TON= 92'400).<sup>[2]</sup> This opens the way for cheap, non-noble metal based catalysts for this reaction.



Bicarbonates and carbonates have been proven to be viable H<sub>2</sub> vectors, as these widely available natural C<sub>1</sub> sources can be easily hydrogenated to formats or to formic acid derivatives.<sup>[3]</sup> Although ruthenium(II) and other platinum group metal compounds are the predominant catalysts in these reactions, iron(II) can be also active, giving a new perspective for the use of abundant and inexpensive Fe-based compounds in HCO<sub>3</sub><sup>-</sup> reduction. For the first time, the direct hydrogenation of CO<sub>2</sub> into formic acid using a homogeneous ruthenium catalyst, in aqueous solution and in dimethyl sulfoxide without any additives, have been realised.<sup>[4]</sup> In water, at 40°C, 0.2 M formic acid can be obtained under 200 bar, however, in DMSO the same catalyst affords 1.9 M formic acid. In both solvents the catalysts can be reused multiple times without a decrease in activity.<sup>[4]</sup>

### Acknowledgement

SNSF, OFEN, CTI, SCCER, CCEM and EPFL are thanked for financial support.

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- [3] A. Dalebrook, W. Gan, M. Grasemann, S. Moret, G. Laurenczy\*, Hydrogen storage: beyond conventional methods, *Chem. Comm.*, **2013**, 49, 8735.
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**Remark:** The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.

B0506 (Elsewhere published)

## Hydrogen Production by Dehydrogenation of Formic Acid using Iridium Catalysts

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### Abstract

The hydrogen storage system based on the interconversion between CO<sub>2</sub> and formic acid (FA) has recently received renewed attention because formic acid contains 4.4wt% of hydrogen and has low toxicity (Figure 1). We have developed homogenous catalysts for CO<sub>2</sub> hydrogenation for hydrogen storage and dehydrogenation of formic acid for hydrogen release. CO-free hydrogen was evolved highly effectively in aqueous media without organic additives under mild reaction conditions. Furthermore, when the reaction was carried out in a closed vessel, high-pressure hydrogen could be supplied. Herein, we describe our design concept for highly efficient catalysts for dehydrogenation of formic acid.

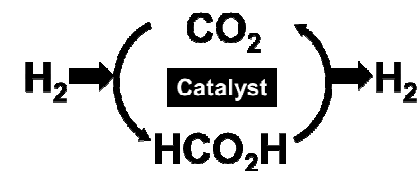


Figure 1. Hydrogen Storage System by Interconversion between CO<sub>2</sub> and Formic Acid.

## B0507 (Fuel Cells SI publication candidate)

### Rod-like FeOOH for Ortho-Para Conversion of Hydrogen

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#### Abstract

Rod-like structured FeOOH powders were first applied to ortho-para hydrogen conversion. The rod-like, micro length, nano diameter, and non-aggregated FeOOH powders were directly prepared by hydrothermal method. The morphology and structure of the powders were characterized by SEM, TEM, and XRD. The powders had a pure tetragonal  $\beta$ -FeOOH structure, with no additional peaks detected. The ortho-para hydrogen conversion properties were calculated by NMR spectrum. The para hydrogen ratio of the catalyzed hydrogen by rod-like FeOOH powders was 64 %. Thus, the spin conversion was observed for the rod-like FeOOH powders, where 15 % of ortho hydrogen at 77 K was converted into para hydrogen.

## B0508 (Fuel Cells SI publication candidate)

### CO<sub>2</sub> Methanation Under Atmospheric Pressure Conditions on a Ni catalyst: Experiments and Kinetic Modelling

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#### Abstract

Hydrogen storage and the associated infrastructure stand out among the major barriers towards a hydrogen based economy. One of the most promising concepts to overcome this problem is the “Power to Gas” (P2G) conversion. In a P2G installation, the surplus electricity coming from a renewable primary energy source (mostly wind and PVs) and not utilized in the electricity grid (mostly for stability reasons), is used to generate hydrogen, or potentially methane, for further use and storage in the natural gas distribution grid. In the aforementioned P2G scheme, electrolysis is utilized for hydrogen generation, while a methanation process is required for generating methane. A methanation process is a catalytically assisted physical-chemical process that generates methane from a mixture of various gases like CO, CO<sub>2</sub> and H<sub>2</sub>. Producing methane using carbon dioxide as a raw material would have a two-fold positive effect: reduction of total CO<sub>2</sub> emissions and conversion of CO<sub>2</sub> to an energy vector.

In the present work, novel methanation experiments are conducted under atmospheric pressure conditions on a Nickel catalyst, in a temperature range between 250 – 500 °C, for stoichiometric (H<sub>2</sub>/CO<sub>2</sub>=4) and hydrogen excess (H<sub>2</sub>/CO<sub>2</sub>=5) feeds. All tests were performed with nitrogen dilution. Stoichiometric experiments depict a maximum CH<sub>4</sub> yield of ≈69% recorded at 364°C (GHSV=10000 h<sup>-1</sup>), whereas hydrogen excess measurements depict increased maximum CH<sub>4</sub> yield (of approximately ≈82%) recorded at 364 °C. Furthermore, experiments implementing a bimetallic catalyst with nickel (Ni) and ruthenium (2%wt) (Ru) have taken place. The Ru catalytic sample resulted in a greater CH<sub>4</sub> yield when chemical equilibrium was still not reached (i.e., at low temperatures), highlighting the positive impact of the Ru addition on the conversion.

In the second part of the paper a basic kinetic study has also been conducted in order to simulate the aforementioned experiments. Although the implemented Xu & Froment [11] model succeeded in capturing the basic trend of the experimental CO<sub>2</sub> conversion “curve” for temperatures between 250 – 500 °C, discrepancies still exist. Future work will focus on optimizing the implemented model's kinetic and adsorption parameters according to the examined conditions.



## B0509 (Fuel Cells SI publication candidate)

### Measurement of hydrogen quantity adsorbed in carbon nanostructures using volumetric method

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#### Abstract

Energy has a great significance in human's life, daily and throughout the year, everyone is in need of it. Despite the tremendous progress in science and technology fields, the world still depends on conventional energy sources (oil, coal, gas), although they are limited and non-permanent. Moreover, the excessive use of fossil fuel causes severe and harmful meteorological phenomena resulting from carbonic exhaust, which contributes to the greenhouse effect. This will induce an energy crisis and have a negative impact on the world economy. It is therefore essential to find clean and renewable energy sources.

Hydrogen has distinctive characteristics, it is clean and permanent. Hence, hydrogen is the energy vector of the future, which can be produced from various sources (electrolysis of water, reforming ...). This vector is a very promising fuel; it can replace gasoline in the thermal engines and be the fuel for combustion batteries to produce electricity. Fortunately, Hydrogen exists in huge quantities in nature; however, it does not exist in the Free State. In order to have dense and assured storage of H<sub>2</sub>, it is essential to answer the problems posed by the storage of low-density and explosive gas. Hydrogen storage stays the significant obstacle within its application as energy source for future. Several methods are used for this purpose (compression, liquefaction, adsorption ...), but they are unsatisfactory.

Adsorption seems a promising solution for storing hydrogen; however, the operations and processes which may explain that are still poorly understood. In this context, we will study the physisorption of hydrogen in carbon nanostructures. The amount of adsorbed hydrogen will be deduced based on the volumetric method, which achieves better understanding and good knowledge of calculation.

## B0801 (Abstract only)

### Nanostructured hydrogen storage materials prepared by high-energy reactive ball milling (HRBM) of magnesium and ferrovandium

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#### Abstract

Hydrogen storage nanocomposites prepared by HRBM of magnesium and vanadium alloys are characterised by exceptionally fast re-hydrogenation even at room temperature and by significant lowering of the hydride decomposition temperature [1]. Replacement of vanadium with ferrovandium in these materials would be very attractive from the economic point of view.

This work reports about the preparation and characterisation of Mg–V–(Fe) hydrogen storage nanocomposites prepared from Mg powder and ferrovandium (FeV; 80 wt.% V) by HRBM with the starting H<sub>2</sub> pressure of ca. 30 bar. Some materials also contained additives of carbon (activated carbon, graphite and multi-walled carbon nanotubes; 5 wt.%) which are known to further improve hydrogenation/dehydrogenation performances of Mg-based hydrogen storage materials [2].

HRBM results in complete hydrogenation of the composite in ≤2 hours of the milling; the final product, depending on the content of FeV in the charge, is characterised by the H storage density from 4 to 6 wt.%. Thermal desorption studies (TDS) showed onset and peak H<sub>2</sub> desorption temperatures of ca. 200°C and 250°C, respectively. XRD revealed the presence of vanadium monohydride, corresponding to the second TDS peak. Morphological analysis (TEM, SEM) showed that HRBM had successfully produced nanocrystalline and amorphous materials with the V-containing catalyst homogeneously distributed over the Mg/MgH<sub>2</sub> matrix. The samples containing the carbon species showed higher hydrogen desorption temperatures, but without the second TDS peak of the vanadium monohydride.

This work is supported by the FP7 program ERAfrica, project RE-037 Advanced Hydrogen Energy Systems "HENERGY".

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- [2] M. Lototskyy, J.M. Sibanyoni, R.V. Denys, M. Williams, B.G. Pollet, V.A. Yartys, Magnesium-carbon hydrogen storage hybrid materials produced by reactive ball milling in hydrogen, *Carbon* vol. 57, pp. 146-160, Jan. 2013.

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## B0802 (Abstract only)

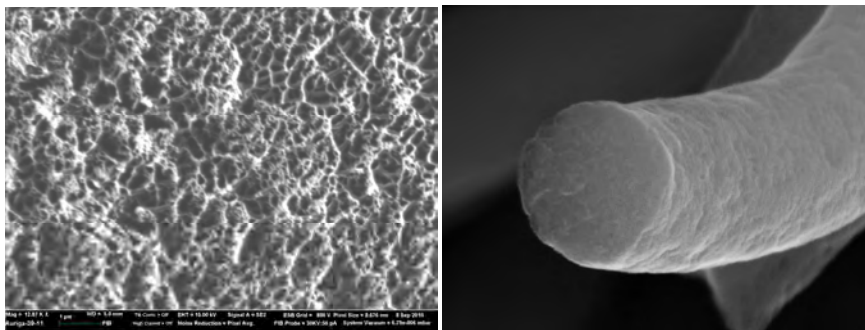
## Nanoconfinement of hydride materials into carbon hosts for reversible hydrogen storages in PEMFCs

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### Abstract

One of the most important factors for effective energy production of fuel cells is reversible hydrogen storage system, which should provide fast hydrogen sorption kinetics, low operating temperature and pressure, compact size, and light weight. Solid state hydrogen storage materials based on nanoparticle of metal, complex, and composite hydrides, such as MgH<sub>2</sub>, LiBH<sub>4</sub>, NaAlH<sub>4</sub>, MgH<sub>2</sub>-LiBH<sub>4</sub>, and etc., have drawn a lot of attentions for fuel cell applications. However, particle agglomeration of these hydrides after several de/rehydrogenation cycles, leading to sluggish reaction kinetics due to lower surface area for hydrogen exchange reaction is one of the most concerned problems. Thus, nanoconfinement of these materials into inert porous carbon hosts (e.g., carbon aerogel scaffolds, carbon-based polymers, and carbon nanofibers) is proposed to not only constrain particle size in nanoscale all over de/rehydrogenation cycles, but also to increase surface area and shorten diffusion distance for hydrogen exchange reaction. In this work, I would like to present nanoconfinement of several hydride materials, i.e., LiBH<sub>4</sub>, LiBH<sub>4</sub>-MgH<sub>2</sub>, LiBH<sub>4</sub>-NaAlH<sub>4</sub>, LiBH<sub>4</sub>-LiAlH<sub>4</sub>, and etc., into carbon hosts. The presentation will be made based on sample preparations and characterizations as well as results and discussion relating to hydrogen storage efficiency and reaction mechanisms during de/rehydrogenation.



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## B0804 (Elsewhere published)

## Solid State Approaches for Portable H<sub>2</sub> Applications

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### Abstract

The HYPER project (1) is an EC FCH JU project between academia and industry to develop an integrated hydrogen-fuelled power pack. One aspect of this project is to develop a solid state hydrogen storage module that can be used in combination with a PEM fuel cell. Two possibilities have been explored for this hydrogen storage module.

One possibility is to use a matrix with a hydride source and an exothermic 'H<sub>2</sub> release system' as a filler material. We will present results based on a MgH<sub>2</sub> matrix (that can theoretically store 7.6 wt.% H<sub>2</sub> on its own) with a filler material comprising of microwave synthesized Mg(OH)<sub>2</sub> (Figure 1) and a chemical hydride. Two hydrides (MgH<sub>2</sub> (2), LiH) have been investigated alongside Mg(OH)<sub>2</sub> as a "one shot" exothermic filler for use with the matrix. Powder X-ray Diffraction, TPD (temperature programmed desorption), kinetic measurements and theoretical calculations will be presented along with possible improvements (such as the use of catalyst) which will be discussed. (3)

Another possibility is to use a material that has a high H<sub>2</sub> gravimetric capacity which is confined within a porous, inert matrix. This can aid in the suppression of any unwanted release of by-products and improve the H<sub>2</sub> desorption properties. We will discuss and compare two different synthesis methods for confining the H<sub>2</sub> storage material and discuss the most promising approaches for moving forward.

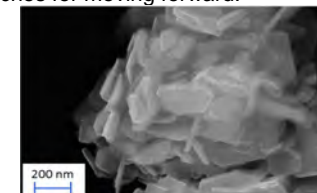


Figure 1: Synthesised Mg(OH)<sub>2</sub>

- 1) HYPER project website can be accessed at: <http://www.hyperportablepower.com>
- 2) F. Leardini, J.R. Ares, J. Bodega, J. F. Fernandez, I. J. Ferrer, C. Sanchez, Phys. Chem. Phys., 2010, 12, 572.
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## B0807 (Fuel Cells SI publication candidate)

### Hydrogen properties and solution energy of hydrogen in beryllium intermetallic compounds

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#### Abstract

Beryllium intermetallic compounds have shown a variety of excellent properties, such as neutron multiplier, refractory function, hydrogen storage, superconductivity and so on. Be<sub>12</sub>M compounds (M=Ti, V and Zr) have been investigated as neutron multiplier in fields of fusion reactor while Be<sub>17</sub>M<sub>2</sub> compounds have been focused on refractory materials. In addition, Be<sub>2</sub>Ms have been known as a Laves phase which is characterized by an A<sub>2</sub>B type compound performing higher H<sub>2</sub> gas storage potential. Although great interest on hydrogen properties of Be<sub>2</sub>Ms owing to its lower density has been aroused from viewpoints of reactivity with H<sub>2</sub>O, trap site of hydrogen and amount of H<sub>2</sub> gas in this compound, few studies on the Be<sub>2</sub>M found and its data base is still unsatisfactory.

Preliminary synthesis of a beryllium intermetallic compound (=Be<sub>2</sub>Ti) as a hydrogen storage material was conducted to clarify its reactivity with water vapor at high temperature and hydrogen storage capacity. X-ray diffraction profiles and electron probe micro-analysis results confirmed that the preliminary synthesis of single phase Be<sub>2</sub>Ti was successful by homogenization treatment and plasma sintering. Hydrogen generation rate of the Be<sub>2</sub>Ti by a reaction with 1 % H<sub>2</sub>O increased as test temperature increased. High temperature exposure with H<sub>2</sub>O leads to formation of TiO<sub>2</sub> on the surface. In addition, hydrogen storage result of Be<sub>2</sub>Ti evaluated by pressure-concentration-temperature curve depicts that Be<sub>2</sub>Ti indicated H<sub>2</sub> gas storage concentration with 0.56 w.t. % (=0.125 H/M) at 298 K, which is relatively low when the H<sub>2</sub> pressure increases up to 13 MPa. As a result of additional PCT measurements, it does not seem to have particle size dependence with regard to hydrogen capacity.

As a result of simulation based on the first principle calculation, it indicated that there were two hydrogen trap sites, tetrahedron and center of triangle with solution energies of -0.52 and -0.05 eV, respectively, indicating maximum trap site with 5.4 w.t. %. This dissimilarity may be thought by the fact that Be<sub>2</sub>Ti sample contains large fraction of oxides, surface oxide layer, which would disturb the surface penetration of hydrogen.

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**Chapter 09 - Sessions B06, B11**  
**B06: FC membranes & other components**  
**B11: Membranes for IT & HT PEMFC**

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## B0601 (Fuel Cells SI publication candidate)

## Graphene Oxide Ionomer Membranes for Proton Exchange Membrane Fuel Cells

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### Abstract

Graphene Oxide (GO) can be used as an ionomer material for polymer electrolyte membrane fuel cells (PEMFCs) due to its strength, lamellar structure, hydrophilicity, and acidic functional groups (Figure 1a). GO paper was prepared from dispersion by vacuum-filtration onto Millipore filters. The resulting membrane is strong and flexible (Figure 1b). Proton conductivity is typically related to a water-mediated ion transport mechanism, therefore water uptake was determined from the dry and water-saturated masses of the membranes to be 31 wt% in GO, compared with 26 wt% for Nafion. This indicates that GO may maintain proton conductivity even under low humidity conditions. The tensile strength (55 MPa) was larger than in Nafion (31 MPa). Conductivity increases with humidity and temperature, to 0.6 mS/cm at 100% RH and 70 °C (Figure 1c). This suggests water-mediated proton conduction, and a thermally activated proton conduction process.

A membrane electrode assembly (MEA) was assembled in which 16 µm thick GO paper was utilized in place of 50 µm thick Nafion in a "graphene oxide membrane fuel cell" (GOMFC). A high open circuit voltage of 1.00 V was obtained at 40 °C (compared to 0.98 V in Nafion) despite the much thinner membrane (Figure 1d). This clearly indicates predominantly protonic conduction and low fuel crossover. The power density is 33.8 mW/cm<sup>2</sup> a trend of increasing power density with decreasing thickness was observed.

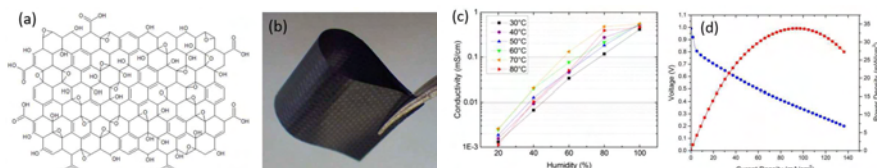


Figure 1. (a) Structure, (b) photograph, (c) conductivity, and (d) MEA performance of GO.

## B0602 (Fuel Cells SI publication candidate)

## A Novel Composite Nafion/Anodized Aluminum Oxide Proton Exchange Membrane

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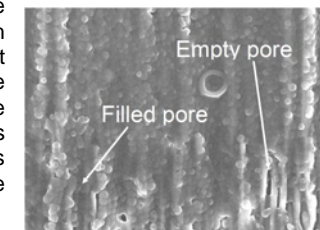
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### Abstract

The high proton conductivity of the Proton Exchange Membranes (PEMs) made of Nafion © results from a random 3D network of water channels formed by bundles of rod-like inverted micelles. An increase in conductivity along the membrane was demonstrated by alignment of these bundles in parallel to the membrane surface; however, PEM Fuel Cell applications require alignment normal to the membrane surface. A few attempts were made to produce such alignment by confining Nafion in nanometric pores of Anodized Aluminum Oxide (AAO) membranes, so far with a limited success. We presume that a likely reason for this failure is that Nafion concentration in the solutions used for the deposition exceeded the threshold concentration  $C^*$ , above which Nafion molecules form aggregates that could not enter the pores because of their size.

By applying a combination of thermal and vacuum methods to through-the-membrane evaporation of Nafion solution with concentration well below  $C^*$ , we achieved considerable filling of the AAO membrane pores with diameter 200 nm (as shown in the picture).

Characterization of such composite membranes poses another challenge. The through-plane resistance measurement by means of Electrochemical Impedance Spectroscopy (EIS) under controlled temperature and relative humidity (RH) conditions is probably the most reliable method, resulting in conductivity of ~ 10 S/m in pure Nafion (25 °C, 100% RH). However, this method is time consuming and requires specialized equipment. Consequently, numerous laboratory methods were proposed, resulting in wide variety of Nafion conductivity values significantly distant from the 10 S/m. With the composite membranes, yet another limitation appears: proton conduction can result from Nafion presumably deposited in the pores as well as from free transport of the supporting acid electrolyte ions through the unblocked pores. We developed two simple and fast EIS-based methods of measuring the membrane resistance and NaCl permeability. The latter, since Nafion demonstrates strong anion exclusion, provides information on the pore blockage. The measuring results of the experimental membrane, pristine AAO membrane and commercial Nafion membranes are reported.





B0603 (Elsewhere published)

## Composite sPEEK-porphyrin membranes development for PEFC applications

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### Abstract

Composite membranes based on sulphonated Polyetheretherketone (sPEEK) and porphyrins with different substituents in the periphery of the macrocycle were developed for PEFC applications at low temperature. A sulphonation degree of 65% was selected for these operative conditions in order to guarantee a good proton conduction. An investigation on different percentages (in the range 0-5wt%) of each porphyrin was carried out to verify the interaction with the polymeric matrix. The membranes were realized with a standardized doctor-blade method, thermally and chemically treated. UV-Vis and Fluorescence emission were carried out to investigate the aggregation state of porphyrins embedded in the membranes. Ionic exchange capacity and water uptake measurements were performed to highlight the physico-chemical properties of membranes. It was found that specific interactions between nitrogenous groups of porphyrin and sulphonic groups of polymer occurred.

Moreover, proton conductivity measurements at low temperatures were performed to understand the influence of the interactions on the proton transport mechanism. The developed membranes were characterized in a PEFC 25cm<sup>2</sup> single cell to verify the electrochemical performance at the selected operative conditions.

B0604 (Fuel Cells SI publication candidate)

## Investigating Electrodes for Intermediate Temperature Polymer Electrolyte Fuel Cell (IT-PEFC): GDL Material Properties and their Influence

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### Abstract

One of the ways Polymer Electrolyte Fuel Cells (PEFCs) can be improved is by increasing their operating temperature (>100 °C) [1], commonly known as the Intermediate Temperature PEFC (IT-PEFC) (120 °C) [2]. This allows for the generation of high temperature heat, which allows more facile heat rejection, while simplifying water management as water will exist solely in the vapour phase. In order to optimise these IT-PEFCs, further improvement in the cell components are necessary.

A combination of simulation and experimental methods has been used to investigate the material properties of the Gas Diffusion Layer so that ideal parameters can be suggested for intermediate temperature operation. Specifically, the porosity, permeability, electrical conductivity and thermal conductivity were investigated. The influence of the GDL thickness, the Microporous layer and hydrophobic treatment were also studied. Results have shown that the GDL porosity is a key factor of influence on the PEFC electrode. The balance between the mass transport capabilities and the electrical conductivity is very important to the success of the electrode. It was found that the cell performance was most sensitive to the GDL porosity when the cell was in the "standard operating" range of 0.7-0.5 V and that a porosity between 40-60 % was best.

The presence of a microporous layer and the hydrophobic treatment improve the MEA performance at intermediate temperature. The thinner GDL showed better performance, which was increased further when operating at higher temperature. The key aspect at high temperature is the balance between water management within the membrane and mass transport in the electrode.

In conclusion, the GDL is an integral component of the PEFC, however, the effect of its properties on the MEA performance is not sufficiently understood. In the work presented, it is shown that the MEA performance is sensitive to changes in the GDL porosity and therefore electrical conductivity. The processing of the GDL is still key to MEA performance at intermediate temperature.

## B0605 (Fuel Cells SI publication candidate)

### High-Velocity and High-Speed Manufacturing Method and Manufacturing Cost Analysis for PEM Fuel Cell Applications

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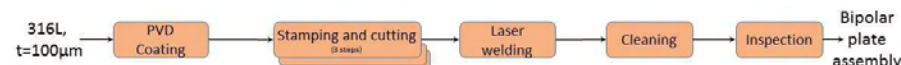
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#### Abstract

One of the key barriers to success for fuel cell applications is the cost, where the manufacturing cost of the bipolar assembly is one of the main cost-drivers on a system level. This paper describes a method from steel to a coated bipolar plate assembly that is addressing the cost perspective by means of an innovative and cost-effective production setup for high-volume manufacturing.

The stamping or embossing process is conducted at high strain rates surpassing conventional methods. It enables more challenging flow patterns to be embossed in both austenitic and ferritic steel. The enhanced forming elongation results in higher power densities. Thus, fewer assemblies are needed in the stack and a reduction of cost per kW.



Apart from the embossing method, the production setup is outlined as being high-precision and high-speed, using existing technologies which have been further developed from high-volume manufacturing of heat exchanger plates.

Finally, a bottom-up manufacturing cost analysis is conducted for a bipolar plate assembly which, for example, can be used for a middle size passenger vehicle. The bipolar plate assembly is assessed using pre-coated steel, high-strain rate embossing and high-speed processing utilising a combination of existing and near-term technologies as a basis, however, the costs were modelled at a high production volume of 500,000 stacks per year. The presented manufacturing costs are based on an activity-based manufacturing cost model.

The cost analysis has been performed per part only and it is concluded that the pricing, approx. 0.97 €/assembly is competitive, although it is slightly higher than has been estimated and reported by Austin Power Engineering.

Promising stamping trials have shown that it is possible to form patterns with a total forming elongation of up to 50 % and a channel pitch well below 1.0 mm. This is a clear indication that the gravimetric power density can be increased and/or the material cost can be reduced. Thus, calculated cost per assembly or per kW will be highly competitive.

## B0606 (Elsewhere published)

### PANI-Metallic Nanoparticles Double Layer Coating for Bipolar Plates in Polymer Electrolyte Fuel Cells

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#### Abstract

Compared to traditional graphite plates, stainless steel Bipolar Plates (BPP) for Polymer Electrolyte Fuel Cells (PEFCs) have the benefit of low cost, enhanced durability and relatively easy manufacturing. However, stainless steel has relatively high interfacial contact resistance (ICR) and low corrosion resistance in PEFC environment [1,2]. PVD coatings are considered ideal for improving the ICR values, however, the coating results in a significant increase in cost. Conductive polymer coatings have been investigated in the literature for improving stainless steel corrosion resistance; however, these coatings result in an increase in ICR. The investigation of TiN electrodeposition revealed reduced ICR values (meeting the DoE target of 20 mΩ.cm<sup>2</sup>). Therefore, TiN nanoparticles have been introduced into the polymer coating using electrophoretic deposition and resulted in a significant decrease in ICR while maintaining corrosion resistance properties comparable to PANI. Furthermore, a dual layer of composite and TiN coating has been explored in this study.

The coatings were evaluated using ex-situ techniques. In addition to FT-IR and FIB-SEM analysis, ex-situ electrochemical corrosion tests were performed to evaluate the corrosion resistance of the coated substrates. ICR values were measured before and after corrosion. The results show significant decrease in the ICR values for the TiN and double layer coating while maintaining acceptable corrosion potential and low corrosion current in the simulated fuel cell environment. The effect of scaling up the coating on stamped flow field plates and pre-stamping platines has been explored.

## B0607 (Abstract only)

### Optimization of Pack Chromising Process Parameters for Proton Exchange Membrane Fuel Cells Bipolar plates using Box–Behnken Experimental Design

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#### Abstract

Proton exchange membrane fuel cells (PEMFC) are clean and efficient power sources that could potentially improve global energy security as well as reduce greenhouse emissions if successfully commercialized for automotive, portable and distributed/stationary power generation. However, the high cost and low durability of the bipolar plates, one of its main components is a major challenge to be addressed for PEMFC to compete with current power generation technologies. Bipolar plates are currently fabricated from graphite which is brittle, permeable to gases and expensive to mass produce thus alternative materials such as stainless steels are under investigation for applications as bipolar plate materials. Stainless steels offer lighter weight, lower production cost and higher mechanical strength advantages over graphite but corrode in PEMFC environments resulting in degradation of cell performance. To mitigate these challenges, these metallic alloys have been coated and/or surface treated by a number of surface modification techniques using the one-factor-at-a-time (OFAT) approach. In this study, Box–Behnken experimental design was employed to optimize pack chromising process parameters namely: activator content (3–7%), temperature (1000–1100°C) and time (3–9 hours) to produce chromium based coatings on 304 stainless steel with the maximum corrosion resistance in 0.5M H<sub>2</sub>SO<sub>4</sub> + 2ppmHF at 70°C. Coatings were characterized by SEM/EDX and XRD. Coatings were characterized by scanning electron microscopy (SEM) with energy dispersive X-ray spectrometry (EDX) and X-ray diffractometer (XRD). Electrochemical polarisation in simulated PEM fuel cells environments and working potentials as well as interfacial contact resistance between the optimized coated surfaces and carbon paper were also evaluated. The results are discussed in relation to the targets for bipolar plates.

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## B0608 (Abstract only)

### Proton exchange membranes prepared from multi-block copolymers based on poly(arylene ether ketone)

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#### Abstract

Multi-block copolymers based on poly(arylene ether ketone) are synthesized. The chemical structure of the hydrophobic and hydrophilic oligomers and the copolymers synthesized from them is identified using <sup>1</sup>H - and <sup>19</sup>F- nuclear magnetic resonance spectroscopy, attenuated total reflection fourier transform infrared spectroscopy, and gel permeation chromatography. The development of distinguished hydrophobic-hydrophilic phase separation is confirmed by small-angle X-ray scattering spectroscopy. The proton conductivity and water uptake along with the thermal, mechanical, oxidative stabilities are measured to investigate the effect of the copolymer structure on the membrane properties. The proton conductivity of the multi-block copolymer membrane is higher than that of the randomly sulfonated poly(ether ether ketone) copolymer (SPEEK), while its water uptake was lower than SPEEK. It results from much more distinct hydrophobic-hydrophilic phase separation formed in the multi-block copolymer membrane than the random one. The ion cluster dimension of the multi-block copolymer membranes is larger than that of the SPEEK membranes from the SAXS analysis. Also, the multi-block copolymer membranes show excellent oxidation stability compared to the random one due to the well-established phase separation.

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Please contact the authors directly for further information.

## B0609 (Abstract only)

## Development of new hybrid membranes for DMFC

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## Abstract

Direct methanol fuel cells (DMFC) have advantages over the conventional ones as they supply fuel in a liquid phase being easier the storage and the recharge compared to other systems that use gas as a fuel. However, it is still necessary to improve them focused on reducing costs, increasing the power, and, at the same time, being environmentally sustainable. The present work has been focused on the research of a novel DMFC strengthen on durability and high performance applied to a portable generator. The improvements are based on the stack design and the development of a polymeric membrane with reduced internal crossover.

Regarding the research on polymeric membranes, Nafion® composites with organic or inorganic fillers have been studied. PVDF-HDF has been used as an organic additive to sandwich the Nafion®. Other inorganic fillers as metal oxides (SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and TiO<sub>2</sub>) have been used to evaluate their contribution to the crossover reduction. Different thicknesses in membranes have been also evaluated. In order to know physicochemical properties of each membrane the following characterization tests have been performed: water uptake, ion exchange capacity (IEC), methanol permeability, proton conductivity, mechanical properties and polarization curves.

The optimum membrane achieved has been a Nafion® composite using inorganic filler of TiO<sub>2</sub> (1.5%) with a thickness of 50 µm. The new membranes have been proven in a DMFC test system in order to obtain their polarization curves at real boundary conditions. Fluid dynamic and thermal simulations (CAE) have been carried out on designed bipolar plates to evaluate water and methanol behavior inside the channels and the heat transfer of plates. Once the most optimal channel design has been frozen, bipolar plates have been manufactured and a 40 cells stack has been assembled obtaining a performance of 20-30 mW/cm<sup>2</sup>, and a peak power of 100W. The new DMFC developed has been integrated in a power generator to be used in leisure applications. The new power generator achieves 2000Wh/day of power capacity.

## Acknowledgments

This research is in the frame of GENECOM project granted by Generalitat Valenciana through Valencian Institute of Business Competitiveness (IVACE) and European Union by European Regional Development Fund (ERDF). The GENECOM project belongs to the call for Technological Centres of IVACE Network.

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## B0610 (Elsewhere published)

## Silica-sulfonic acid-functionalized hybrid membranes synthesized by sol-gel for direct methanol fuel cells.

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## Abstract

Organic/inorganic hybrid membranes based on (3-glycidoxypopyl) trimethoxysilane (GPTMS) and 3-mercaptopropyl trimethoxysilane (MPTMS) have been prepared by sol-gel method and organic polymerisation, as candidate materials for proton exchange membranes in direct methanol fuel cell (DMFC) applications. The –SH groups of MPTMS are oxidized to sulfonic acid groups, which are attributed to enhance the proton conductivity of hybrid membranes. Membranes characterization includes degree of sulfonation, ion exchange capacity, water uptake, methanol permeability and proton conductivity. In particular, our hybrid membranes demonstrated proton conductivities as high as 0.1 S/cm, which is comparable to that of Nafion®, while exhibiting two orders of magnitude lower methanol permeability as compared to Nafion®. These results show that this kind of hybrid membranes possess high proton conductivity due to the proton conducting path through the silica pseudo-PEO network in which sulfonic acid groups work as proton donor.

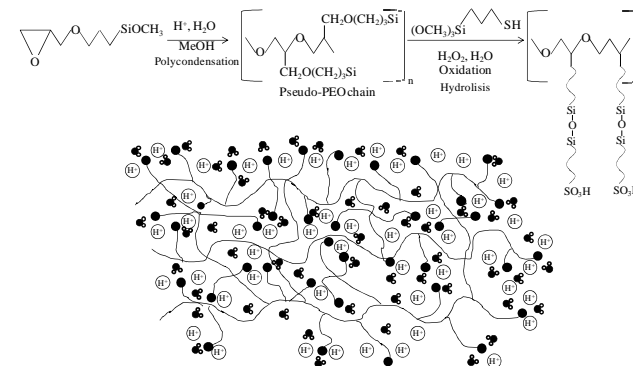


Fig. 1. Illustration of the hybrid structure simulating the protons transfers, where: represented water molecules, protons, and sulfonic acid groups.

## Acknowledgements

This project is supported by Comunidad de Madrid, Fondo Social Europeo and Fondo Europeo de Desarrollo Regional under PILCONAER S2013/MAE-2975.

Remark: The Authors did not wish to publish their full contribution in these proceedings. The topic of this Abstract will be published in Journal of Power Sources 2015. Please contact the authors directly for further information.

## B0611 (Abstract only)

### Polysulfone based Nanocomposite Membranes for Alkaline Fuel Cell Applications

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#### Abstract

Recent developments and the need for lower cost and more efficient fuel cells have created interest in anion exchange membrane fuel cells (AEMFCs) [1]. The use of metal-free anion-exchange membranes (AEMs) avoids CO<sub>2</sub> poisoning (i.e., precipitation of carbonate salts), which is the major obstacle in conventional alkaline fuel cells using sodium or potassium hydroxide as the electrolyte [2]. To date, AEMs based on quaternized polymers have been reported for use in anionic fuel cells. Among these materials, aromatic polymers are the preferred candidates for fuel cell applications due to their excellent thermal and mechanical properties as well as their resistance to oxidation and stability in acidic and alkaline conditions [3,4]. However, the stability of the fixed cationic site in alkaline conditions is a concern due to nucleophilic attack by anions. The introduction of inorganic filler in the polymer matrix supplies the polymer with good thermal resistance and improves the mechanical strength, the flexibility, dielectric, ductility, and processability of the membrane [5,6].

The presentation will focus on the performance evaluation and preparation of polysulfone nanocomposite membrane materials by recasting procedure for alkaline alcohol fuel cells applications. Characterization techniques will include SEM, TGA, AFM and physical properties such as water uptake, ionic conductivity and IEC measurements of these membranes will be presented with reference to recent advances reported in literature.

Keywords: Quaternized polysulfone, nanocomposite membrane, alkaline fuel cell

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Remark: Only one page abstract was available at the time of completion.  
Please contact the authors directly for further information.

## B1101

### Synthesis and characterization of cubic mesoporous silica as additives for proton conducting membranes

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#### Abstract

In this work we present the latest results on proton conducting mesoporous Si-MCM-48 materials with different amounts of sulfonic acid groups. The materials were prepared by the co-condensation method and investigated by gas sorption, NMR spectroscopy and electrochemical impedance spectroscopy. The successful incorporation of mercapto-propyltrimethoxysilane (MPMS) into the mesoporous framework was proven by <sup>29</sup>Si-NMR measurements. They show that all used MPMS is incorporated in the Si-MCM-48 structure. The deconvolution of the <sup>29</sup>Si-MAS-NMR spectra shows that Si atoms of the functionalizing silane are linked to the host framework via three or two bonds. The proton conductivity was investigated by electrochemical impedance spectroscopy (EIS). The maximum conductivity was found for the sample with highest loading of sulfonic acid groups (30% MPMS) as  $\sigma = 2.9 \cdot 10^{-3}$  S/cm at 140 °C and 100% relative humidity.



B1102

## Development of Charge-Transfer Complex Hybrid Films As Alternative PEM For High-Temp PEFC

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### Abstract

Stable operation of PEFC at high temperature more than 100 °C has some advantages such as improvement of fuel efficiency. The achievement of high-temp operation of PEFC is strongly required to develop new alternative PEMs which have high durability, high proton conductivity at high temperature and low dependency to humidity change. We have developed new alternative PEMs which have completely different concept of molecular design compared with conventional PEMs. The developed PEMs consist of hydrocarbon PEMs such as sulfonated polyimides (SPI) with low-molecular weight additives, and these compounds form charge-transfer (CT) complex in the membranes. The formed CT complex in the membranes can work as physical cross-linkers to stabilize and modify various properties for PEM application. The additives can modify their molecular structures freely if the additives retain capability of CT formation. However, we have not introduced the function to the additive molecules yet.

In this presentation, we modified the additive molecule and designed proton conductive additive (2,6-dipropyl naphthalene disulfonic acid, SDPN). SDPN has two sulfonic acids (proton conductor) with propyl linkers (hydrophobic unit) connected to naphthalene unit (CT formation unit). Sulfonic acid would be placed sulfonic acid of SPI. Therefore, the CT complex hybrid films consisting of SDPN and SPI would have packed-acid region and physical cross-linked region by CT complex in the membrane. The packed-acid region would contribute proton conductivity at lower humid condition and CT complex region would work as physical stabilizer at high temperature. On the basis of this concept, we evaluated proton conductivity of the CT complex hybrid films consisting of SDPN at high-temp condition (<120 °C).

At high temperature condition (100-120 °C), the CT complex hybrid films showed about 100 mS/cm at 100 RH%. These values are higher than Nafion 212. We also evaluated humidity effect to the CT complex hybrid films at high temperature. The proton conductivity of the CT films decreased with the decrease of humidity at 120 °C. However, the proton conductivity of the CT films was higher than Nafion 212 at all humidity.

B1103 (Abstract only, elsewhere published)

## Influence of Temperature Related Operation Faults on HT-PEMFC MEA Performance and Durability

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### Abstract

The interest in High Temperature Proton Exchange Membrane Fuel Cell (HT-PEMFC) technology has been increasing in the past few years due to the advantages of the technology related to improved electrode reaction kinetics, high CO tolerance, simplified heat and water management and the possible use of alternative and non-noble catalyst materials. The high operating temperature offers very attractive applications of the technology in Combined Heat and Power (CHP) systems but at the same time it requires newly temperature resistant materials and fuel cell components to be developed.

The Membrane Electrode Assembly (MEA) is the most crucial fuel cell component in a PEMFC. It has been reported that the best so far commercially available High Temperature MEAs (HT-MEA) are those produced by BASF which are easily achieving the highest performance of 0.6 A cm<sup>-2</sup> at +0.6 V and at 160 °C with a long-term stability of over 20,000 hours together with a degradation rate of ~6 μV h<sup>-1</sup> (@ 160 °C). The other market players as for example FuMA-Tech GmbH who offers Fumea<sup>®</sup> MEA products with performance of 0.6 A cm<sup>-2</sup> at +0.6 V and 160 °C with good durability during the first 900 hours test at 160 °C. The performance of Advent Technologies SA HT-MEAs - **TPS<sup>®</sup> MEA** – are slightly lower and are able to reach 0.35 A cm<sup>-2</sup> at +0.6 V and at 180 °C with excellent long term stability of the MEA at over 4,000 hours test with a degradation rate of ~9 μV h<sup>-1</sup> (@ 180 °C). Danish Power Systems<sup>®</sup> with the flagship product Dapozol<sup>®</sup> MEA reported performance of 0.4 A cm<sup>-2</sup> at +0.6 V and 160 °C and >5,000 hours lifetime in continuous operation.

Unfortunately in 'real' applications and due to faults in operation, the continuous maintaining of nominal working conditions cannot be ensured at all times; and deviations of various parameters such as for instance temperature or reactants supply from nominal values do occur. In those unfavourable operating conditions several MEA components degradation and corrosion processes occur and influence the MEA performance and durability. The most important thing is to know how to mitigate the degradation processes caused by ensuring operation fault by adjusting other operating parameters and developing careful and systematic shutdown strategies.

This paper reports on the influence of several temperature cycling operation faults on HT-MEA performance and durability. Temperature cycling at full and no load conditions is simulated and various reactant supply and purging strategies are applied. The performance of the HT-MEAs is studied with the mean of polarisation plots and Electrochemical Impedance Spectroscopy (EIS) methods. In this study, the most harmful temperature faults are shown and determined and strategies for mitigation of MEA degradation are suggested.

Remark: The authors did not wish to publish their full contribution in these proceedings and would like to publish elsewhere. Please contact the authors directly for further information.

B1104 (Elsewhere published)

## Multilayer membranes for IT-PEFC

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### Abstract

Polymer Electrolyte Fuel Cells (PEFCs) operate at around 80 °C and face problems like water and heat management due to these operating conditions. It is well accepted that the performance of PEFCs can be improved by operating at higher temperatures ( $80 < T \leq 120$  °C). This is because operation at higher temperature will accelerate the rate of the chemical reaction, facilitate water and heat management. These are normally referred to as Intermediate Temperature Polymer Electrolyte Fuel Cells (IT-PEFC) in order to differentiate them from high temperature ( $T = 180$  °C). However, the polymer membrane used in IT-PEFC conditions must be able to hold the water at these higher temperatures in order to transport the protons. This is not the case with the standard commercial Nafion membrane when operating over 100 °C. The present study investigates the use of multilayered membranes (MM) using Nafion and sulphonated polyindene (SPInd). Two different types of MM membranes were made: i) N/SPInd/N and ii) N/N. The component membrane single layers were cast using the polymeric solutions separately and then the layers were hot-pressed together. Characterization of the membranes using water uptake, ion exchange capacity (IEC), FT-IR and electron microscopy revealed that the water uptake for N/SPInd/N is higher than that of Nafion while the IEC is equivalent to cast Nafion. The proton conductivity test was also carried out to confirm the performance of the membranes.

## B1105 (Fuel Cells SI publication candidate)

### Proton Conductivity of Porous Zirconium-Organic Frameworks with Protic Ionic Liquids

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#### Abstract

Infiltration of the protic ionic liquid (PIL) triethylammonium trifluoromethanesulfonate (TEA-TFA) into the pores of zirconium metal organic-frameworks (Zr-MOFs) formed from interpenetrated networks (called PIZOFs) leads to highly proton conducting dry solids. The PIZOF family is build-up from long rod-like 2,5-di-substituted 1,4-di-(4-carboxy-phenyl-ethynyl) benzenes as linkers and  $\text{Zr}_6\text{O}_4(\text{OH})_4(\text{CO}_2)_{12}$  as Inorganic Building Units. The modular synthesis of the linkers allows tailoring the environment in the pores via the side chains carrying different functional groups. In case of PIZOF-7 the side chains are polyethylene glycol (PEG) units, in case of PIZOF-11 long alkyl chains narrow the pores. By infiltration of different PIZOFs with 50 wt.% PIL nanocomposites exhibiting proton conductivities up to  $4.2 \times 10^{-3} \text{ S/cm}$  at 120 °C under anhydrous conditions were obtained. For a proton conducting material operating in a water-free state this conductivity is quite promising. The obtained proton conductivity strongly depends on the chemical nature of the PIZOF pores, i.e. the kind of side chains at the linkers. Gas adsorption studies show that the side chains strongly influence the porosity and the hydrophilicity of the PIZOF materials.

## B1106 (Fuel Cells SI publication candidate)

### Analysis of crack structures of HT-PEFC electrodes from in-situ synchrotron radiographs

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#### Abstract

The behavior of high-temperature polymer electrolyte fuel cells (HT-PEFC) was investigated at different operating conditions. The crack structure induced by the drying process of the catalyst material during its fabrication can be visualized by means of synchrotron X-ray radiography in through-plane mode [1] and qualitatively analyzed with established image processing techniques. We detected structures – cracks and blocks – in the images for characterization of the morphology. The cracks were analyzed with statistical methods for quantification.

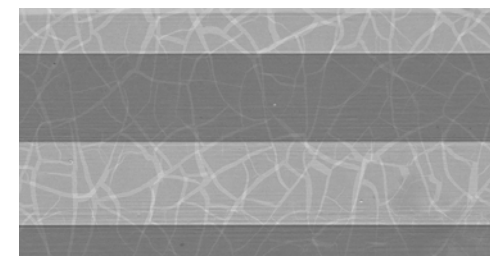


Fig. 1: Normalized X-ray radiograph of a HT-PEFC at 140 mA cm<sup>-2</sup> [2]

X-ray radiographs were taken from a HT-PEFC operated under electrical load in-situ. We focused on the crack widths and their distribution depending on their location under the channels or under the ribs of the flow field and on the relationship to different operating conditions [2]. As one result we found different crack widths under the ribs and under the channels of the flow field and we identified an impact of the operating conditions on the crack structure.

B1107 (Elsewhere published)

## Optimization of Poly2,5 benzimidazole (ABPBI) Membrane for High Temperature Fuel Cell Application

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### Abstract

Acid-doped ABPBI membrane with good proton conducting properties at high temperatures is considered as the best suitable membrane for high temperature fuel cell (HTPEM) application. The fundamental part of membrane preparation depends upon the perfect concentration of polymer solution. It decides the film forming capability of the solution, also the strength of the well prepared membrane. The addition of polymers to Newtonian fluid like methane sulfonic acid produces a deep rheological change. Because of their unique molecular structure, elastic behavior of polymer became a viscoelastic fluid in its solvent and gives the spectacular properties of material. The optimization of membrane was done of a suitable viscoelastic solution on the basis of the hardness and film forming capability supported by viscosity and topography of the membrane. Molar concentration of 5.6 moles/liter with viscosity of 0.52 Pa.S having hardness 0.074 GPa is optimized for HTPEM application.

B1108 (see A0502)

## Investigations on the H<sub>3</sub>PO<sub>4</sub>-Uptake of Polybenzimidazole type Polymers using RAMAN Spectroscopy

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### Abstract

In the last years phosphoric acid doped polybenzimidazol (PBI) became a curial role as proton conducting electrolyte membrane in high temperature polymer electrolyte fuel cells (HT-PEFC). In here, typical operation temperatures of 120 to 200 °C and very low humidity ionic conductivities of 10<sup>-1</sup> to 10<sup>-2</sup> S cm<sup>-1</sup> can be measured.

Several experimental studies, e.g. [1, 2], demonstrate H<sub>3</sub>PO<sub>4</sub>-doping process of different PBI-type materials. Unfortunately, no general applicable model for kinetics of the adsorption processes, which are able to describe the whole accessible range of doping degrees, has been published yet. However, the correlation of the interactions between H<sub>3</sub>PO<sub>4</sub> molecules and polymer chains as well as the ad-sorption isotherm, the polycondensation equilibria of H<sub>3</sub>PO<sub>4</sub> and the corresponding implications on the proton conductivity are finally not illuminated.

Here, we show investigations of the adsorption process of H<sub>3</sub>PO<sub>4</sub> on a commercial cross-linked PBI derivative (Fumapem AM-55). A number of membranes have been prepared at different doping levels and analyzed to elucidate the adsorption processes of H<sub>3</sub>PO<sub>4</sub> as a function of temperature and concentration. Karl-Fischer, pH-titration and RAMAN spectroscopy are used to characterize the membranes [3]. In addition, the adsorption equilibria of the uptake process on non-crosslinked m-PBI and AB-PBI have been analyzed with different kinetic models for our and for literature data. The behavior of all PBI-type polymers can be described satisfactorily with a BET-like adsorption isotherm (see Fig.1). By means of RAMAN spectroscopy re-

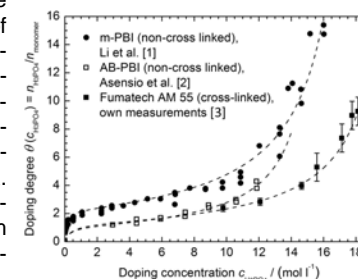


Fig. 1: Adsorption isotherm for H<sub>3</sub>PO<sub>4</sub> doped PBI, compiled and evaluated data from literature.

gions in the isotherm can be correlated to the protonation of the polymer chains, to the formation of H-bonds directly on the chains and to still adsorbed H<sub>3</sub>PO<sub>4</sub> molecules.

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Remark: The extended abstract for this contribution is given by "A0502".

## Chapter 10 - Session B09

### Fuel processing and hydrogen purification

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## B0901 (Fuel Cells SI publication candidate)

### Improved PBI Membranes for High Temperature Electrochemical Hydrogen Purification

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#### Abstract

Phosphoric acid (PA) doped polybenzimidazole membranes made by the PPA process have been the main focus of our research efforts for more than a decade. These membranes exhibit an excellent combination of properties including high proton conductivities, excellent fuel cell performance, and long-term durability. For both fuel cell and hydrogen pump devices, the improvement in membrane mechanical properties at high temperatures could lead to further increases in durability and lifetimes of the membranes and resulting devices. We have been particularly interested in membrane compressive creep properties and have developed test protocols which are being used to understand the compressive creep properties and develop structure-property relationships for PPA processed membranes. Correlations of copolymer structure to high temperature creep properties will be discussed as well as approaches to increasing polymer solids content while maintaining membrane proton conductivities. We will also discuss the recent investigations in terms of hydrogen pumping applications, which may have broad applications in both emerging energy applications and current industrial gas markets.



B0902

## On-site hydrogen generation from biodiesel and diesel

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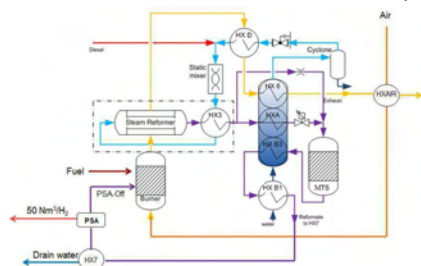
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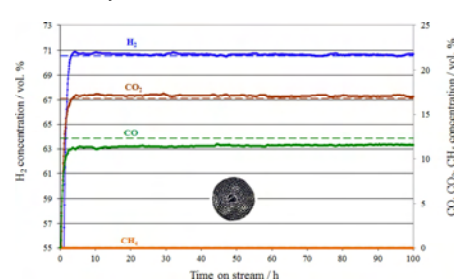
### Abstract

The lack of a hydrogen distribution infrastructure poses an obstacle for the introduction of fuel cell vehicles to the market. Therefore it is reasonable to consider using liquid fuels with existing infrastructure and high energy density for on-site hydrogen generation. Within the FP7 project NEMESIS2+ (01/2012-06/2015, [www.nemesis-project.eu](http://www.nemesis-project.eu)) a small-scale hydrogen generator capable of producing 50 Nm<sup>3</sup>·h<sup>-1</sup> from biodiesel and diesel is currently being developed. Reduction of hydrogen production costs (< 4 € per kg), high overall system efficiency (> 65 %), stable long-term operation (> 1000 hours) and high H<sub>2</sub>-purity (5.0) are among the main objectives of the NEMESIS2+ project. Currently, the pre-commercial prototype undergoes a final testing phase.

Results of the experimental and modeling work on lab-scale and prototype-level are presented. Special emphasis is placed on evaluating the applicability of direct steam reforming of diesel and biodiesel at various operating conditions using a precious metal catalyst. By desulphurizing the fuel (< 2 ppmw), applying a high catalyst inlet temperature (> 800 °C), a high steam-to-carbon ratio (S/C=5) and a low feed mass flow per open area of catalyst, a stable product gas composition close to chemical equilibrium has been achieved over 100 hours of on-stream exposure. Catalyst deactivation was not observed.



Process flow diagram of Nemesis2+ prototype



Longevity steam reforming of biodiesel

B0903 (Fuel Cells SI publication candidate)

## CO free reformat for stationary LT-PEM fuel cells technical and commercial benefits of selective methanation

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### Abstract

First the role of gas processing out of available commercial fuels like natural gas, biogas and LPG for the market successes of stationary LT-PEM systems is addressed. For this LT-PEM systems it is discussed the key role of robust, cheap and efficient CO removal technology within the fuel processing system.

The paper emphasize selective methanation (SelMeth) as the CO removal technology with advantages not only for operational and efficiency aspects but also for material costs, packaging and reduced maintenance efforts. In comparison with well-established preferential oxidation (PrOx) this technical and commercial advantages are shown based on a 1m<sup>3</sup>/h fuel processing system.

The transfer of beneficial SelMeth into the commercial product line **FLOX<sup>®</sup> fuel processor module FPM** is introduced. With its proprietary thermal management the integration in the vicinity of the shift stage was realised, although there exist special challenges for the design and operation of the fuel processor itself. To complete this outlook, test results and degradation mechanisms of a 1m<sup>3</sup>/h **FLOX<sup>®</sup> reformer** are shown after **20.000h** in a field test under real conditions.

This reformer is the core component of the 1kW<sub>el</sub> CHP **FLOX<sup>®</sup> micropower** which is part of a privately financed field test in Germany. As a highlight **OpenE** is introduced, a grid independent power supply concept for a single family home, including the home refueling of a battery-electrical car.

It turned out that solving the problem of proper thermal integration into the fuel processor an upscale from originally **1m<sup>3</sup>/h up to 10m<sup>3</sup>/h** was possible without additional challenges. Even more, first tests show the potential of an **upscale to 50m<sup>3</sup>/h**. This comes along with reduced specific costs of up to 80% for the complete fuel processing system.

## B0904 (Fuel Cells SI publication candidate)

### HIL simulations of a Real-Time Fuel Processor Model

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#### Abstract

In this article a real-time model for dynamic simulation of a fuel processor is presented and used for HIL testing of the PLC for a truck Auxiliary Power Unit (APU) system. The APU comprises a PEM fuel cell and fuel processor to enable direct utilization of on-board diesel. The system is developed in FCGEN (Fuel Cell based on-board power GENeration), an EU project under the FP7 program (FCH JU). One critical challenge is to design the control system (PLC) to ensure failsafe and environmental friendly start-up and operation. The start-up phase of the fuel processor is the most critical part, since it is a highly dynamic process involving several reactors. It is advantageous to verify the control system before the fuel processor is assembled to avoid possible breakage of components. Such verification can be done with a real-time model representing the physical system. In this work such a model is created using Modelica and Dymola and used for testing and verification of control loops. Two test setups are used; an FMI based approach where the model is exported as a so called functional mock-up unit (FMU) from Dymola and imported into MATLAB/Simulink for testing on a desktop PC, and a second approach where the model is exported to a dedicated HIL target machine. It is shown that both approaches can be used for testing and verification.

## B0905 (Elsewhere published)

### Study on on-board fuel reforming for hydrogen production using exhaust gas

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#### Abstract

In current days, fuel economy of automobile become major concerns for not only consumers but also automobile products. The addition of hydrogen in lean burn combustion is one of the way to increase fuel economy. By the way, for supply hydrogen to automobile engine, we need to hydrogen source. On-board fuel reforming can be a solution for hydrogen supply in automobile system. To produce hydrogen with fuel reformer, we need oxidizer. Current fuel reformer need to additional water tank and air compressor. So we use exhaust gas, due to there are enough steam and oxygen in engine exhaust gas and we have experience of exhaust gas reuse as EGR system.

In this work, we found the possibility of fuel reforming with using exhaust gas by catalytic reforming experiments. We used our fuel reforming system using iso-octane on the monolith coated CGO-Pt catalyst. Fuel was fully converted by hydrogen and synthetic gas during changing exhaust gas ratio, temperature, composition of exhaust gas and GHSV of reactant. Maximum fuel conversion efficiency was 78% at certain operating condition. After iso-octane test, we apply gasoline fuel to our fuel reforming process. Maximum hydrogen production amount and conversion efficiency are similar to the case of iso-octane. However, the sensitivity of EGR ratio should be solved to apply the reforming system to on-board gasoline engine. After general plots of reformate gas composition is similar to iso-octane pre-test. Maximum conversion efficiency of exhaust gas reforming is 78% and fuel conversion is almost 100% under EGR ratio 2~3%. However in case of gasoline, catalytic failure occurs in lower exhaust gas ratio (about 1~2%) due to low oxidant amounts. Accordingly the results, the sensitivity of EGR ratio should be solved to apply the reforming system to on-board gasoline engine.

B0906 (Elsewhere published)

## Operating Strategies for Fuel Processing Systems with a Focus on Water-Gas Shift Reactor Stability

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### Abstract

Auxiliary power units with fuel cells offer the advantages of highly efficient electricity production in combination with low emissions. Fuel cell systems find beneficial application in means of transportation, such as aircraft, trucks, trains or ships, where fossil fuels will continue to be indispensable for propulsion in the near-term future.

Fuel cell systems developed at Forschungszentrum Jülich convert diesel and kerosene fuels in an autothermal reformer (ATR) into a hydrogen-rich syngas. The reformat is further conditioned in a two-stage water-gas shift (WGS) reactor to lower the carbon monoxide concentration from ≈10 vol.-% to ≈1 vol.-% (dry basis) before it is fed into the high-temperature polymer electrolyte fuel cell (HT-PEFC). However, operation of the fuel cell system involved deactivation of the noble metal catalyst in the water-gas shift reactor under steady state operation, as well as after startup/ shutdown. Former experimental results led to the conclusion that catalyst deactivation might be caused by the presence of higher hydrocarbons in the dry gas phase due to incomplete fuel conversion in the ATR. This contribution presents experiments concerning fuel conversion during startup and shutdown as well as under steady state operation. These experiments revealed a much higher concentration of higher hydrocarbons during the transients in comparison to steady state. In addition, further conversion of higher hydrocarbons in the WGS reactor was observed. As earlier experiments showed no obvious correlation between WGS catalyst deactivation and the concentrations of higher hydrocarbons typically observed under steady state operation, prevailing experiments focus on improving fuel conversion in the reformer during startup and shutdown. In this context, new startup/shutdown strategies were developed. The new strategies enable improved fuel conversion in comparison to the "classical" strategies applied. Concentrations of higher hydrocarbons were lowered by a factor of up to 10 for startup and a factor of up to 400 for shutdown. Special measures were developed to protect the WGS catalyst from deactivation by other phenomena which appeared while applying the new strategies. The results were reproduced using four different diesel and kerosene fuels. The newly developed strategies for starting up and shutting down the fuel cell system improve fuel conversion in the reformer and may possibly prevent or at least mitigate catalyst deactivation in the water-gas shift reactor.

B0907

## Low Temperature Methanol Steam Reformer with Heat Exchanger Structure Thermally Integrated with a HT-PEMFC

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### Abstract

A low temperature methanol steam reformer has been designed, manufactured and characterized. The operating temperature is 175-180 °C which is notably lower than the conventional operating temperature of methanol steam reformers (around 250 °C). This low temperature enables thermal integration with a high temperature PEM fuel cell, which operates around 180 °C. The exothermic fuel cell reaction feeds heat to the endothermic reforming reaction enhancing the system efficiency.

The heat is transferred via heat exchange liquid in a layered heat exchanger structure. Using this structure instead of a common tubular structure improves the heat transfer. Figure 1 shows the more detailed structure of the methanol steam reformer. The catalyst used in the reformer is a novel catalyst developed in University of Porto and ground to particle size 150-250 µm.

After manufacturing and packing with catalyst the reformer was characterized in various operating conditions for producing the required amount of hydrogen for a 350 We HT-PEMFC.



Figure 1. The structure of the LT-MSR. To the left: flow directions of the reformer. To the middle: the physical appearance of the catalyst layers. To the right: the finalized reformer.

## B0908 (Fuel Cells SI publication candidate)

## Hydrogen Gas Purifiers for Fuel Cells

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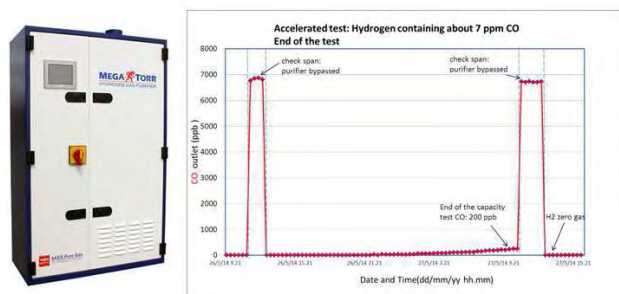
## Abstract

Hydrogen is the most common gas used to operate fuel cells (FCs). The performance of proton exchange membrane FCs is sensitive to the hydrogen gas purity. Of particular concern are specific gaseous contaminants such as carbon monoxide, sulphur compounds, and ammonia that are known to drastically reduce the FC efficiency even when present at low concentrations (in the ppb range). To eliminate efficiency losses due to hydrogen purity, dedicated hydrogen gas purifiers are now available specifically for FCs; their adoption protects the FCs and guarantees consistent gas purity is supplied throughout their lifetime.

Different purification technologies have been developed to match the wide variety of applications and to manage various impurities that are dependent on the H<sub>2</sub> source.

For gas sources where nitrogen is present above the acceptable limit, palladium membrane purifiers can be used to reduce the nitrogen concentration to the desired level. At the same time, the other impurities like carbon monoxide, sulphur compounds, ammonia, hydrocarbons, etc. are also removed.

For applications where the main concern is the presence of reactive gases, such as carbon monoxide and sulphur compounds, adsorber purifiers can eliminate these impurities down to the single digit ppb range or better. This technology is suitable to cover a very broad range of flow rates, from a few sccm up to 1000 m<sup>3</sup>/h. The purity performance of both technologies has been proven with state of the art analyzers and will be discussed in the paper. The figure below shows a practical realization of a purifier and its ability to remove CO down to < 200 ppb.



## B0909 (Elsewhere published)

## Experimental study on diesel reforming with hydrogen peroxide

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## Abstract

Diesel has a high density of hydrogen and a well-equipped infrastructure, which are beneficial properties for hydrogen production. In the case of diesel reforming, auto-thermal reforming (ATR) which uses both oxygen and steam as an oxidant is well known for appropriate method. Especially, in low-oxygen environments such as under the sea, alternative oxidant is required to produce hydrogen when using diesel reforming for driving fuel cells without using oxygen or air.

In this work, hydrogen peroxide was proposed in diesel reforming as an alternative oxidant of both steam and oxygen due to its high volumetric oxygen density. The first objective of this research was to study the influence of hydrogen peroxide in reforming of diesel by comparing the oxidants between hydrogen peroxide and both oxygen and steam. Hydrogen peroxide was decomposed into oxygen and steam before being supplied into reactor. In addition, O<sub>2</sub>/C, H<sub>2</sub>O/C were determined by concentration of hydrogen peroxide. The second objective of this research was to evaluate catalytic activity depending on the concentration of hydrogen peroxide. These reforming experiments were conducted with Korean commercial diesel by using hydrogen peroxide that concentration was varied from 22.5 wt.% to 48.6 wt.% and the reaction temperature was ramped from 700°C to 850°C.

The results showed that diesel reforming with hydrogen peroxide had almost same fuel conversion and reformat gas composition compared to when reformed with oxidants of both steam and oxygen. In addition, at the 48.6 wt.% concentration of hydrogen peroxide, the reforming efficiency was over 70% at the entire temperature region. From these results we can suggest hydrogen peroxide as an alternative oxidant in diesel reforming for low-oxygen environments.

## B0910 (Fuel Cells SI publication candidate)

### A 1kW Gasoline Fuel Processors for Mobile HT-PEMFCs

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#### Abstract

Hydrogen is spotlighted as renewable and eco-friendly energy. H&power(HNP) has been developing a gasoline fuel processor which reforms gasoline to hydrogen in a very efficient way. The fuel processor consists of primary reforming, de-sulfurizer and CO removal. The conversion efficiency is 78.4% on the LHV basis. Since its expectable application is mobile and transportable ones, it has been seriously verified in a variety of field tests. For instant, it did successfully good jobs to tests; 1)shock/vibration, 2)raining, 3)dusty, 4)-32/50 deg.C, 5)quick start-up and so on.

It meets the requirement in the military-standard-810G protocol. This paper is to show the results from the tests.

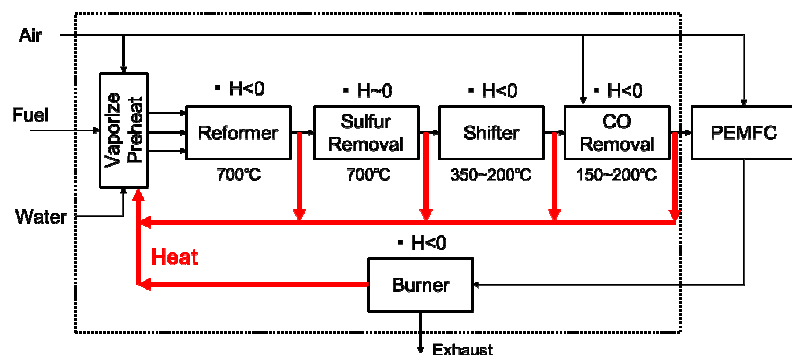


Fig.1. Composition of 1kW gasoline fuel process.

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## Chapter 11 - Session B12

### Industrial applications/Microbial fuel cell/Assessments

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## B1201 (Elsewhere published)

### Sustainability assessment of alkaline fuel cells – what can we learn?

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#### Abstract

What are the environmental impacts of a fuel cell system and how do they compare to competing systems? How can sustainability assessment methods provide support in various project phases? How important is a life cycle perspective when evaluating electricity production with an Alkaline Fuel Cell (AFC)? This work shows how the methodologies of Life Cycle Assessment (LCA) can be implemented to help answer these questions, using examples from a current research project.

Within the 7<sup>th</sup> European Framework Program, project POWER-UP will develop stationary applications of a newly developed AFC<sup>1</sup>. The POWER-UP system will be the first large-scale AFC application with ca. 500 kW electrical capacity and potential use of the excess heat, fuelled by hydrogen generated as a by-product of the chlor-alkali process. The Paul Scherrer Institut (PSI) is responsible for a comprehensive sustainability assessment of the system including investigation of potential life cycle environmental impacts, (total) costs, related risks, and weighting of such aspects against each other in a Multi-Criteria Decision Analysis (MCDA).

The environmental hotspots of the AFC system including the impacts of design parameters such as system efficiency, cell lifetime, and recyclability for impact categories such as greenhouse gas (GHG) emissions, metal depletion, and cumulative energy demand<sup>2</sup> are identified. For example, recycling of cell substrates and catalysts was found to reduce impacts by over 40% in all categories analyzed, and by over 85% in four out of six categories. The impact of different fuel production pathways also has large influence on the results. Finally, the system performance is compared to competing electricity generation technologies in terms of environmental impacts. An outlook will provide insight into how these and other results can further be integrated into the MCDA tool.

<sup>1</sup> <http://project-power-up.eu/>

<sup>2</sup> See publication Cox, B. and K. Treyer (2015). "Environmental and economic assessment of a cracked ammonia fuelled alkaline fuel cell for off-grid power applications." Journal of Power Sources 275(0): 322-335

B1202

## Stack Development at AFC Energy- Aiming towards the Deployment of World's Largest Alkaline Fuel Cell System

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### Abstract

At AFC Energy, UK we are continuously striving to meet our objectives towards the deployment of the world's largest alkaline fuel cell system at Air Products' industrial gas plant in Stade, Germany. The system will equip multiple cartridges containing stacks which are made of several cells connected electrically. In order to gain further insights as to how a systems' balance of plant will respond when multiple cartridges are connected to it, several experiments are carried out both with and without stacks. It has been observed that the multiple stacks when connected at different positions of the balance of plant could experience operational in-homogeneity due to pressure drops and temperature differences. This operational in-homogeneity could lead to difference in performance amongst multiple stacks. Interestingly, multiple stacks degrade identically due to a common single balance of plant which ensures identical electrolyte concentration and environmental conditions for all stacks. Due to the confidence gained in the durability data, this study allows us to explore durability of stacks when made with different manufacturing processes and operated differently. As a result of this, novel methods of operating stacks can be developed based on improved durability which will lead to a commercial success of the project POWER-UP.

B1203 (Fuel Cells SI publication candidate)

## A 50kW PEMFC system durability study at industrial site operated with industry grade hydrogen

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### Abstract

Chlor-alkali industry both in Finland and globally produces a large amount of by-product hydrogen. This hydrogen is currently only partially utilized as a chemical, or as a fuel for heat and power production. PEMFC offers a great possibility to utilize this hydrogen cost-efficiently for electricity production with high efficiency.

In national DuraDemo project in Finland, a 50 kW PEMFC pilot system has been designed, built, integrated to an industrial application and operated by VTT. PEMFC pilot is using by-product hydrogen from a chlor-alkali plant in Äetsä, western part of Finland. The performance of the PEMFC pilot plant is reported for the operation period of one and half years from early 2014 to summer 2015. The efficiency and characteristics of stacks, balance-of-plant and power electronics components are measured and analyzed.

The change of components characteristics during the operational period of several thousand hours is analyzed using the collected data. Reversible and irreversible degradation of the membrane electrode assemblies (MEAs) are reported for the accumulated operational period.

The experiences from start-up, shut-down and remote monitoring are discussed and improvements are proposed for the design of the system as well as for the operation and remote monitoring. The requirements for an industrial site operation of demonstration unit are discussed in terms of safety, education and communication.

The feasibility of using by-product hydrogen for base, peak and regulation power production in changing electricity markets is analyzed.

## B1204 (Fuel Cells SI publication candidate)

### High Platinum Cost: Obstacle or Blessing for Commercialization of Fuel Cell Technology

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#### Abstract

Polymer electrolyte fuel cells (PEFCs), at the early stage of the commercialisation, have tremendous potential for transport and portable applications. Similar to any other new technologies, PEFC technology is also facing several challenges and uncertainties during pre-commercialization phase. Use of the platinum as catalyst in PEFCs is considered as one of the key obstacles arising from its high cost and scarcity. In particular, cost and the durability of the fuel cells are one prime challenges toward the commercialization of the fuel cells. Current cost of PEFC technology are estimated to be at least five fold higher than the target cost, even with the consideration of cost saving by mass production. Generally, high cost of platinum, is blamed and considered as the main hurdle towards the commercialization, since, it is not possible to bring down the cost of platinum by mass production of fuel cells. In present work, a life cycle cost analysis is carried out based on the inflation and discount rate of the market for different economic zone and it is shown that the high platinum cost could be beneficial and should promote the commercialization of the fuel cells if proper business model is in place instead of acting as hurdle.

## B1205

### Booster Technology for Hydrogen Compression – Challenges and Solutions

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#### Abstract

Fuel cell driven vehicles operated with compressed hydrogen are typically using composite cylinders in order to store the gas at pressures of up to 700 bar. The supply of hydrogen in the required volume and pressure is the logistical challenge of every filling station since the gas has to be transferred and compressed with minimal use of energy. However, the technical challenges are sometimes not noticed and should be looked at in this paper. The compression technology we are looking at is the reciprocating air driven booster. They are an economical alternative to electrical driven compressors and comply with the explosion proof directive 94/9/EC in the category 2G/2D, group IIC.

Boosters used for filling station pressures of up to 700 bar are typically operated in different stages up to 1000 bar in order to enable an adequate differential pressure. At these pressures materials with high yield strengths ( $R_{p0.2}$ ) are required. Austenitic stainless steel of the 316L series as referred to in the IGC document 121/04/E has become a standard for many high pressure hydrogen applications since it shows good resistance against hydrogen embrittlement. The corresponding material code for 1.4404 lists yield strengths of up to 320 MPa [1] which can be improved by cold working to values of about 750 MPa [2]. Since one of the limiting factors for the cold working process is the dimension, different solutions have to be found when the available mechanical properties are not sufficient. For the final compression stage of a typical booster station the standard material comes to its limits according to the FEM analysis and the use of cold worked material is not possible because of the diameter and the limitation of cold working. An alternative material suitable for hydrogen with yield strengths of greater 500 MPa is required and found with the creep resistant steel 1.4980. The material has a yield strength ( $R_{p0.2}$ ) of 600 MPa [3] and a high nickel content of 25.3% [3] which meets the mechanical requirements plus those of the Japanese KHK regulation which opens a new geographical target market.

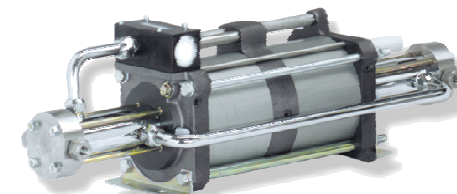


Fig. 1: Typical air driven booster

B1207

## Start-up approach based on hybrid system emulator with a re-compression system for a pressurized Solid Oxide Fuel Cell Gas Turbine

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### Abstract

This paper presents a novel machine start-up technique for SOFC hybrid system based on a re-compression approach. This approach shows the reality of operating the system without the manufacturer's usual technique of using the standard control system. A hybrid system emulator rig located at Savona, Italy will be used for these research activities. The experimental test rig consists of an emulator that is based on a 100 kW microturbine connected to a modular vessel designed for fuel cell emulation. The microturbine pipes were carefully insulated and connected to a high temperature modular vessel necessary to emulate the dimension of an SOFC stack and lastly, for the purpose of re-compression, the test rig was modified to accommodate a turbocharger capable of increasing the fuel cell pressure (using part of recuperator outlet flow). This is necessary for operating at high efficiency conditions hybrid systems based on a cathodic recirculation driven by an ejector. For both economic reasons and to avoid system abnormal operations during the plant start-up conditions, a theoretical activity is very vital. A dynamic model of the solid oxide fuel cell gas turbine system was developed in Matlab®-Simulink® environment to investigate the transient behaviour during start-up phase. The results obtained shows reasonable values for several parameters, such as surge margin, turbine outlet temperature, and rotational speed. The results demonstrated the feasibility of this machine coupling (the microturbine with a turbocharger) avoiding risk operations during the start-up phase.

B1208 (Abstract only)

## Eco-friendly textile dye degradation coupled to bioelectricity generation using Microbial Fuel Cell (MFC) technology

Hilor Pathak\*, Dhatri Chaudhari

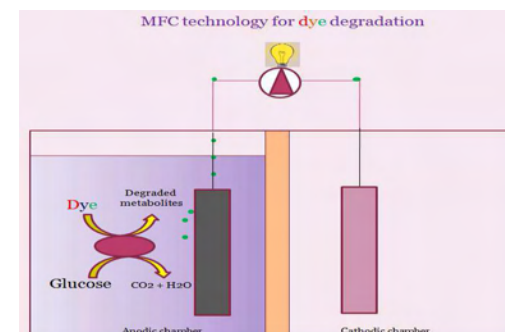
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### Abstract

Reactive azo dyes are considered as one of the most detrimental pollutants from industrial effluents and therefore their biodegradation is receiving constant scientific consideration. Textile effluent treatment has been a challenge since long, hitherto, no sustainable technology has yet been developed. Very recently the microbial fuel cell (MFC) technology has emerged as one of the promising technology for treatment of azo dye degradation concomitantly generating electricity. In the present study, a bacterial culture designated as HHGP was isolated which was able to decolorize textile industrial dye – Reactive Brown as evaluated by spectroscopic analysis. Cultural parameter optimization was also performed to enhance the biodegradation ability of the culture. The degradation of Reactive Brown was evaluated by various analytical techniques (FTIR, UV-Visible spectroscopy and GC-MS analysis) and consequently a pathway of degradation of reactive brown was also elucidated. The toxicity profile of degraded metabolites was assessed by phyto-toxicity assay. The bacterium HHGP was also evaluated for bioelectricity generation via an MFC set up. The maximum voltage output of 700mV and current generation of 1.03mA was observed with dual chamber system connected by agar salt bridge with copper plates as electrodes. Thus, the microbe HHGP demonstrates ability to degrade completely the textile dye - Reactive Brown alongwith loss of its toxicity. To the best of our knowledge, this is the first study focusing on biodegradation of reactive brown dye from textile effluent using microbial isolate and concomitant generation of bioelectricity in the process.



Remark: Only one page abstract was available at the time of completion. Please contact the authors directly for further information.

## B1209 (Fuel Cells SI publication candidate)

**Landfill Leachate: A Promising Substrate for Microbial Fuel Cells**

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**Abstract**

Landfill leachate emerges as a promising feedstock for microbial fuel cells. In the present investigation, direct air-breathing cathode-based microbial fuel cells (MFCs) are fabricated to investigate the potential of landfill leachate. Three microbial fuel cells that have different cathode areas are fabricated and investigated for 17 days under open circuit conditions. The maximum open circuit voltage (OCV) is observed to be as high as 1.29 V (Fig. 1) which is the highest OCV ever reported in literature using landfill leachate. The maximum cathode area specific power density achieved in the reactor is 1513 mW m<sup>-2</sup> (Fig. 2). Further studies are under progress to understand the origin of high OCV obtained from landfill leachate-based MFCs.

## B1210 (Fuel Cells SI publication candidate)

**Accessing Fuel Cell opportunities in European Research and Innovation**

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**Abstract**

**Who is this presentation for?** Those responsible for or involved in funding acquisition. Typically “post-doc and above” will attend.

**How can this presentation help you?** Whilst you may know of the significant opportunities at the European level, finding the ideal strategy for you or your organisation can be challenging. Euresearch is the key access point in Switzerland for European research and innovation. Euresearch will be present at EFCF and can help you determine your optimal approach for European opportunities.

**What questions will be answered at the European opportunities session?**

- What European opportunities can be expected in 2015 related to Fuel Cells?
- What topics are likely to be funded, especially in the 2015 calls?
- Who has already been funded or participated successfully in another way?
- What are the new rules for the European opportunities?
- How can Euresearch further support you?

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**Keywords:** fuel cell, funding, technology transfer, partnering, strategy, international overview, regional activities, products, demonstration, deployment, SOFC, stationary power generation, hydrogen production and distribution, transport, refueling infrastructure



## B1211 (Abstract only)

### Enhanced Electron Transfer by a Magnetic Self-assembled Conductive Fe<sub>3</sub>O<sub>4</sub>/Carbon Nanocomposites in *E. coli*-Catalyzed Mediator-less Microbial Fuel Cells

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#### Abstract

The sluggish electron transfer between microorganisms and anode is one of the major factors that lower the power production in microbial fuel cells (MFC). In order to enhance the electron transfer and improve MFC efficiency, the anode surface was modified with various Fe<sub>3</sub>O<sub>4</sub>/carbon nanomaterial composites using a magnetic assembling technique. The Fe<sub>3</sub>O<sub>4</sub>/CNT composite modified anodes with various Fe<sub>3</sub>O<sub>4</sub> contents were first investigated to find the optimum ratio of the nanocomposite for the best MFC performance. The Fe<sub>3</sub>O<sub>4</sub>/CNT modified anodes produced much higher power densities than unmodified carbon anode and the 30wt% Fe<sub>3</sub>O<sub>4</sub>/CNT modified anode exhibited a maximum power density of 830mW/m<sup>2</sup>. In the Fe<sub>3</sub>O<sub>4</sub>/CNT composite modified anode, Fe<sub>3</sub>O<sub>4</sub> helps to attach the CNT on anode surface by its magnetic attraction and forms a multilayered network, whereas CNT offers a better nanostructure environment for bacterial growth and helps electron transfer from *E.coli* to electrode resulting in the increase in the current production with the catalytic activity of bacteria.

The second part of this study also examined the utility of various conductive carbon nanomaterials (*i.e.*, graphite nanofibers (GNF), reduced graphene oxide (rGO) and multi-walled carbon nanotubes (MWCNT)) owing to their superior physicochemical properties. The carbon nanomaterials form composites with Fe<sub>3</sub>O<sub>4</sub> and is used to modify the interface between microorganisms *E. coli* and electrode. Among different carbon nanomaterial supports, the MFC with Fe<sub>3</sub>O<sub>4</sub>/CNT shows the best performance followed by Fe<sub>3</sub>O<sub>4</sub>/rGO and Fe<sub>3</sub>O<sub>4</sub>/GNF. The results demonstrate that CNT is the appropriate carbon support to form nanocomposites with Fe<sub>3</sub>O<sub>4</sub>. The difference in the MFC performance and the electron transfer mechanism for different carbon nanostructures were discussed by analyzing the structural and electrochemical properties of the composite carbon materials.

1. In Ho Park, Yoon Hye Heo, Pil Kim and Kee Suk Nahm, RSC Adv., 3, 2013,16665–16671
2. In Ho Park, Maria Christy, Pil Kim, Kee Suk Nahm, Biosensors and Bioelectronics 58, 2014, 75–80

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4 July - 7 July 2017



**[www.EFCF.com](http://www.EFCF.com) in Lucerne, Switzerland**

## Chapter 12 - Session B15

### Portable/Back-up/Renewable

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## B1501

### FCH JU HYPER – results from the 100 W<sub>e</sub> HYPER system field testing and risk assessment analysis

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#### Abstract

The HYPER Portable Power Pack is an innovative system, based on a flexible design that incorporates a modular fuel cell and interchangeable hydrogen storage. The system has been designed and developed under a FCH JU funded project (2012-2015) and we have recently made the transition to prototype demonstration, encountering and addressing a number of challenges along the way. The key elements of the HYPER system are:

1) A LT PEM fuel cell based on a 20-50 W<sub>e</sub> module that can be assembled to provide electrical output of up to 500 W<sub>e</sub>.

2) Two types of (interchangeable) hydrogen storage module:

a) Compressed gas hydrogen storage (300 and 700 bar, respectively).

b) Solid-state hydrogen storage module based on best in class technology.

3) A common interface (balance of plant and control electronics) to enable use with alternative hydrogen supply modules.

The ultimate aim is to create a flexible platform that can be readily customized to meet a range of application specific requirements including: power output (up to 500 W<sub>e</sub>), energy content and fuelling options. Prototype testing with the HYPER 100 W<sub>e</sub> system has been underway since May 2015, focused on two specific applications:

1) A field battery charger (in Germany)

2) A multi-application portable power pack for future use by emergency services to provide remote lighting and device (computer, phone) recharging (in France).

The testing includes hydrogen module interchange and re-fuelling where appropriate.

A risk assessment was performed on the complete HYPER system in order to ensure safe operation of the whole unit. Our experience highlighted considerable ambiguity in the formal procedures and requirements for the testing and certification of prototype and field demonstration systems. Substantial additional resource was required to resolve and address these issues. Key criteria included: transport of high pressure hydrogen cylinders or solid state storage tanks to site, assembly/disassembly of equipment on site, start up and shut down procedures of the components and the whole system, operation of the equipment, and maintenance and repair on site. In each case the nature of the hazard, its likelihood, proposed mitigation actions and control strategy were assessed.

This paper presents practical insights from the risk assessment process that were subsequently used to inform the final design of the prototype system, and should be beneficial to similar projects undertaking early field deployment.

## B1502 (Fuel Cells SI publication candidate)

**CFD Modelling of a New PEM Fuel Cell Configuration for Portable Applications**

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**Abstract**

Recent research in fuel cell domain made this form of energy to be considered a potential source for electricity generation. There are several challenges that must be overcome in order that the fuel cells to be widely used in portable applications, such as the ability to use logistic fuels, reliability of components, the prevention of cathode contamination with impurities from the used air, reducing the size and weight, competitive cost.

In general, the PEM fuel cell requires hydrogen and oxygen to produce electricity, the gas being supplied through pressurized systems for both the anode and the cathode. Due to the requirements of the dimension and weight reduction, a solution based on forced convection for air supplying in the cathode side is analysed in order to eliminate some of the auxiliary systems necessary. As a result, the use of mathematical models and numerical investigations for a better understanding of the fundamental processes and characteristics associated with air cathode operation is required.

A CFD analysis for a 44 cm<sup>2</sup> air breathing PEM fuel cell is presented in this paper with focus on investigating the influence of some factors (operating conditions and geometrical configurations) on the cell performance. Two widths for the cathode channels were investigated (1.5 mm and 2 mm) and our study revealed that the smaller width gives the highest rate of electrical generation. Regarding the operating conditions, the influence of air temperature at cathode inlet for 1.5mm width case was analysed for 2 inlet pressures at cathode channels (6000 Pa and 1000 Pa). The results showed a decrease with 6% in the current density for 6000 Pa case and with 11% for the 1000 Pa case. Identifying critical and optimal parameters is an important task in the study of air breathing PEM fuel cells and more numerical investigations are needed for maximizing the cell performance.

## B1503

**PEM Fuel Cell Systems as Backup Solution for POLYCOM Applications**

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**Abstract**

The operation of many technical applications in case of grid failures is ensured by backup systems. Common solutions for short outages are systems with batteries, for longer outages with diesel generators. In addition or replacement for these solutions fuel cells are promising technical and ecological benefits to potential users as they work efficient, silent and without local emissions. Besides, long autonomy times can be realized by dimensioning the hydrogen storage according to end user demands. Moreover, the operation can be extended without interruption of the operation.

Applications which may profit from these options are uninterruptible power supply systems for the radio security network POLYCOM. In several cantons of Switzerland an autonomy time of 72 hours is required for the communication infrastructure for national emergency services. Fuel cell technology promises to simplify the process for continuously operation during three days.

In close collaboration with producers and end users Lucerne School of Engineering and Architecture tested market-ready fuel cell backup systems for POLYCOM applications in Switzerland. In- and outdoor systems are installed according to end user demands. The systems work in a power range from 2 to 4 Kilowatt. Hydrogen is supplied by 50 Liter pressure cylinders at 200 bar.

During a testing period of two years, grid failures were performed monthly at each site according to a common agreed testing protocol. In addition, 72 hours testing was performed at two sites. The triggering of the grid failure simulations was done remotely and the performance data of the fuel cell systems are logged during the tests.

In this report we focus on the reliability, operational stability and start-up behaviour of the system. Furthermore, we prepared a concept for complementary operation of batteries and fuel cells during 72 hours operation.

The research for one installation was funded in the context of the European Union's Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n° 256766. The research for the second installation was funded by the Swiss National Federal Office.

## B1504 / B1507

### Hour by hour simulation of solar hydrogen energy system in conjunction with renewable energy sources

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#### Abstract

A renewable hydrogen energy system, consisting of a PV array, wind turbine, electrolyzer, hydrogen storage, fuel cell and a battery bank is analyzed. Its performance is simulated within one year using real meteorological hourly data for solar insolation and wind speed. Three different load profiles are analyzed, namely constant load, daily cyclic load and daily cyclic load superimposed on seasonal variations. Simulation is used to compare two different control strategies for turning on and off the electrolyzer and the fuel cell, namely (i) electrolyzer is turned on whenever there is an excess of renewable power available, and the fuel cell is turned on whenever power from renewable energy is not sufficient to satisfy the load.; (ii) battery state of charge is used as a trigger for both electrolyzer and fuel cell turning on and off. The conclusion is that there is no universally better control strategy - while the first strategy results in better energy utilization the second strategy results in fewer electrolyzer and fuel cell turning on and off.

Remark: The content of Extended Abstract presented here is also valid for B1507.

## B1505

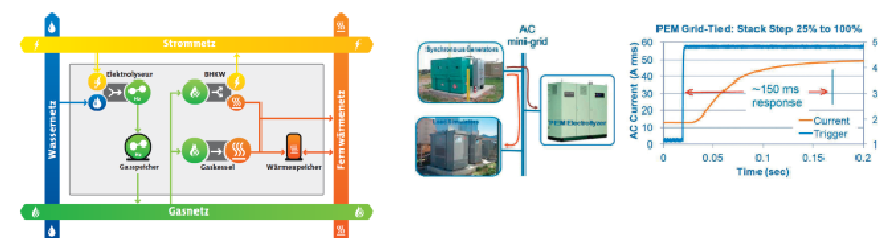
### Hybrid Plant Aarmatt – a novel renewable energy concept applying PEM electrolysis

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#### Abstract

Regio Energie Solothurn has built a plant based on a novel energy concept combining distributed heat, electricity and gas grid to a convergent system, often referred to as "Power-to-Gas". Hydrogen from electrolysis is a promising technology providing linkages between other infrastructures such as transportation to provide flexibility in the overall solution. Hydrogen has the capability to store massive amounts of energy in a relatively small volume, with no carbon footprint when generated from electrolysis of water and renewable energy. To be able to use excess / stranded power from their regional PV grid, Regio Energie decided to install 2 PEM electrolyzers of 350 kW input, to generate hydrogen, which will serve as an energy carrier. Hydrogen can be seasonally stored and / or used in various grids if and when needed. The two PEM electrolyzers serve as the core of the system. These units are well suited to handle the fluctuating power available from 0 to 100%. Fast changes can be handled without deterioration of the units as has been evaluated by NREL.



Regio Energie selected the PEM electrolyzer of Proton OnSite due to the long-term experience of these units, which are used in industrial applications since 18 years. The need for grid control (e.g., load shifting and frequency regulation) is also an important reason why such electrolyzers are applied. For this purpose, they can be remotely started and stopped based on the grid demand. The paper will report about the practical experience with this concept and the role it can play managing sustainable energies in light of the "Energy turnaround" goals. It will also inform about the fine-tuning of the operating regimes of this Hybrid plant and the resulting next steps.

B1506

## Stand-alone PEMFC system based on solar hydrogen

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### Abstract

Proton Exchange membrane Fuel Cell (PEMFC) system operation based on solar hydrogen is analysed here from energy management point of view. Powered by photovoltaic field, the overproduction is stored through PEM electrolyser producing hydrogen which will be later used by the PEMFC. Batteries and Super capacitors (Scaps) packs are used to smooth power, and also, ensure respectively energy and power charging/discharging process. Here, a suitable deterministic rule-based method underlain by heuristic approach is presented. This method aims to perform proper energy management strategy of the multi-source system based on solar hydrogen. Besides the State Of Charge (SOC) management of the involved sources in order to satisfy security-based thresholds, power smoothing on the terminals of the low dynamics devices, namely PEMFC and PEM electrolyser, is performed preserving the PEM tools lifetime. Furthermore, the medium dynamics are smoothed on the terminals of the batteries pack, the Scaps ensuring the fast transient dynamics. According to the earlier mentioned proper energy management strategy some simulations, based on experimentally validated energy sources models, are performed by using theoretical and measurement insolation profiles.

B1507 / B1504

## Hour by hour simulation of solar hydrogen energy system in conjunction with renewable energy sources

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### Abstract

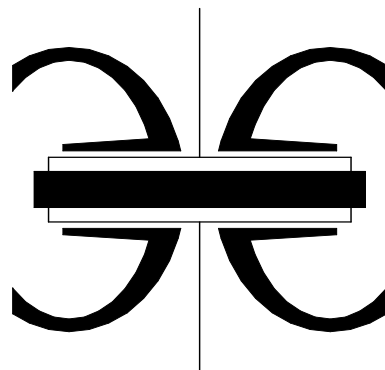
A renewable hydrogen energy system, consisting of a PV array, wind turbine, electrolyzer, hydrogen storage, fuel cell and a battery bank is analyzed. Its performance is simulated within one year using real meteorological hourly data for solar insolation and wind speed. Three different load profiles are analyzed, namely constant load, daily cyclic load and daily cyclic load superimposed on seasonal variations. Simulation is used to compare two different control strategies for turning on and off the electrolyzer and the fuel cell, namely (i) electrolyzer is turned on whenever there is an excess of renewable power available, and the fuel cell is turned on whenever power from renewable energy is not sufficient to satisfy the load.; (ii) battery state of charge is used as a trigger for both electrolyzer and fuel cell turning on and off. The conclusion is that there is no universally better control strategy - while the first strategy results in better energy utilization the second strategy results in fewer electrolyzer and fuel cell turning on and off.

Remark: The content of Extended Abstract is presented in B1504.



International FUEL CELL and HYDROGEN Conference

# 5<sup>th</sup> European PEFC & H<sub>2</sub> Forum 2015



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**5 – 8 July 2016**

**4 – 7 July 2017**

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Institute of Fluid Science, Tohoku University  
Miyagi/Japan

Institute of Polymer Science and Technology (ICTP-CSIC)  
Madrid/Spain

Institute of Power Engineering, Department of Thermal  
Processes  
Warsaw/Poland

Instituto de Cerámica y Vidrio (CSIC)  
Madrid/Spain

Instituto Superior Técnico (IST)  
Lisbon/Portugal

Intelligent Energy  
Loughborough/United Kingdom

International Institute for Carbon-Neutral Energy Research  
(I2CNER)  
Fukuoka/Japan

International Institute for Carbon-Neutral Energy Research  
(WPI-I2CNER)  
Fukuoka/Japan

International Research Center for Hydrogen Energy  
Fukuoka/Japan

Istanbul Technical University, Electrical & Electronics  
Faculty  
Istanbul/Turkey

Istituto di Tecnologie Avanzate per l'Energia "Nicola  
Giordano"  
Messina/Italy

Istituto per lo Studio dei Materiali Nanostrutturati, c/o  
Dipartimento di Scienze Chimiche  
Messina/Italy

J. Stefan Institute  
Ljubljana/Slovenia

Johnson Matthey PLC. (JM)  
London/United Kingdom

Korea Advanced Institute of Science and Technology  
Daejeon/Korea

Korea Institute of Energy Research  
Daejeon/Republic of Korea

Kyushu University  
Fukuoka/Japan

Laboratory of Alternative Energy Conversion Systems,  
Department of Mechanical Engineering/University of  
Thessaly  
Volos/Greece

Laboratory of Electrochemical Devices based on Solid  
Oxide Proton Electrolytes/Institute of High Temperature  
Electrochemistry  
Yekaterinburg/Russia

Laboratory of Physical Chemistry, ETH Zürich  
Zürich/Switzerland

LEITAT Technological Center  
Barcelona/Spain

Los Alamos National Laboratory  
Los Alamos/New Mexico/United States

Loughborough University, Department of Aeronautical and  
Automotive Engineering  
Loughborough/United Kingdom

LPMRN laboratory, Bordj-Bou-Arredj University  
El Anasser/Algeria

Lucerne School of Engineering and Architecture, CC  
Thermal Energy Systems & Process Engineering  
Horw/Switzerland

Materials for Energy Conversion, Swiss Federal  
Laboratories for Material Science and Technology (EMPA)  
Dübendorf/Switzerland

MAXIMATOR GmbH  
Nordhausen/Germany

McPhy Energy  
La Motte-Fanjas/France

Modeling in Electrochemical Process Engineering, RWTH  
Aachen University  
Aachen/Germany

Modelon AB, Ideon Science Park  
Lund/Sweden

National Institute of Advanced Science and Technology,  
Energy Technology Research Institute  
Ibaraki/Japan

National Institute of Advanced Science and Technology,  
Research Center for Compact Chemical System  
Sendai/Japan

National Research and Development Institute for  
Cryogenics and Isotopic Technologies - ICIT Rm. Valcea  
Râmnicu Vâlcea/Romania

National Research Technological Univ. "MISIS"  
Moscow/Russia

National Technical University of Athens  
Athens/Greece

NEXT ENERGY • EWE Research Centre for Energy  
Technology at the University of Oldenburg  
Oldenburg/Germany

Next Generation Fuel Cell Research Center (NEXT-FC)  
Fukuoka/Japan

NRC Kurchatov Institute  
Moscow/Russia

Paul Scherrer Institut (PSI), Electrochemistry Laboratory  
Fuel Cell Systems  
Villigen/Switzerland

PaxiTech SAS  
Munich/Germany

Politecnico di Milano, Department of Energy  
Milano/Italy

Politecnico di Torino  
Torino/Italy

PowerCell AB  
Göteborg/Sweden

proionic GmbH  
Grambach/Austria

PT&B SILCOR GmbH  
Barleben/Germany

Regio Energie Solothurn  
Solothurn/Switzerland

Research Centre Juelich  
Juelich/Germany

Research Institute for Ubiquitous Energy Devices, AIST  
Ikeda/Osaka

RWTH Aachen University, Faculty of Mechanical  
Engineering  
Aachen/Germany

RWTH Aachen University, Institute of Automobile  
Engineering (ika)  
Aachen/Germany

Saes Getters Spa  
Milan/Italy

School of Chemical Engineering, Sungkyunkwan University  
Kyunggi/Republic of Korea

School of Chemistry, Institute of Science, Suranaree  
University of Technology  
Nakhon Ratchasima/Thailand

School of Chemistry, University of Glasgow  
Glasgow/United Kingdom

School of Mechanical and Manufacturing Engineering,  
Dublin City University  
Dublin/Ireland

School of Mechanical Engineering, Kookmin University  
Seoul/Republic of Korea

School of Mechanical, Aerospace and Civil Engineering,  
The University of Manchester  
Manchester/UK

School of Nano-Bioscience and Chemical Engineering,  
Ulsan National Institute of Science and Technology  
Ulsan/Republic of Korea

Seoul National University, School of Chemical and  
Biological Engineering  
Seoul/Republic of Korea

SINTEF Materials and Chemistry  
Trondheim/Norway

SISM Laboratory, Setif University  
Setif/Algeria

Southern Federal University  
Rostov-on-Don/Russia

Sustainable Innovations Inc.  
East Hartford/(CT)/US

Swiss Federal Office of Energy  
Bern/Switzerland

Swiss Light Source, Paul Scherrer Institut (PSI)  
Villigen/Switzerland

Tata Motors European Technical Centre (TMETC),  
International Automotive Research Centre  
Coventry/United Kingdom

Technical University of Denmark, Department of Energy  
Conversion and Storage  
Roskilde/Denmark

Technion – The Israel Institute of Technology, Faculty of  
Chemical Engineering  
Haifa/Israel

Technological Institute of children's products & leisure  
(AIJU)  
Alicante/Spain

Technological Institute of Energy (ITE)  
Valencia/Spain

The Centre for Hydrogen and Fuel Cell Research  
Birmingham/United Kingdom

The Fuel Cell Research Center (ZBT)  
Duisburg/Germany

Thermal Engineering Group, Energy Engineering  
Department, University of Sevilla  
Sevilla/Spain

Thermochemical power group, University of Genoa  
Genoa/Italy

Tshwane University of Technology  
Pretoria/South Africa

U.S. Department of Energy  
Washington (DC)/USA

Unité de Catalyse et de Chimie du Solide, Equipe de  
Chimie du Solide, UMR CNRS 8181, ENSCL/UST  
Lille/France

University Duisburg-Essen  
Duisburg/Germany

University of Birmingham, Centre for Hydrogen & Fuel Cell  
Research  
Birmingham/United Kingdom

University of Birmingham, Chemical Engineering  
Birmingham/United Kingdom

University of Calabria, Department of Mechanical, Energy  
and Management Engineering  
Rende/Italy

University of Craiova, Department of Chemistry  
Craiova/Romania

University of Felix Houphouet Boigny, Signals and Systems  
laboratory  
Abidjan/Ivory Coast

University of Franche-Comte, FEMTO-ST/FCLAB  
Belfort/France

University of Leeds  
Leeds/United Kingdom

University of South Carolina  
Columbia (SC)/USA

University of the West of Scotland  
Paisley/United Kingdom

VITO NV  
Mol/Belgium

VTT Technical Research Centre of Finland  
Tampere/Finland

WS Reformer GmbH  
Renningen/Germany

Zentrum für BrennstoffzellenTechnik ZBT GmbH  
Duisburg/Germany

Zentrum für Sonnenenergie- und Wasserstoff-Forschung  
Baden-Württemberg  
Ulm/Germany

**Thanks to all the Institutions enabling know-how  
Growth, Transfer and Realization in Applications.**

**Thank you for joining the European Fuel Cell Forum**

 **12<sup>th</sup> European SOFC and SOE Forum**

**5 – 8 July 2016**

 **6<sup>th</sup> European PEFC and H<sub>2</sub> Forum**

**4 – 7 July 2017**

**[www.EFCF.com](http://www.EFCF.com)**

# List of Exhibitors

Registered by 22 June 2015

5<sup>th</sup> EUROPEAN PEFC & H<sub>2</sub> FORUM 2015

30 June - 3 July 2015 KKL Lucerne/Switzerland

	Company	Exhibits
<b>B09</b>	<b>AP&amp;T</b> Box 32 52321 Ulricehamn Sweden <a href="http://www.aptgroup.com">www.aptgroup.com</a>	Material and production line for fuel cell plates
<b>B16</b>	<b>Airbus Group Innovations</b> Willy-Messerschmitt-Strasse 1 81663 München Germany <a href="http://www.hyperportablepower.com">www.hyperportablepower.com</a>	100 W HYPER System Portable Power Pack + Battery Charger
<b>B06</b>	<b>ARBOR Fluidtec AG</b> Loonstrasse 10 5883 Niederrohrdorf Switzerland <a href="http://arbor.swagelok.com">arbor.swagelok.com</a>	Swagelok Products and Services
<b>B12</b>	<b>AVL List GmbH</b> Hans-List Platz 1 8070 Graz Austria <a href="http://www.avl.com">www.avl.com</a>	THDA FC Monitoring "Total Harmonic Distortion Analysis" for stack operation control

	Company	Exhibits
<b>B13</b>	<b>Bronkhorst (Schweiz) AG</b> Nenzlingerweg 5 4153 Reinach Switzerland <a href="http://www.bronkhorst.ch">www.bronkhorst.ch</a>	Mass Flow Meters and - Controllers, Pressure Sensors and -Controllers, Evaporator
<b>B02</b>	<b>Bürkert Contromatic AG Schweiz</b> Bösch 71 6331 Hünenberg Switzerland <a href="http://www.buerkert.ch">www.buerkert.ch</a>	Mass Flow Controllers, Mass Flow Meters, Valves, Sensors
<b>B01</b>	<b>CEA LITEN</b> 17, rue des Martyrs 38058 Grenoble France <a href="http://www-liten.cea.fr">www-liten.cea.fr</a>	R&D
<b>B09</b>	<b>Cell Impact</b> Plåtvägen 18 66060 Karlskoga Sweden <a href="http://www.cellimpact.com">www.cellimpact.com</a>	High-velocity press for stamping, forming, compaction and shearing



	Company	Exhibits
<b>B08</b>	<b>Diamond Lite S.A.</b> Rheineckerstr. 12 PO Box 9 CH-9425 Thal Switzerland <a href="http://www.diamondlite.com">www.diamondlite.com</a>	PEM Electrolyzer
<b>B14</b>	<b>Enterprise Europe Network - Switzerland / Euresearch</b> Effingerstrasse 19 3008 Bern Switzerland <a href="http://www.swisseen.ch">www.swisseen.ch</a>	Innovation opportunities from Europe and beyond Partnering for your innovation or technology need SME support to access EU research projects
<b>B05</b>	<b>FIS Inc.</b> 3-36-3 Kitazono 664-0891 Itami, Hyogo Japan <a href="http://www.fisinc.co.jp">www.fisinc.co.jp</a>	Hydrogen Sensor Modules (Automotive) and other Hydrogen Sensor Solutions
<b>B16</b>	<b>HYPER</b> Co-ordinator <b>Orion Innovations</b> 1, Quality Court, Chancery Lane London United Kingdom <a href="http://www.hyperportablepower.com">www.hyperportablepower.com</a>	100 W HYPER System Portable Power Pack + Battery Charger

	Company	Exhibits
<b>B16</b>	<b>Institute of Power Engineering</b> Mory 8 01-330 Warsaw Poland <a href="http://www.hyperportablepower.com">www.hyperportablepower.com</a>	100 W HYPER System Portable Power Pack + Battery Charger
<b>B16</b>	<b>Joint Research Centre</b> P.O. Box 2 1755 ZG Petten The Netherlands <a href="http://www.hyperportablepower.com">www.hyperportablepower.com</a>	100 W HYPER System Portable Power Pack + Battery Charger
<b>B10</b>	<b>Maximator Schweiz AG</b> Warpelstrasse 7 3186 Düringen Switzerland <a href="http://www.maximator.ch">www.maximator.ch</a>	Hydrogen High Pressure Pumps, Valves, Fittings, Tubes, Test and Production Equipment
<b>B16</b>	<b>McPhyEnergy</b> Zone d'activité 26190 La Motte-Fanjas France <a href="http://www.hyperportablepower.com">www.hyperportablepower.com</a>	100 W HYPER System Portable Power Pack + Battery Charger
<b>B07</b>	<b>M-Field Energy Ltd.</b> No. 377, Sec 4, Chung Hsing Rd. Chutung, Hsinchu 31061 Taiwan, R.O.C. <a href="http://www.m-field.com.tw">www.m-field.com.tw</a>	Coffee Cart, Fuel cell system (UEH system), Forklift

	Company	Exhibits
<b>B17</b>	<b>New Cosmos Electric Co. Ltd.</b> 2-5-4 Mitsuya-Naka, Yodogawa-ku 532-0036 Osaka Japan <a href="http://www.new-cosmos.co.jp">www.new-cosmos.co.jp</a>	Hydrogen Gas Detection for Fuel Cell Applications
<b>B05</b>	<b>Novatronic Deutschland GmbH</b> Kauler Straße 36 51429 Bergisch Gladbach Germany <a href="http://www.novatronic.de">www.novatronic.de</a>	Gas Sensing Solutions
<b>B16</b>	<b>PaxiTech SAS</b> 32 rue de Comboire 38130 Echirolles France <a href="http://www.hyperportablepower.com">www.hyperportablepower.com</a>	100 W HYPER System Portable Power Pack + Battery Charger
<b>B08</b>	<b>Regio Energie Solothurn</b> Rötistrasse 17 4502 Solothurn Switzerland <a href="http://www.regioenergie.ch">www.regioenergie.ch</a>	Project "Hybridwerk with PEM Electrolyzer"
<b>B11</b>	<b>SAES Pure Gas, Inc.</b> 4175 Santa Fe Rd. 93401 San Luis Obispo, CA United States <a href="http://www.saespuregas.com">www.saespuregas.com</a>	Hydrogen Gas Purifiers

	Company	Exhibits
<b>B09</b>	<b>Sandvik Materials Technology</b> 6365 SBTM 81181 Sandviken Sweden <a href="http://www.smt.sandvik.com">www.smt.sandvik.com</a>	Coated strips for inter-connects and bipolar plates in fuel cells
<b>B03</b>	<b>S<sup>++</sup> Simulation Services</b> Waldstraße 5 82418 Murnau-Westried Germany <a href="http://www.splusplus.com">www.splusplus.com</a>	Current density distribution measurement devices, single cell voltage measurement devices
<b>B16</b>	<b>University of Glasgow</b> School of Chemistry Joseph Black Building G12 8QQ Glasgow United Kingdom <a href="http://www.hyperportablepower.com">www.hyperportablepower.com</a>	100 W HYPER System Portable Power Pack + Battery Charger
<b>B04</b>	<b>UST Umweltsensortechnik GmbH</b> Dieselstrasse 2 + 4 98716 Geschwenda Germany <a href="http://www.umweltsensortechnik.de">www.umweltsensortechnik.de</a>	Hydrogen Gas Sensors; Hydrogen Gas Detectors; Temperature Sensors; Measure-ment Technology
<b>B15</b>	<b>V&amp;F Analyse- und Messtechnik GmbH</b> Andreas Hofer-Strasse 15 6067 Absam Austria <a href="http://www.vandf.com">www.vandf.com</a>	Mass Spectrometer

# List of Booths

## 5<sup>th</sup> EUROPEAN PEFC & H<sub>2</sub> FORUM 2015

30 June - 3 July 2015 KKL Lucerne/Switzerland

Booth	Exhibitor	Country	Website
B01	CEA LITEN	France	<a href="http://www-liten.cea.fr">www-liten.cea.fr</a>
B02	Bürkert Contromatic AG	Switzerland	<a href="http://www.buerkert.ch">www.buerkert.ch</a>
B03	S++ Simulation Services	Germany	<a href="http://www.splusplus.com">www.splusplus.com</a>
B04	UST Umweltsensortechnik GmbH	Germany	<a href="http://www.umweltsensortechnik.de">www.umweltsensortechnik.de</a>
B05	FIS Inc.	Japan	<a href="http://www.fisinc.co.jp">www.fisinc.co.jp</a>
	Novatronic Deutschland GmbH	Germany	<a href="http://www.novatronic.de">www.novatronic.de</a>
B06	ARBOR Fluidtec AG	Switzerland	<a href="http://arbor.swagelok.com">arbor.swagelok.com</a>
B07	M-Field Energy Ltd	Taiwan	<a href="http://www.m-field.com.tw">www.m-field.com.tw</a>
B08	Diamond Lite S.A.	Switzerland	<a href="http://www.diamondlite.com">www.diamondlite.com</a>
	Regio Energie Solothurn	Switzerland	<a href="http://www.regioenergie.ch">www.regioenergie.ch</a>
B09	AP&T	Sweden	<a href="http://www.aptgroup.com">www.aptgroup.com</a>
	Cell Impact	Sweden	<a href="http://www.cellimpact.com">www.cellimpact.com</a>
	Sandvik Materials Technology	Sweden	<a href="http://www.smt.sandvik.com">www.smt.sandvik.com</a>
B10	Maximator Schweiz AG	Switzerland	<a href="http://www.maximator.ch">www.maximator.ch</a>
B11	SAES Pure Gas, Inc	United States	<a href="http://www.saespuregas.com">www.saespuregas.com</a>
B12	AVL List GmbH	Austria	<a href="http://www.avl.com">www.avl.com</a>
B13	Bronkhorst (Schweiz) AG	Switzerland	<a href="http://www.bronkhorst.ch">www.bronkhorst.ch</a>
B14	Enterprise Europe Network - Switzerland / Euresearch	Switzerland	<a href="http://www.swisseen.ch">www.swisseen.ch</a>
B15	V&F Analyse- und Messtechnik GmbH	Austria	<a href="http://www.vandf.com">www.vandf.com</a>
B16	HYPER	International	<a href="http://www.hyperportablepower.com">www.hyperportablepower.com</a>

Airbus Group Innovations  
 Institute of Power Engineering  
 Joint Research Centre  
 McPhyEnergy  
 PaxiTech SAS  
 Orion Innovations  
 University of Glasgow

Germany  
 Poland  
 The Netherlands  
 France  
 France  
 United Kingdom  
 United Kingdom

B17 New Cosmos Electric Co. Ltd.

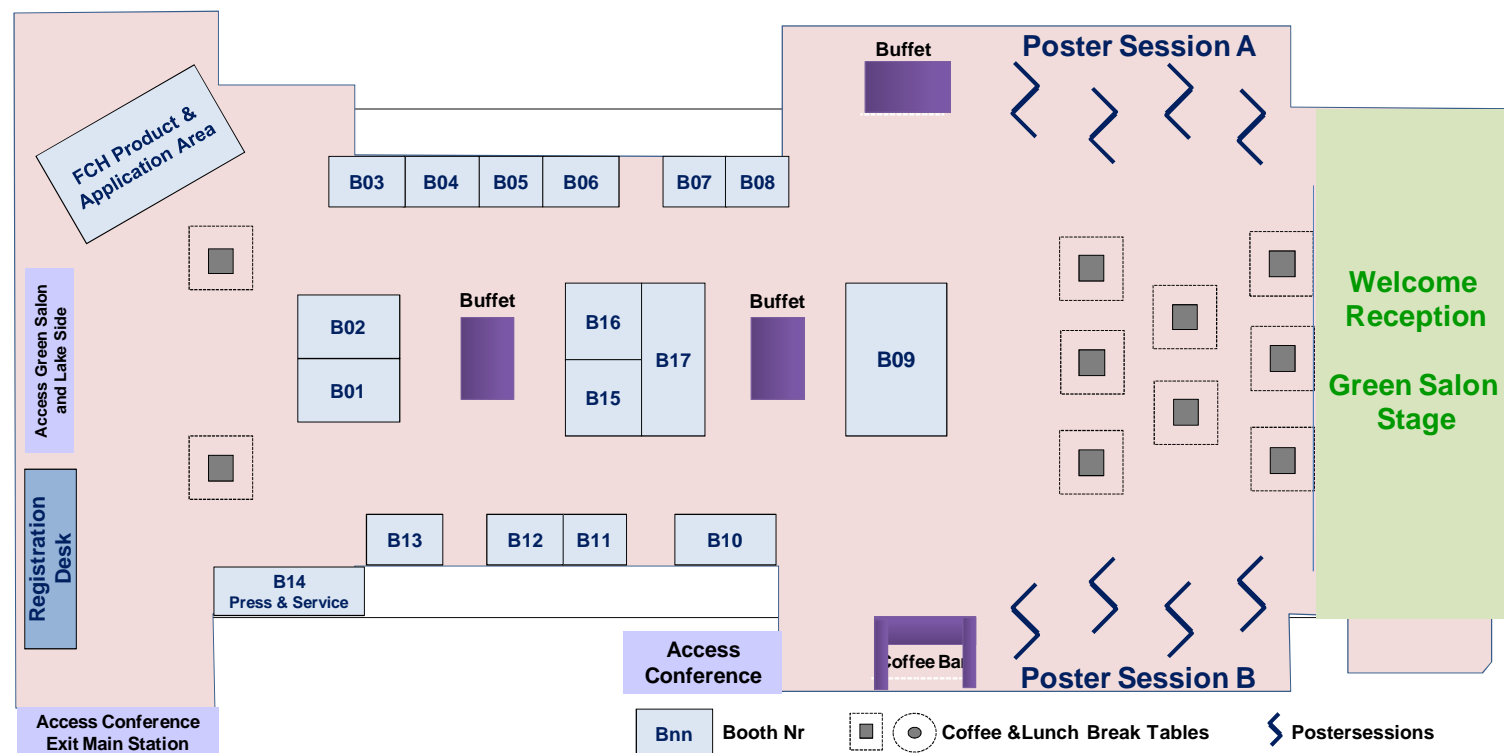
Japan

[www.new-cosmos.co.jp](http://www.new-cosmos.co.jp)

# Floorplan

KKL Luzerner Saal

5<sup>th</sup> EUROPEAN PEFC & H<sub>2</sub> FORUM 2015 30 June - 3 July 2015 KKL Lucerne/Switzerland



# Green Salon Situation Plan

1 - 2 July 2015 KKL Lucerne/Switzerland



## Produkt-Exponate (Europaplatz)

- P01 Windturbine Infotafel (Wepfer Technics)
- P02 H<sub>2</sub> Tankstelle (Pangas/Linde)
- P03 FC PW (Daimler)
- P05 FC PW (Belenos)
- P06 FC PW (Honda - itac)
- P07 FC LKW Infotafel (Proton Motor)
- P08 Self-Wohnzelle (EMPA)
- P09 Gabelstapler (m-Filed)
- P10 Hydroxy Boot (HEIG-VD)
- P21 Solarstromspeicher (Inspire AG)
- P22 a/b Schnellladetankstellen (Inspire AG)
- P23a Batterie-Fahrzeuge (Inspire AG)
- P23b Batterie-Fahrzeuge (Inspire AG)
- P24 Batterie-Bagger (Inspire AG)

## Produkt-Exponate (Luzerner Saal)

- P41 H<sub>2</sub> Reformer (WS Reformer)
- P42 Elektrolyseur Provider (Diamond Lite B08)
- P43 Hochdruckpumpe (Maximator Schweiz B10)
- P44 95kW Autostack (PowerCell, ZSW, Dana)
- P45 FC UEH system (m-Filed)
- P46 FC Power module Coffee Cart (m-Filed)
- P47 HYPER Portable Battery Charger (Orion Innovations, Airbus Group Innovations, Institute of Power Engineering, JRC, McPhy Energy, PaxiTech, Uni Glasgow, B16)
- P48 H<sub>2</sub> Railbar (CeKaTec, S12)
- P49 H<sub>2</sub> Kocher (EMPA)
- P50 H<sub>2</sub> Grill (EMPA)
- P51 Zapfsäulenmodell (Airliquide)
- P52 H<sub>2</sub>-Dispenser (CTS Energy s.r.l.)
- P53 FC-Velo, Leicht H<sub>2</sub> Tank (CTS Energy s.r.l.)



# Outlook 2016

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 5<sup>th</sup> EUROPEAN PEFC AND H<sub>2</sub> FORUM 2015. However, looking a bit beyond these intensive days, we see another important event emerging at a not too far horizon in 2016:

## The 12<sup>th</sup> European SOFC&SOE 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 12<sup>th</sup> EUROPEAN SOFC&SOE FORUM will be THE major event of the year 2016 for SOFC scientists, experts, engineers, and 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. The technical focus lies on specific engineering and design approaches and solutions for materials, processes and components. While SOFC see now the first products entering their first markets, more people become conscious about the much larger potential of ceramic membrane reactors. This evolution from pure fuel cells towards generic ceramic membrane reactors gains in attention. Solid Oxide Electrolysers will therefore have their own dedicated sessions possibly combined with further gas processing applications.

About 500 participants and more than 30 exhibitors (19 already pre-registered) are expected from more about 36 nations. In its traditional manner, the meeting aims at a fruitful dialogue between researchers, engineers and manufacturers, hardware developers and users, academia, industry and utilities. The technology is now translated in first commercial products, while both fundamental and incremental research remains a very important part of the activities. To represent this large scope, the EFCF's International Board of Advisors has **elected**

**Prof. Nigel Brandon** from **Imperial College London**

as **Chairman** of the next conference. He presents both a strong academic background in materials and industrial experience as co-founder and early CEO of Ceres Power. Today, he leads a research group focussed on science, engineering and technology of electrochemical devices for energy applications, with particular focus on SOFC and SOE.

A Scientific Advisory Committee has been formed again 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 12<sup>th</sup> EUROPEAN SOFC&SOE FORUM will take place from 5 to 8 July 2016, in the KKL of Lucerne.

We look forward to welcoming you 2017 again in Switzerland.



The organisers Olivier Bucheli & Michael Spirig

## Outlook 2017

The 6<sup>th</sup> EUROPEAN PEFC&H<sub>2</sub> FORUM will take place **4 – 7 July 2017** in Lucerne, Switzerland again.





## Your event in Lucerne

Imagine holding your business event where people like to come for their holidays. Lucerne, at the heart of Switzerland. With domestic and international connections second-to-none and a professionally run conferencing infrastructure, we aim to see your business event reap the rewards of success.

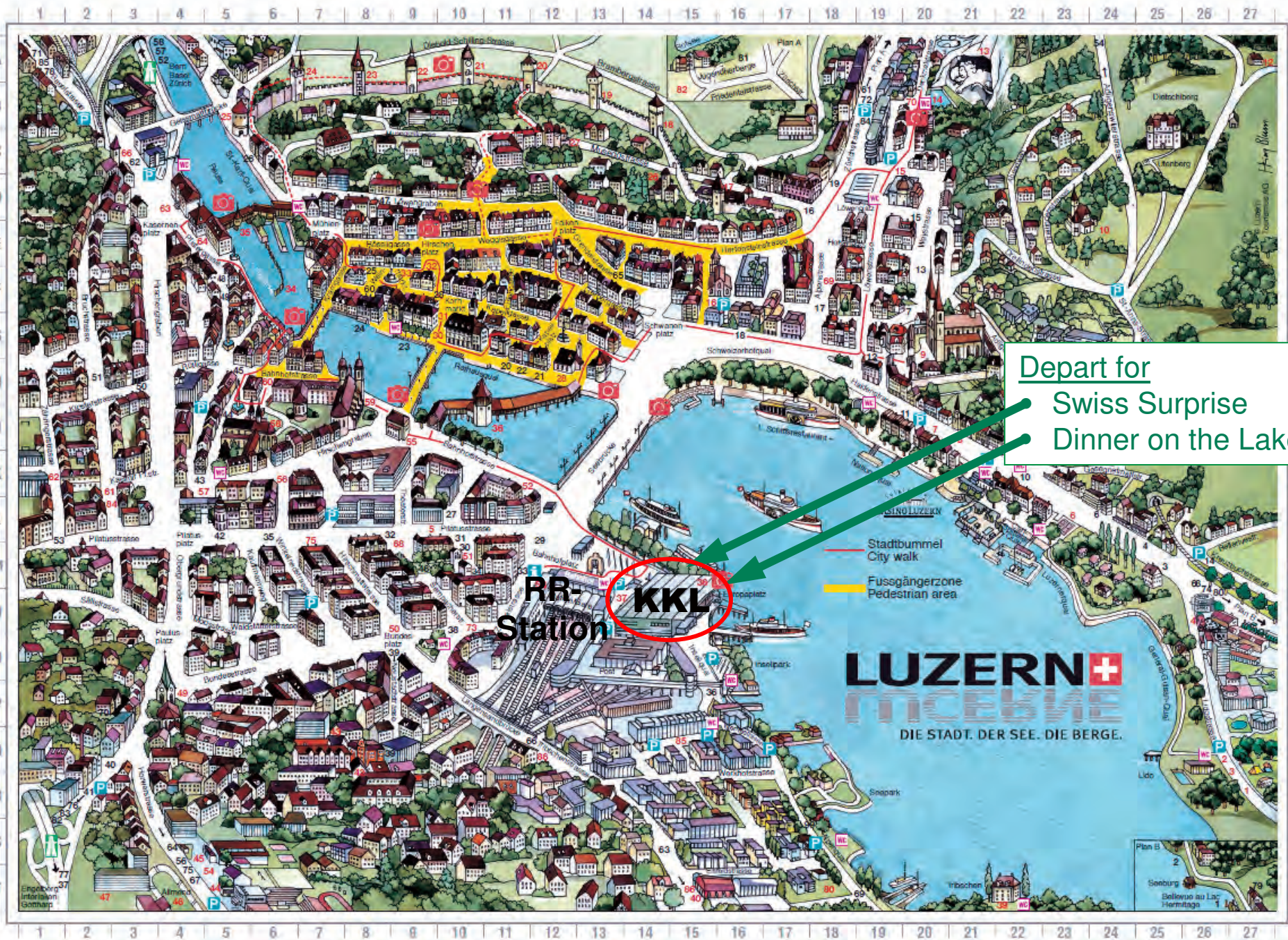
**Lucerne Tourism Ltd.**  
 Lucerne Convention Bureau  
 Bahnhofstrasse 3, CH-6002 Lucerne  
 Phone +41 (0)41 227 17 07  
 Fax +41 (0)41 227 17 18  
[convention-bureau@luzern.com](mailto:convention-bureau@luzern.com)  
[www.luzern.com/business](http://www.luzern.com/business)

**Business Development Lucerne**  
 Alpenquai 30, CH-6005 Lucerne  
 Phone +41 (0)41 367 44 00  
 Fax +41 (0)41 367 44 01  
[info@luzern-business.ch](mailto:info@luzern-business.ch)  
[www.luzern-business.ch](http://www.luzern-business.ch)

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 BUSINESS DEVELOPMENT







International FUEL CELL and HYDROGEN Conference  
with Exhibition and Green Salon including All Hydrogen Fuel Cells like PEFC, HTPEM, AFC, PAFC  
Direct Alcohol Fuel Cells like DMFC & H<sub>2</sub> production, storage, infrastructure

# 5<sup>th</sup> EUROPEAN PEFC AND H<sub>2</sub> FORUM

30 June - 3 July 2015 Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

## Schedule of Events

<b>Tuesday – 30 June 2015</b>	11:00 - 16:00	Exhibition set-up
	09.30 - 10:00	Tutorial Registration (KKL Club Room 3-4)
	10:00 - 17:00	Tutorial held by Dr. Günther Scherer & Dr. Jan Van herle
	16:00 - 18:00	Poster pin-up (continued on following morning)
	16:00	Official opening of the exhibition
	16:00 - 18:00	On-site Registration (continued on following days)
	18:00 - 19:00 from 19:00	Welcome gathering in the KKL Luzerner Saal Thank-You Dinner with special invitation only
<b>Wednesday – 1 July 2015</b>	08:00 - 16:00	On-site Registration is open, to be continued on following days
	08:00 - 09:00	Speakers' Breakfast in the Auditorium Foyer on the 1 <sup>st</sup> floor of the KKL
	09:00 - 18:00	Conference Sessions 1–6 including on “International Overviews and Programmes” from USA, Europe and South Africa as well as on “Automotive FC Development in Asia with Focus China”, poster presentation by authors, networking and exhibition
	09:00 - 18:00	Poster area and exhibition are open
	09:00 - 18:00	“Green Salon”, B2B meeting point and marketplace for a sustainable mobility and energy systems – “Well to Wheel” with focus on FCH technology including complementary technologies
<b>Thursday – 2 July 2015</b>	18:30 - 23:00	Swiss Surprise Evening – separate registration for 80 places to be booked on a first-come-first-served basis
	08:00 - 09:00	Speakers' Breakfast in the Auditorium Foyer on the 1 <sup>st</sup> floor of the KKL
	09:00 - 18:00	Conference Sessions 7–12 including keynotes on “Electrocatalysis of Oxygen Reduction Reaction” as well as on “Status and future of hydrogen technologies (production/purification and storage)”, Poster presentation by authors, network and exhibition
	13:00	Press Conference by invitation only and continued in the following event
	09:00 - 18:00 19:30 - 23:00	“Green Salon”, B2B marketplace, 2 <sup>nd</sup> day, VIP reception and Hydrogen-Party Great Dinner on the Lake
<b>Friday – 3 July 2015</b>	08:00 - 09:00	Speakers' Breakfast in the Auditorium Foyer on the 1 <sup>st</sup> floor of the KKL
	09:00 - 15:30	Conference Sessions 13–17 on catalyst structures, manufacturing, FC modelling, Stack and system integration, operation, H <sub>2</sub> production, Portable/Back-up/Renewable, FC Mobility applications, networking and exhibition
	15:30 - 16:15	Closing and Award Ceremony: Christian Friedrich Schönbein
	16:15 - 17:00	Goodbye coffee and travel refreshment in front of the Auditorium

**Motto 2015: Bringing Hydrogen Fuel Cells & Hydrogen,  
as part of our energy future, closer to deployment.**