Conference Agenda

21st EFCF Conference in Series with Tutorial, Exhibition and Application Market

6th EUROPEAN PEFC & Electrolyser Forum 2017

4 – 7 July 2017

KKL Lucerne / Switzerland

Chaired by
Dr. Isotta Cerri, Toyota Motor Europe
Prof. Dr. Angelika Heinzel, ZBT GmbH, Uni Duisburg-Essen

International FUEL CELL, ELECTROLYSER & HYDROGEN Conference covering: Car OEM status, H_2 Economy + Market Keynotes; All H_2, Direct Alcohol, Microbial FCs; Redox Flow Battery comparison; Alkaline + PEM Electrolysis; PEC; H_2 storage, processing, purification, compression; CO_2 Reduction; Green Salon, Grid Service Markets symposium

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

Name:
Address:
Phone:
E-Mail:

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

International FUEL CELL, ELECTROLYSER & HYDROGEN Conference with Exhibition and Green Salon,
covering: All Hydrogen, Direct Alcohol, Microbial FCs; Redox Flow Battery comparison; Alkaline + PEM Electrolysis;
PEC; H_2 storage, processing, purification, compression; CO_2 Reduction; Green Salon, Grid Service Markets symposium

www.EFCF.com

6th European PEFC & Electrolyser Forum

4 – 7 July 2017 Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

Chaired by

Dr. Isotta Cerri
Toyota Motor Europe

Prof. Dr. Angelika Heinzel
ZBT GmbH, Uni Duisburg-Essen

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
Obgardihalde 2, 6043 Luzern-Adligenswil, Switzerland
Tel. +41 44-586-5644 Fax +41-43-508-0622 forum@efcf.com www.EFCF.com

6th European PEFC & Electrolyser Forum 2017

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SWISS

Official Carrier

This event is endorsed by:

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

Welcome by the Organisers

Olivier Bucheli & Michael Spirig

European Fuel Cell Forum
Obgardihalde 2
6043 LUZERN / Switzerland

Welcome to the 6th European PEFC & Electrolyser Forum 2017. As from the year 2000, this 21st conference in series of conferences in Fuel Cell, Electrolyser 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 Advisors (IBoA), this year's event focuses on low temperature fuel cells and electrolysers, covering polymer and alkaline electrolytes fuelled with hydrogen, alcohol and other fuels, or operated as water electrolysers. The topics range from materials to systems and FC&H applications. A strong presence of car manufacturers provides an industrial perspective for a first mass market, and electrolysis has gained a lot of interest for the production of zero carbon hydrogen from renewables. The 250 participants offer top opportunities for technical exchange and networking, and 3 side events on “Monitoring, Diagnostic and Control for FC”, ”European Grid Service Markets” and “Similarities & Differences of FC vs Redox Flow Batteries” embed the technology in different directions.

In the history of the Forum since 1994, 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. Those range from materials to components and sensors as well as diagnosis tools. They are exhibited in the "Luzerner Saal", where refreshments are served and networking activities take place around the booths of the 18 exhibiting firms.
To increase the political and public awareness for FCH technologies, EFCF also organizes the 4th "Green Salon” on 5&6 July, the future marketplace for Sustainable Energy & Mobility Solutions. About 9 commercial or closed to commercial cars, where presended, where 5 are foreseen for a Drive-In for everybody and other FCH products are present.
We would like to thank the conference chairladies Dr. Isotta Cerri from Toyota Motor Europe and Prof. Dr. Angelika Heinzel from ZBT/Uni Duisburg, the Scientific Organising Committee (SOC) and the Scientific Advisory Committee (SAC) for their excellent work. Based on more than 220 submitted contributions, they have composed a sound scientific program picturing the recent progress – we look forward to seeing this exciting program of the EUROPEAN PEFC & ELECTROLYSER FORUM 2017. We also hope that the charming and inspirational atmosphere of Lucerne allows many strong experts to initiate or confirm partnerships, that result in innovative products and solutions and will add more pieces to 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

...and we are looking very optimistic on the 2018, 2019, 2020 & 2021 EFCF events, where we have already arranged the collaboration with very recognized chairs and chair ladies **www.EFCF.com/20yy**

Conference Schedule & Program see last Page, Booklet, Web Link to Proceedings & www.EFCF.com

FINAL ANNOUNCEMENT

21st EFCF Conference in Series with Tutorial, Exhibition and Application Market

6th EUROPEAN PEFC & Electrolyser Forum

4 – 7 July 2017

KKL Lucerne / Switzerland

Chaired by
Dr. Isotta Cerri, Toyota Motor Europe
Prof. Dr. Angelika Heinzel, ZBT GmbH Uni Duisburg-Essen

4 July 2017
FUEL CELL TUTORIAL
by Dr. Jan Van herle, EPFL
Dr. Günther G. Scherer, formerly PSI

International FUEL CELL, ELECTROLYSER & HYDROGEN event including:
Car OEM status, H_2 Economy + Market Keynotes; All H_2, Direct Alcohol, Microbial FCs;
Redox Flow Battery comparison; Alkaline + PEM Electrolysis; PEC; H_2 storage, processing, purification, compression; CO_2 Reduction; Green Salon, Grid Service Markets symposium

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REGISTER now on www.EFCF.com

Convenient hotel rooms are blocked until 15 May 2017

Next EFCF events:

- **13th European SOFC and SOE Forum** 2018 **3** – 6 July
- **7th European Low -Temperature Fuel Cells/ Electrolysers & H_2 Processing Forum** 2019 2 – 5 July

www.EFCF.com **in Lucerne, Switzerland**

Conference Session Overview

see also: booklet with full program & web link with all conference proceedings

		Auditorium		Convention Foyer	
We 5 July	**A01**	P1: Opening Session: The bridge to the Hydrogen Economy			
	A02	Automotive OEM Status	**B02**	Non-precious metal catalysts	
	A03	**Auditorium Foyer**		Poster Session I covering All Oral Session Topics	
	A04	Bridge to Product: Stack, system & manufacturing	**B04**	Pt-Catalysts and supports	
	A05	Durability, testing and degradation mitigation	**B05**	H_2 from Electrolysers: Concepts & costs	
Th 6 July	**A06**	P2: Keynote: Green Power for Green Hydrogen			
	A07	Analysis & evaluation of system components	**B07**	H_2 Storage: Concepts & systems	
	A08	Membranes & MEAs	**B08**	Modelling & Diagnostics of Pt-Catalysis	
	A09	**Auditorium Foyer**		Poster Session II covering All Oral Session Topics	
	A10	Characterisation of materials & degradation	**B10**	Electrolyser cell & stack performance	
	A11	Transport phenomena limitation	**B11**	Fuel processing, purification & compression	
Fr 7 July	**A12**	Durability, testing & optimisation for operation	**B12**	Electrochemical CO_2-Reduction: Overview & potentials	**C12**
	A13	Diagnostics and Simulations	**B13**	Industrial achievements & inventions	**C13**
	A14	Bridge to Products: From material to cells & stacks	**B14**	Electrolysers & FCs - Implementation & Expectations	**C14**
	A15	P3: Closing Ceremony with Keynote by the Gold Medal of Honour Winner 2017		Legend: Px: = Plenary;	

Special EVENTS Overview

www.EFCF.com/SE

Club Rooms

Th 4 July
1day Workshop

FCH-JU projects DIAMOND & HEALTH-CODE organise

Monitoring, Diagnostics & Control for Fuel Cells

One-Day
Workshop

KKL, Lucerne, Switzerland
July 4, 2017, 9.00-18.00

This workshop will focus on the implementation and use of the technology beyond the project duration. Its objective is to exploit the technology in commercial means after the project ends. The workshop will summarize the progress towards the exploitation by industrial partners and potential customers. In addition, mid-term results achieved by HEALTH-CODE will be shown and discussed as well. The work of more than 30 scientists and engineers from 14 teams will be presented aiming at drafting a coherent scenario for the effective development of monitoring, control and diagnostics methodologies able to improve performance and durability of fuel cells.

Free - Registration required
www.**EFCF**.com/**MDC**
MDC@EFCF.com

Supported by
6th European PEFC & ELECTROLYSER Forum

Th 6 July
Grid Market Symposium

Symposium on

European Grid Service Markets

Grid Flexibility & Business
with new Technologies such as Electrolysers
Control reserves, direct marketing, dynamic load management, virtual power plant, …

July 6, 2017
9.00-18.00 KKL
Lucerne, Switzerland

QualyGridS

The way in which the **electrical energy market** is organized in Europe is changing, opening opportunities for more flexibility in generation and consumption. **New sustainable technologies** for storage and conversion of energy such as water electrolysers, fuel cells, batteries, thermal and compressed air storage systems meet the needs of the **future transmission and distribution grid**.

Registration*
www.**EFCF**.com/**GSM**; GSM@EFCF.com

Organised by QualyGridS &
6th European PEFC & ELECTROLYSER Forum

* 50.- CHF for EFCF participants
Symposium only: 350.- CHF incl. refreshments, business lunch, documents, access to exhibition & poster area

Fr 7 July
Special Sessions

C12 **PEC** Water Splitting, **Microbial** & Direct **Formic Acid** FC

C13

C14

Similarities & Differences

Fuel Cells - Redox Flow Batteries

Keynotes & Expert Discussions in
Special Session

KKL, Lucerne, Switzerland
July 7, 2017, 10.00-16.00

As electrochemical reactors, Redox Flow Batteries (RFB) display certain similarities with low temperature Polymer Electrolyte Fuel Cells (PEFCs), but also differences. The aim of this special session is to outline these similarities and differences. Leading stakeholders will present their most recent progress in RFB-technologies and its scientific aspects. Participants will profit from this high-level exchange and can contribute their experiences in the field and propose expectations for future common R&D in intensive discussions.

Registration*
www.**EFCF**.com/**RFB**; RFB@EFCF.com

* Free for EFCF participants
Special Session only: 250.- CHF incl. refreshments, business lunch, documents, access to exhibition & poster area;

In-Front of KKL/Exhibiton Hall

We 5 July
Th 6 July
Drive-In
FCH-Product Exhibition

Green Salon
Elektromobility
Hydrogen - Fuel Cells - Batteries
Drive-In
Networking
KKL Luzern , 5. + 6. Juli 2017

www.H2-Mobility.ch GreenSalon@H2-Mobility.ch

Chairs' Welcome to the 6th European PEFC & Electrolyser Forum 2017

Dr. Isotta Cerri
Toyota Motor Europe Belgium

Prof. Dr. Angelika Heinzel
ZBT GmbH Uni Duisburg-Essen Germany

Dear Conference Participants,

it is with great pleasure and honour that we welcome you all here in the charming city of Lucerne to the 6th edition of the European PEFC & Electrolyser Forum, the 21st series of the very historical and prestigious European Fuel Cell Forum.

This year the conference will review the main technologies to pave the way for a sustainable and clean hydrogen economy: low temperature fuel cells and electrolysers. Parallel sessions are dedicated to fuel processing and CO_2 electrochemical conversion. The program is very rich and strong, providing the opportunity to connect the end users' vision and strategy to the scientific community's research efforts.

With more than 200 contributions this year's program features the latest research from material development, with focus on Platinum and non precious metal catalysts, to the final stack product, including the design and manufacturing challenges, analysis and evaluation.

Together with the international Scientific Advisory Committee the program has been set up aiming at the high quality and relevance of the various oral and poster contributions, that in the form of extended abstracts will be included in the electronic proceedings. Selected papers have the possibility to be published in a special issue of the international Journal "Fuel Cells – From Fundamentals to Systems".

With the specific technical exhibition, the opportunity to look into the latest products and services from industry, suppliers, test equipment providers and research laboratories will be offered.

In order to increase the public and political awareness the major automotives will attend presenting talks on their development status and exhibiting latest fuel cell vehicles, available for an exciting ride & drive at the "Green Salon".

In the closing and awards ceremony of the 2017 Gold Medal of honour, the audience will be privileged to assist to the key note given by the winner, Prof. Hubert Gasteiger of Technical University of Munich. He will be in 2019 the succeeding chair.

We would like to thank especially the EFCF organizers, Michael Spirig and Oliver Bucheli, with the excellent supporting team, the Scientific program committee, the Session chairs, the invited plenary and keynote speakers.

We invite you to attend this scientific, but also industry-oriented event, which offers plenty of opportunities for extensive discussions, to establish new contacts and to strengthen existing relationships after the oral presentations, during the poster sessions, while visiting the exhibition or at the social events.

We are certain that you will enjoy being in Lucerne for this exciting forum under the motto:

**Fuel Cells & Reversible Technologies:
From Materials & Components to Applications – Practical Inventions & Competitive Solutions.**

Isotta Cerri & Angelika Heinzel

Conference Schedule & Programme

Wednesday, July 5, 2017

Auditorium

09:00	**P1: Opening Session The bridge to the Hydrogen Economy**	**A01**
09:00	**Welcome by the Organizers** Michael Spirig, Olivier Bucheli; European Fuel Cell Forum, Lucerne/Switzerland	A0101
09:05	**Welcome by the Chairladies** Angelika Heinzel (1), Isotta Cerri (2); (1) ZBT GmbH, Duisburg/Germany, (2) Advanced Technology Division, Production Engineering Group, Toyota Motor Europe, Zaventem/Belgium	A0102
09:15	**Welcome to Switzerland** Stefan Oberholzer, Rolf Schmitz, Walter Steinmann; Swiss Federal Office of Energy, Bern/Switzerland	A0103
09:30	**Who is building the bridge to the hydrogen economy - update on industry status challenging next step (EU)** Jorgo Chatzimarkakis; Hydrogen Europe, Brussels/Belgium	A0104
10:00	**Expectations - Evaluation of the FCH Technologies** Olivier Bishop; Shell (Switzerland) AG, Baar/Switzerland	A0105
10:30	**Break - Ground + First Floor in the Exhibition**	

Scientific Advisory Committee (SAC)

- Dr. Naveed Akhtar / Formerly at AFC Energy, UK
- Dr. Antonino Arico / CNR-ITAE
- Dr. Felix Barreras / LITEC CSIC-University of Zaragoza
- Prof. Andrea Casalegno / Politecnico di Milano
- Dr. Sara Cavaliere / Montpellier University
- Dr. Isotta Cerri / Toyota Motor Europe Belgium (Chair)
- Dr. Antonio Chaparro / CIEMAT
- Prof. Christophe Coutanceau / Université de Poitiers
- Prof. Michael Eikerling / Simon Fraser Univ
- Dr. Silvie Escribano / CEA
- Prof. Andreas Friedrich / DLR
- Dr. Graham Hards / Johnson Matthey Fuel Cells
- Prof. Angelika Heinzel / ZBT, Uni Duisburg (Chair)
- Prof. Daniel Hissel / FCLAB Uni de Franche-Comte
- Prof. Jens Oluf Jensen / DTU
- Prof. Joannis Kallitsis / University of Patras
- Dr. Pertti Kauranen / Aalto University
- Prof. D. Kramer / Univ Southampton
- Prof. Ulrike Krewer / TU Braunschweig
- Prof. Werner Lehnert / FZJ
- Prof. Göran Lindbergh / KTH Royal Institute of Technology
- Prof. Karl J. J. Mayrhofer / MPI für Eisenforschung GmbH
- Prof. Mogens Mogensen / TU of Denmark
- Prof. Stephen Paddison / University of Tennessee Knoxville
- Dr. Jürgen Rechberger / AVL List GMBH
- Prof. Thomas Schmidt / PSI Paul Scherrer Institut
- Dr. Tom Smolinka / Fraunhofer ISE
- Dr. Thomas Steenberg / DAPOSY
- Prof. Robert Steinberger-Wilckens / Uni of Birmingham
- Prof. Ifan Stephens / DTU
- Dr. Günther G. Scherer / formerly PSI Paul Scherrer Institute
- Dr. Francesco Triulzi / Solvay Speciality Polymers
- Prof. Hiroyuki Uchida / University of Yamanashi
- Dr. Manfred Waidhas / Siemens AG
- Prof. Zhichuan Jason Xu / Nanyang Technological University
- Prof. Jianbo Zhang / Tsinghua University

Wednesday, July 5, 2017

Auditorium

11:00 **P3: Automotive OEM Status** **A02**

11:00 **Toyota Vehicle Strategy and Development** A0201

Isotta Cerri;

Advanced Technology Division, Production Engineering Group, Toyota Motor Europe, Zaventem/Belgium

FCV Development - Vision and Status A0203

Jörg Wind;

11:30 Daimler AG, Kirchheim unter Teck/Germany

New fuel cell stack and development method for the Fuel Cell System of the Honda CLARITY FUEL CELL and Honda's activity towards the Hydrogen Society A0204

11:45 Takeshi Moriya (1), Nobuhiro Saito (1), Kenji Nagumo (1), Masakuni Yamamoto (1), Atsushi Hiraide (1), Masashi Sugishita (1), Hiroto Chiba (1), Thomas Brachmann (2);

Convention Foyer

Non-precious metal catalysts **B02**

Oxygen Electrocatalysis on Transition Metal Spinel Oxides B0201

Zhichuan (Jason) Xu (1,2,3);

(1) School of Materials Science and Engineering, Nanyang Technological University, , (2) Solar Fuels Laboratory, Nanyang Technological University, , (3) Energy Research Institute@NTU, ERI@N, Interdisciplinary Graduate School, Nanyang Technological University, Singapore/Singapore

Composition-Stability Relations for Non-Noble Metal Catalysts for Polymer Electrolyte Fuel Cell Cathodes B0202*

Juan Herranz (1), Thomas J. Schmidt (1,2);

(1) Electrochemistry Laboratory, Paul Scherrer Institut, Villigen PSI/Switzerland, (2) Laboratory of Physical Chemistry, ETH Zürich, Zurich/Switzerland

Insights into Perovskite Nano-Catalysts as Oxygen Electrodes for the Electrochemical Splitting of Water B0203

Emiliana Fabbri, Maarten Nachtegaal, Xi Cheng, Tobias Binninger, Thomas J. Schmidt;

Energy & Environment Division, Paul Scherrer Institut, Villigen/Switzerland

Polymer derived Fe-N/C Electrocatalysts for the Oxygen Reduction Reaction B0204

	(1) Honda R&D Co., Ltd. Automobile R&D Center, Haga-gun/Tochigi/Japan, (2) Honda R&D Europe (Deutschland) GmbH, Offenabach/Germany		Julia Melke(1,2), Patrick Elsässer (1), Felix Gerke (3), Laura Carolina Pardo(3), Anna Fischer (1,2); (1) Institute of Inorganic and Analytical Chemistry, University Freiburg, Freiburg/Germany, (2) FMF – Freiburg Materials Research Center, University Freiburg,, Freiburg/Germany, (3) Department of Chemistry, Technical University Berlin, Berlin/Germany	
12:00	**Engineering and validation of a cryo-compressed hydrogen storage system to maximize driving range in automotive zero emissions driving applications.**	A0205	**Graphene Hybrid Electrodes for PEM Fuel Cells**	B0205
	Christophe Schwartz; BMW Group, Powertrain, Hydrogen, Alternative Fuel Tanks, Munich/Germany		Lale Işıkel Şanlı (1), Sajjad Ghobadi (2), Melis Yetkin (2), Selmiye Alkan Gürsel (1,2); (1) Sabanci University, Nanotechnology Research and Application Center, Istanbul/Turkey, (2) Faculty of Engineering and Natural Sciences, Istanbul/Turkey	
12:15	**Audi h-tron Strategy**	A0206	**Graphene and Graphene Oxide in low temperature fuel cells for enhanced performance**	B0206
	Petra Hackenberg-Wiedl, Jürgen Jablonski ; Audi AG, Ingolstadt/Germany		Sirhan Al Batty, Baki Ozdincer, Maria Perez Page, Remy Sellin, Stuart Holmes; School of Chemical Engineering and Analytical Science, The University of Manchester, Manchester/United Kingdom	
12:30	**Lunch - 2nd Floor on the Terrace** **Coffee - Ground + First Floor in the Exhibition** **& in the Poster Session**			

Wednesday, July 5, 2017

Auditorium Foyer

13:15	**Poster Session I (covering All Oral Session Topics)**	**A03**

Wednesday, July 5, 2017

	Auditorium		Convention Foyer	
14:30	**Bridge to Product: Stack, system & manufacturing**	**A04**	**Pt-Catalysts and supports**	**B04**
14:30	**Mission accomplished – Auto-Stack Core delivers top of class FC technology** André Martin (1), Ludwig Jörissen (2); (1) André Martin Consulting, Idstein/Germany, (2) Centre for Solar and Hydrogen Research (ZSW), Ulm/Germany	A0401	**Oxygen Reduction Activity and Durability of Nanoparticulate Pt Supported on Boron Carbide** Colleen Jackson (1), Graham T. Smith (1,3), David Inwood (2), Andrew S. Leach (2), Penny S. Whalley (2), Andrea E. Russell (2), Pieter B.J. Levecque (1), Denis Kramer (3); (1) University of Cape Town , HySA/Catalysis Centre of Competence, Cape Town/South Africa, (2) University of Southampton, School of Chemistry, Southampton/UK, (3) University of Southampton, Engineering Sciences, Southampton/UK	B0401
14:45	**Cathode Exhaust Gas Recirculation For Polymer Electrolyte Fuel Cell Stack** Florian Becker (1), Florian Pillath (1), Josef Kallo (2); (1) German Aerospace Center (DLR) Institute of Engineering Thermodynamics, Hamburg/Germany, (2) German Aerospace Center (DLR) Institute of Engineering Thermodynamics, Stuttgart/Germany	A0402*	**Fabrication and characterization of electrospun nanofiber electrodes for PEFCs** Dechun Si (1), Shangshang Wang (1), Jun Huang (1), Cheng Wang (2), Jianbo Zhang (1,3); (1) Department of Automotive Engineering, State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing/China, (2) Institute of Nuclear and New Energy Technology, Tsinghua University, Beijing/China, (3) Beijing Co-Innovation Center for Electric Vehicles, Beijing Institute of Technology, Beijing/China	B0402
15:00	**Dry start-up performance of PEM fuel cell for pressurized operation** Young Sang Kim (1), Im Mo Kong (2), Min Soo Kim (3);	A0403	**Oxide-supported PEFC Electrocatalysts** Kazunari Sasaki (1-4), Masahiro Iwami (2), Makito Okumura (2), Yoshiki Nakazato (2), Shohei Matsumoto (2), Zhiyun Noda (3), Junko Matsuda (4), Akari Hayashi (1,2,3);	B0403

	(1) Department of Eco-Machinery System, Korea Institute of Machinery & Materials, Daejon/Korea, (2) Korea Automotive Technology Institute, Gwangju/Korea, (3) Department of Mechanical and Aerospace Engineering, Seoul National University, Seoul/Korea		Kyushu University, (1) Next-Generation Fuel Cell Research Center (NEXT-FC), , (2) Department of Hydrogen Energy Systems, , (3) International Research Center for Hydrogen Energy, , (4) International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Fukuoka/Japan	
15:15	**Process Innovation in Electrochemical Power Generation Devices**	A0404*	**Investigation of Carbon Nanofiber (CNF) Supported Platinum Electrocatalysts for the Use in PEM Fuel Cells**	B0404
	Takuya Hasegawa;		Pit Podleschny (1,3), Ulrich Rost (1), Roxana Muntean (1), Gabriela Marginean (1), Michael Brodmann (1), Ivan Radev (2), Volker Peinecke (2), Angelika Heinzel (2);	
	Nissan Motor Co., Ltd., Yokohama/Japan		(1) Westfälische Hochschule University of Applied Sciences, Gelsenkirchen/Germany, (2) The Fuel Cell Research Center ZBT, Duisburg/Germany	
15:30	**Challenges and solutions in the R2R manufacturing of fuel cell membranes**	A0405	**Carbon support modification for high performance low Pt loaded cathodes**	B0405
	Thomas Kolbusch, Martin Busch, Klaus Crone, Nico Meyer;		Gregor Harzer (1), Alin Orfanidi (1), Pankaj Madkikar (1), Hany Elsayed (1), Tim Kratky (2), Hubert Gasteiger (1);	
	Coatema Coating Machinery GmbH, Dormagen/Germany		(1) Technical Electrochemistry, Department of Chemistry and Catalysis Research Center, Technical University of Munich, Garching/Germany, (2) Department of Chemistry and Catalysis Research Center, Technical University of Munich, Garching/Germany	
15:45	**Experimental plant balancing and cell voltage analysis of a high temperature proton exchange membrane fuel cell stack with natural gas fuel processor**	A0406	**Recent Developments of Electrocatalysts and Membrane Electrode Assembly in DICP**	B0406
	Elmar Pohl (1), Frank Beckmann (2), Carlo Tregambe (3);		Zhigang Shao;	
	(1) OWI – Oel-Waerme-Institut GmbH, Herzogenrath/Germany, (2) inhouse engineering GmbH, Berlin/Germany, (3) ICI Caldaie S.p.A., Frazione Campagnola di Zevio (Verona)/Italy		Fuel Cell System and Engineering Laboratory, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Liaoning/China	
16:00	**Break - Ground + First Floor in the Exhibition**			

Wednesday, July 5, 2017

	Auditorium		Convention Foyer	
16:30	**Durability, testing and degradation mitigation**	**A05**	**H2 from Electrolysers: Concepts & costs**	**B05**
16:30	**Effects, damage characteristics and regeneration potential of traffic-induced nitric oxide emissions in PEM fuel cells under variable operating conditions** Ulrich Misz (1), Anja Talke (2), Angelika Heinzel (1), Peter Beckhaus (1); (1) ZBT GmbH, Duisburg/Germany, (2) Daimler AG, Kirchheim/Teck-Nabern	A0501	**Performance enhancing study for Large scale PEM electrolyzer cells based on hydraulic compression** Florian Wirkert, Ulrich Rost, Jeffrey Roth, Michael Brodmann; Westfälische Hochschule University of Applied Sciences, Gelsenkirchen/Germany	B0501*
16:45	**A new approach to mitigation of membrane degradation caused by mechanical and chemical stressors** Marta Zatoń (1), Nicolas Donzel (1), Luca Pasquini (1), Sara Cavaliere (1), Jacques Rozière (1), Deborah Jones (1), Luca Merlo (2), Silvain Buche (3), Graham Hards (3); (1) ICGM Aggregates Interfaces and Materials for Energy, Montpellier/France, (2) Solvay Specialty Polymers, Bollate/Italy, (3) Johnson Matthey Fuel Cells, Reading/UK	A0502	**Hydrogenics' MegaWatt PEM platform, operational monitoring data from prototype and 1.2MW units** D. Van Dingenen, P. Fawcus, J. Vaes; Hydrogenics Europe NV , Oevel/Belgium	B0502
17:00	**Impact of the operation modes on the reversible and non-reversible degradation mechanisms of a PEMFC** Sylvie Escribano, Fabrice Micoud, Anais Finkler, Hortense Laforêt, Laure Guétaz, Marion Chanderis; CEA/LITEN, DEHT, Grenoble Cedex	A0503	**PEM Electrolyser-project Arzberg (Germany) and modular LOHC-Energy storage system** Carsten Krause; AREVA H2Gen GmbH, Köln/Germany	B0503*
17:15	**EU Harmonised Test Protocols for Automotive Applications** Georgios Tsotridis; European Commission Joint Research Centre, Petten/The Netherlands	A0504	**PEM water electrolysis: impact of cell design and porous components properties on mass transport limitation** F. Fouda-Onana (1), S. Chelghoum (1), G. Serre (1), K.Bromberger (2), T.Smolinka, M.Chandesris (1); (1) Univ.Grenoble CEA, LITEN, Grenoble/France, (2) Fraunhofer Institute for Solar Energy Systems, Freiburg/Germany	B0504

17:30	**CO2 Enrichment In Anode Loop And Correlation with CO Poisoning Of Low Pt Anodes In PEM Fuel Cells**	A0505	**Achieving Cost Reduction in PEM Electrolysis by Material Development**	B0505
	Simon Erbach (1), Martin Heinen (1), Gabor Toth (1), Merle Klages (2), Donat Gaudreau (3), Michael Ages (3), Andreas Putz (3), Sebastian Epple (4);		K. Andreas Friedrich, Philipp Lettenmeier, Asif S. Ansar, Li Wang, Aldo S. Gago;	
	(1) Daimler AG, Kirchheim unter Teck/Germany, (2) NuCellSys GmbH, Kirchheim unter Teck/Germany, (3) AFCC Automotive Fuel Cell Cooperation Corp., CA-Burnaby/Canada, (4) MS2 Engineering und Anlagenbau GmbH , Kirchheim unter Teck/Germany		German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Stuttgart/Germany	
17:45	**Durability studies in a unitized regenerative fuel cell**	A0506	**Cost Break Down and Cost Reduction Strategies for PEM Water Electrolysis Systems**	B0506
	Amit C. Bhosale, Reeshab Goenka, Prakash C. Ghosh;		Tom Smolinka (1), Nikolai Wiebe (1), Magnus Thomassen (2);	
	Department of Energy Science and Engineering, IIT Bombay, Powai Mumbai/India		(1) Fraunhofer Institute for Solar Energy Systems ISE, Freiburg/Germany, (2) SINTEF - Materials and Chemistry, Trondheim/Norway	
18:00	**End of Sessions**			

18:30	**Swiss Surprise** **Registered participants meet between KKL and railway station**	

Scientific Organising Committee (SOC)

- Dr. George Bandlamudi / ZBT
- Dr. Isotta Cerri / Toyota Motor Europe Belgium (Chair)
- Dr. Stephane Cotte / Toyota Motor Europe
- Prof. Angelika Heinzel / ZBT, Uni Duisburg (Chair)
- Dr. Jörg Karstedt / ZBT
- Dr. Falko Mahlendorf / Lehrstuhl Energietechnik
- Dr. Jürgen Roes / Lehrstuhl Energietechnik
- Dr. Genis Turon / Toyota Motor Europe
- Dr. Francesco Valle / Toyota Motor Europe

Morning Morning

Thursday, July 6, 2017

	Auditorium		Convention Foyer	
09:00	**P4: Keynote: Green Power for Green Hydrogen**	**A06**		
09:00	**Wind - Electrolysers - Hydrogen - Fuel Cells - Market partnership with prospects** Giles Dickson; WindEurope asbl/vzw, Brussels/Belgium	A0601*		
09:25	**5 Min to change to Auditorium for B08 Session**			

Morning Morning

Thursday, July 6, 2017

	Auditorium		Convention Foyer	
09:30	**Analysis & evaluation of system components**	**A07**	**H2 Storage: Concepts & systems**	**B07**
09:30	**Novel concept for evaporative cooling of fuel cells: an experimental study based on neutron imaging** M. Cochet, A. Forner-Cuenca, V. Manzi, M. Siegwarts, D. Scheuble, P. Boillat; Paul Scherrer Institut, Villigen/Switzerland	A0701	**Towards a hydrogen-free hydrogen economy – Catalytic challenges in the hydrogenation and dehydrogenation of Liquid Organic Energy Carrier Systems** Peter Wasserscheid (1,2), Andreas Bösmann (1), Patrick Preuster (1); (1) Lehrstuhl für Chemische Reaktionstechnik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen/Germany, (2) Forschungszentrum Jülich, „Helmholtz-Institut Erlangen-Nürnberg“ (IEK-11), Erlangen/Germany	B0701
09:45	**Analysis of water distribution and evaporation rate in gas diffusion layers**	A0702	**Magnesium Oxide an Effective Non-Transition Metal Oxide Catalyst For Hydrogen Storage Improvement of Magnesium Hydrides**	B0702

	Sreeyuth Lal, Adrien Lamibrac, Jens Eller, Felix N. Büchi; Electrochemistry Laboratory, Paul Scherrer Institut, Villigen PSI/Switzerland		Mahmoud Reda; Canadelectrochim, Calgary Alberta/Canada	
10:00	**PEFC Catalyst Layer Modeling in CFD Simulations: From Interface to Agglomerate Models**	A0703	**Hydrogen storage by physisorption in nanostructured graphene-based materials: simulations and experiments**	B0703
	Clemens Fink (1), Nejc Kosir (2), Reinhard Tatschl (1); (1) AVL List GmbH, Graz/Austria, (2) AVL-AST d.o.o., Maribor/Slovenia		Igor A. Baburin, Gotthard Seifert; Technische Universität Dresden, Theoretische Chemie, Dresden/Germany	
10:15	**Tailoring electrosprayed carbon layers**	A0704	**Hydrogen Blending into the Gas Distribution Grid: The Case Study of a Small Municipality**	B0704
	J. J. Conde, C. A. Maffiotte, M. J. Benito, M. A. Folgado, A. M. Chaparro, P. Ferreira-Aparicio; Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, CIEMAT, Madrid/Spain		Marco Cavana, Andrea Lanzini, Pierluigi Leone; Energy Department , Politecnico di Torino, Torino/Italy	
10:30	**Break - Ground + First Floor in the Exhibition**			

International Board of Advisors (IBoA)

- Prof. Joongmyeon Bae, KAIST, Daejeon, Korea
- Prof. Frano Barbir, University of Split, Croatia
- Dr. Ulf Bossel, ALMUS AG, Switzerland
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- Dr. Jari Kiviaho, VTT, Finland
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- Dr. Florence Lefebrve-Joud, CEA, France
- Prof. Paulo Emilio V. de Miranda, Coppe, Brazil
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- Prof. Vladislav A. Sadykov, Boreskov Institute of Catalysis, Russia
- Prof. Massimo Santarelli, Politecnico di Torino, Italy
- Prof. Kazunari Sasaki, Kyushu University, Japan
- Dr. Günther G. Scherer, ex PSI, Villigen, Switzerland, Singapore,
- Dr. Günter Schiller, DLR Stuttgart, Germany
- Dr. Subhash Singhal, Pacific Northwest National Laboratory, USA
- 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

Thursday, July 6, 2017

	Auditorium		Convention Foyer	
11:00	**Membranes & MEAs**	**A08**	**Modelling & Diagnostics of Pt-Catalysis**	**B08**
11:00	**PBI Membranes for Fuel Cells and Electrolyzers** Brian C. Benicewicz; University of South Carolina, Columbia/USA	A0801	**Water Phenomena in PEFC Catalyst Layers as the Origin of the Pt Loading Effect: A Modelling Study** Tasleem Muzaffar, Michael H. Eikerling; Simon Fraser University, Department of Chemistry, Burnaby/BC/Canada	B0801
11:15	**Understanding the degradation of High-Temperature PEM Fuel Cells** Elisabeth Therese Ulrikkeholm, Hector Rodrigo García, Hans Aage Hjuler*, Thomas Steenberg; Danish Power Systems, Egeskovvej/Kvistgaard	A0802	**Dynamic Modelling of Surface Oxide Growth and Reduction at Platinum** Heather Baroody (1), Gregory Jerkiewicz (2), Michael H. Eikerling (1); (1) Simon Fraser University, Department of Chemistry, Burnaby/BC/Canada, (2) Queens University, Department of Chemistry, Kingston/ON/Canada	B0802
11:30	**A comparison of HT-PEM MEA performance within the German project QUALIFIX** Julian Büsselmann, Vietja Tullius, Wiebke Germer, Peter Wagner, Alexander Dyck; NEXT ENERGY · EWE Research Centre for Energy Technology at the University of Oldenburg, Oldenburg/Germany	A0803	**Two-Dimensional, Non-Isothermal Simulation Model of an Alkaline Fuel Cell (AFC): Effect of Temperature on the Polarization Curve** Felix A. E. Kunz (1), Angelika Heinzel (1), (2), Jürgen Roes (1); (1) Department of Energy Technology, University of Duisburg-Essen, Duisburg/Germany, (2) Zentrum für Brennstoffzellen Technik (ZBT), Duisburg/Germany	B0803
11:45	**Proton Conducting Ionic Liquids as Non-Aqueous Electrolytes in HT-PEFCs – Interaction with PBI-type Polymers and ORR Kinetics** C. Korte, K. Wippermann, J. Wackerl, S. Kuhri, W. Lehnert;	A0804	**Molecular Simulations of Oxygen Scattering and Surface Diffusion on Ionomer Surface** Masataka Nakauchi (1), Takuya Mabuchi (2), Takuma Hori (3), Yuta Yoshimoto (3), Ikuya Kinefuchi (3), Hideki Takeuchi (4), Takashi Tokumasu (2);	B0804

	Institute of Energy and Climate Research, IEK-3: Electrochemical Process Engineering, Forschungszentrum Jülich GmbH, Jülich/Germany		(1) Graduate School of Engineering, Tohoku University, , (2) Institute of Fluid Science, Tohoku University, Miyagi/Japan, (3) Department of Mechanical Engineering, The University of Tokyo, Tokyo/Japan, (4) Department of Social Design Engineering, National Institute of Technology, Kochi College, Nankoku Kochi/Japan	
12:00	**Stable Aquivion® based MEAs: investigation on catalyst and ionomer**	A0805	**Physical Modeling of the Proton Density in Catalyst Layer Nanopores of PEM Fuel Cells**	B0805*
	Irene Gatto (1), A. Carbone (1), A. Saccà (1), A.S. Aricò (1), V. Baglio (1), C. Oldani (2), L. Merlo (2); (1) Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano", Messina/Italy, (2) Solvay Specialty Polymers, Bollate/Italy		Tasleem Muzaffar, Michael H. Eikerling; Simon Fraser University, Department of Chemistry, Burnaby/BC/Canada	
12:15	**Poly(arylene ether sulfone) containing spirobiindane moieties for electrode binder in solid alkaline exchange membrane fuel cells**	A0806	**Pt-Ni Aerogels as Cathode Catalysts in Polymer Electrolyte Fuel Cells**	B0806
	Jieun Choi (1,2), So Young Lee (1), Sung Jong Yoo (1), Jong Hyun Jang (1), Yung-Eun Sung (2)*, Hyoung-Juhn Kim (1)**; (1) Fuel Cell Research Center, Korea Institute of Science and Technology (KIST), Seoul/Republic of Korea, (2) School of Chemical Biological Engineering, Seoul National University, Seoul/Republic of Korea		Sebastian Henning (1), Hiroshi Ishikawa (2), Laura Kühn (3), Juan Herranz (1), Alexander Eychmüller (3), Thomas Schmidt (1,4); (1) Electrochemistry Laboratory, Paul Scherrer Institut, Villigen/Switzerland, (2) Fuel Cell Nanomaterials Center, University of Yamanashi, Kofu/Japan, (3) Physical Chemistry, Technische Universität Dresden, Dresden/Germany, (4) Laboratory of Physical Chemistry, ETH Zurich, Zürich/Switzerland	
12:30	**Lunch - 2nd Floor on the Terrace** **Coffee - Ground + First Floor in the Exhibition** **& in the Poster Session**			

Thursday, July 6, 2017

Auditorium Foyer

13:15	**Poster Session I (covering All Oral Session Topics)**	**A09**

Thursday, July 6, 2017

	Auditorium		Convention Foyer	
14:30	**Characterisation of materials & degradation**	**A10**	**Electrolyser cell & stack performance**	**B10**
14:30	**A Systematic Approach for Fuel Cell Characterization** Yasser Rahim, Holger Janßen, Werner Lehnert; Institute of Energy and Climate Research (IEK-3),, Jülich/Germany	A1001	**Structural Characterization of Porous transport layers for polymer electrolyte water electrolysis cells** Tobias Schuler (1), Thomas J. Schmidt (1,2), Felix N. Büchi (1); (1) Electrochemistry Laboratory, Paul Scherrer Institut, Villigen-PSI/Switzerland, (2) Laboratory of Physical Chemistry, ETH Zürich, Zurich/Switzerland	B1001
14:45	**Challenges and Possibilities of EIS on PEMEC** Katrine Elsøe (1), Mikkel Rykær Kraglund (2), Johan Hjelm (1), Torben Jacobsen (3), Laila Grahl-Madsen (4), Mogens Bjerg Mogensen (1); (1) Department of Energy Conversion and Storage, Technical University of Denmark, DTU, Roskilde/Denmark, (2) Department of Energy Conversion and Storage, Technical University of Denmark, Kgs. Lyngby/Denmark, (3) Department of Chemistry, Technical University of Denmark, Kgs. Lyngby/Denmark, (4) EWII Fuel Cells A/S, Odense SØ/Denmark	A1002	**Enhanced performance and durability of low catalyst loading PEM water electrolyser based on a short-side chain perfluorosulfonic ionomer** Antonino Salvatore Aricò (1), Stefania Siracusano (1), Vincenzo Baglio (1), Nicholas Van Dijk (2), Luca Merlo (3); (1) CNR-ITAE, Messina/Italy, (2) ITM Power (Research) Ltd, Unit H, Sheffield/UK, (3) Solvay Specialty Polymers Italy SpA, Bollate/Italy	B1002
15:00	**Multilayer Coating for Aluminium Plates in Polymer Electrolyte Fuel Cells** Verena Lukassek, Thomas-Maik John (2), Jens Wartmann, Georg Dura, Angelika Heinzel; Zentrum für BrennstoffzelllenTechnik , Duisburg/Germany	A1003	**Developments for Alkaline Electrolysis: From materials to laboratory electrolysers** Wenbo Ju (1), Lorenzo Pusterla (1), Meike V. F. Heinz (1), Dariusz Burnat (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, Freiburg/Germany	B1003*

15:15	**Performance analysis of lab-scale Polymer Electrolyte Fuel Cells at various operation parameters** Marcel Heinzmann (1), Jan Haußmann (2), André Weber (1), Ellen Ivers-Tiffée (1); (1) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany, (2) Schaeffler Technologies AG & Co. KG, SHARE am KIT, Karlsruhe/Germany	A1004	**Investigation on porous transport layers for PEM electrolysers** Arne Fallisch, Jagdishkumar Ghinaiya, Kolja Bromberger, Maximillian Kiermaier, Thomas Lickert, Tom Smolinka; Fraunhofer Institute for Solar Energy System ISE, Freiburg/Germany	B1004
15:30	**Electron Paramagnetic Resonance Spectroscopy Studies of Transition Metal Ion-Chelating Ordered Mesoporous Carbons for Oxygen Reduction Catalysis** Caroline Janson, Anders Palmqvist; Chalmers University of Technology, Department of Chemistry and Chemical Engineering, Göteborg/Sweden	A1005	**Towards understanding of component aging in dynamically operated polymer electrolyte water electrolyzers** Ugljesa Babic (1), Thomas J. Schmidt (1,2), Lorenz Gubler (1); (1) Paul Scherrer Institut , Villigen PSI/Switzerland, (2) Laboratory of Physical Chemistry, ETH Zürich, Zürich/Switzerland	B1005
15:45	**Effect of Platinum Oxides on Reversible and Irreversible Degradation in Polymer Electrolyte Fuel Cells** Andrea Baricci (1), Matteo Zago (1), Thomas Jahnke (2), Andrea Casalegno (1); (1) Politecnico di Milano, Dipartimento di Energia, Milano/Italy, (2) German Aerospace Center (DLR), Stuttgart/Germany	A1006	**Towards selective test protocols for accelerated in situ degradation of PEM electrolysis components** Thomas Lickert; Fraunhofer Institute for Solar Energy System ISE, Freiburg/Germany	B1006
16:00	**Break - Ground + First Floor in the Exhibition**			

Thursday, July 6, 2017

	Auditorium		Convention Foyer	
16:30	**Transport phenomena limitation**	**A11**	**Fuel processing, purification & compression**	**B11**
16:30	**Understanding performance limitations in anion-exchange membrane fuel cells**	A1101	**Biorobur Plus: Advanced direct biogas fuel processor for robust and decentralized hydrogen production**	B1101
	Göran Lindbergh, Annika Carlson, Björn Eriksson, Henrik Grimler, Carina Lagergren, Rakel Wreland Lindström;		Samir Bensaid, Debora Fino;	
	Applied Electrochemistry, School of Chemical Science and Engineering, KTH Royal Institute of Technology, Stockholm/Sweden		Politecnico di Torino, Torino/Italy	
16:45	**Gas transport in PEFC gas diffusion layers and its analysis for upscaling**	A1102	**Demonstration of a Methanol Fuel Processor System for the Production of Pure Hydrogen**	B1102
	Dieter Froning (1), Junliang Yu (1), Uwe Reimer (1), Ingo Manke (2), Werner Lehnert (1,3);		Ulrich Gardemann (1), Tobias Meijer (1), Michael Steffen (1), Tihamer Hargitai (2), Fredrik Silversand (2);	
	(1) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research, IEK-3: Energy Process Engineering, Jülich/Germany, (2) Helmholtz-Zentrum Berlin GmbH, Institute of Applied Materials, Berlin/Germany, (3) Modeling in Electrochemical Process Engineering, RWTH Aachen University, Aachen/Germany		(1) ZBT GmbH, Duisburg/Germany, (2) Catator AB, Lund/Sweden	
17:00	**Single cell study of water transport in PEMFCs with electrosprayed catalyst layers**	A1103	**Electrochemical Hydrogen Separation using HT-PEMFC**	B1103
	M.A. Folgado, J.J. Conde, P. Ferreira-Aparicio, A.M. Chaparro;		George Bandlamudi, Michael Steffen, Angelika Heinzel;	
	Dep. of Energy, CIEMAT, Madrid/Spain		Zentrum für Brennstoffzellen Technik - ZBT, Duisburg/Germany	
17:15	**Evidence of large heterogeneity in water distribution at the sub millimeter scale during PEMFC operation thanks to Neutron Scattering**	A1104	**Hydrogen production by reforming for industrial and transport applications**	B1104
	A. Morin, N. Martinez, S. Lyonnard, G. Gebel;		Isabel Frenzel (1), Florian Rau (1), Andreas Herrmann (1), Dimosthenis Trimis (2), Hartmut Krause (1);	

	CEA/Université Grenoble Alpes, Grenoble/France		(1) TU Bergakademie Freiberg, Institute of Thermal Engineering, Freiberg/Germany, (2) Karlsruhe Institute of Technology, Engler-Bunte-Institute, Karlsruhe/Germany	
17:30	**Impact of Microporous Layer Structural Properties on Oxygen Transport in PEM Fuel Cells** Christoph Simon, Dena Kartouzian, Joseph Endres, Benjamin Nefzger-Loders, Hubert A. Gasteiger; Technical Electrochemistry, Technical University of Munich, Garching/Germany	A1105	**Reliability of Reformer Gas-Facing Material for Safe Hydrogen Production Service** Seung-Wook Baek (1), Yun-Hee Lee (1), Jung Hyun Kim*(2), Bo Sik Kang (3), Eun Ju Song (1), Un Bong Baek (1) ; (1) Korea Research Institute of Standards and Science (KRISS), Daejeon/Republic of Korea, (2) Hanbat National University, Daejeon/Republic of Korea, (3) Korea Insitute of Machinery & Materials (KIMM), Daejeon/Republic of Korea	B1105
17:45	**Porous binder: Contribution to gas transport in fuel cell gas diffusion layers** Adrien Lamibrac, Jens Eller, Felix N. Büchi; Electrochemistry Laboratory, Paul Scherrer Institut, Villigen PSI/Switzerland	A1106	**Techno-economic Analysis of State-of-the-Art Electrochemical Hydrogen Compressors (EHCs)** Whitney G. Colella (1), Monjid Hamdan (2); (1) Gaia Energy Research Institute, Arlington/VA/USA, (2) Giner Inc., Newton/MA/USA	B1106
18:00	**End of Sessions**			

19:30	**Dinner on the Lake** **Boarding 19.20 - Lake side of KKL pier 5/6 - back 23.15** **(short stop in Brunnen 22.30 for early return by train)**	

Friday, July 7, 2017

Auditorium

09:00 Durability, testing & optimisation for operation A12

09:00 **Physical modelling and analyses of catalyst degradation in PEM fuel cells** A1201*

Heather Baroody (1,2), Drew Stolar (2), Thomas Kadyk (3), Michael H. Eikerling (1);

(1) Simon Fraser University, Department of Chemistry, Burnaby/BC/Canada, (2) Ballard Power Systems, Burnaby/BC/Canada, (3) Institute for Energy and Process Engineering, Braunschweig University of Technology, Braunschweig/Germany

09:15 **The Importance of Failure: Understanding degradation mechanisms in PEM electrolysers** A1202

Nicholas van Dijk, James Dodwell, Rachel Backhouse;

ITM Power (Research) Ltd, Sheffield/UK

09:30 **Advanced Materials for High-Temperature PEM Fuel Cells** A1203*

Elisabeth Therese Ulrikkeholm, Hector Rodrigo García, Hans Aage Hjuler, Thomas Steenberg;

Danish Power Systems, Egeskovvej/Kvistgaard

09:45 **Improved durability in DMFC: local optimization of catalyst layers** A1204

Claudio Rabissi (1), Matteo Zago (1), Madeleine Odgaard (2), Laila Grahl-Madsen (2), Andrea Casalegno (1);

(1) Department of Energy, Politecnico di Milano, Milano/Italia, (2) EWII Fuel Cells A/S, Odense SØ/Denmark

Convention Foyer

Electrochemical CO2-Reduction: Overview & potentials B12

Scale-up of direct Electrochemical Reduction of concentrated CO2 in Aqueous Systems B1201

Maximilian Fleischer, Günter Schmid;

Siemens AG, Corporate Technology, Research in Energy and Electronics, München/Deutschland

Study of modified Cu thin films for electrochemical reduction of carbon dioxide B1204

Anastasia A. Permyakova (1), Alexandra Patru (1), Juan Herranz (1), Thomas J. Schmidt (1,2);

(1) Electrochemistry Laboratory, Paul Scherrer Institut, Villigen PSI/Switzerland, (2) Laboratory of Physical Chemistry, ETH Zürich, Zurich/Switzerland

Co-electrolysis of CO2 and water in a polymer electrolyte membrane cell B1205

10:00	**Durability Studies of High Temperature PEM Fuel Cells. Operational Parameters, Accelerated Testing and Acid Retention**	A1205	Piero Negro (1), Francesca Niccoli (1), David Sebastián (2), Alessandra Palella (2), Sabrina Zignani (2), Lorenzo Spadaro (2), Vincenzo Baglio (2), Antonino S. Aricò (2); (1) Innovation Laboratory, Global Product Innovation, Italcementi s.p.a., Bergamo/Italy, (2) CNR-ITAE, Messina/Italy	
	Jens Oluf Jensen (1), Tonny Søndergaard (1), Lars N. Cleemann (1), Thomas Steenberg (2), Hans Aage Hjuler (2), Qingfeng Li (1); (1) Department of Energy Conversion and Storage, Technical University of Denmark, Kgs. Lyngby/Denmark, (2) Danish Power Systems Ltd., Kvistgård/Denmark			
10:15	**Real time startup simulation of a high temperature PEM fuel cell for combined heat and power generation**	A1206	**Heat-treated Cobalt-Copper Electrodes for Formic Acid Production from Carbon Dioxide**	B1206
	Gregor Tavčar (1), Peter Urthaler (2), Christoph Heinzl (3), Tim Lochner (3), Ambrož Kregar (1), Tomaž Katrašnik (1), Reinhard Tatschl (2); (1) Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana/Slovenia, (2) AVL List GmbH, Graz/Austria, (3) Elcore GmbH, München/Germany		Zhichuan (Jason) Xu (1,2,3); (1) School of Materials Science and Engineering, Nanyang Technological University, , (2) Solar Fuels Laboratory, Nanyang Technological University, , (3) Energy Research Institute@NTU, ERI@N, Interdisciplinary Graduate School, Nanyang Technological University, Singapore/Singapore	
10:30	**Break - Ground + First Floor in the Exhibition**			

Friday, July 7, 2017

	Auditorium		Convention Foyer	
11:00	**Diagnostics and Simulations**	**A13**	**Industrial achievements & inventions**	**B13**
11:00	**Quantification of feature detectability of subsecond X-ray Tomographic Microscopy of PEFC** Hong Xu, Thomas J. Schmidt, Felix N. Büchi, Jens Eller; Electrochemistry Laboratory, Paul Scherrer Institut, Villigen PSI/Switzerland	A1301	**Investigation of 2 MW PEMFC power plant for hydrogen recovery from chlor-alkali industry** Giulio Guandalini (1), Stefano Campanari (1), Stefano Foresti (1), Jorg Coolegem (2), Jan ten Have (3); (1) Politecnico di Milano, Department of Energy, Milano/Italy, (2) Nedstack Fuel Cell Technology B.V., Arnhem/The Netherlands, (3) MTSA Technopower B.V., Arnhem/The Netherlands	B1301*
11:15	**Extracting PEFC electrochemical properties from current interrupt measurement** Amir Niroumand (1,2), Motahareh Safiollah(1), Mark Olfert (1), Michael Eikerling (2); (1) Greenlight Innovation Corp., Burnaby/BC/Canada, (2) Department of Chemistry, Simon Fraser University, Burnaby/BC/Canada	A1302	**Energy analyses of fuel cell electric vehicles (FCEVs) under European weather conditions and various driving behaviours** Benedikt Hollweck (1), Matthias Moullion (2), Michael Christ (2), Gregor Kolls (2), Jörg Wind (1); (1) Daimler AG, Kirchheim unter Teck/Germany, (2) NuCellSys GmbH, Kirchheim unter Teck/Germany	B1302
11:30	**Understanding of PEMFC Conditioning Behaviors** Nana Zhao, Zhong Xie, Zhiqing (Ken) Shi; Energy, Mining & Environment, National Research Council Canada, Vancouver/B.C. Canada	A1303	**PEMFC operation with reformate gas in a micro-CHP system based on membrane-assisted reformer** Stefano Foresti (1), Giampaolo Manzolini (1), Sylvie Escribano (2); (1) Politecnico di Milano, Department of Energy, Milano/Italy, (2) CEA, LITEN/DEHT, Grenoble Cedex/France	B1303
11:45	**Water Management In Alkaline Membrane Direct Methanol Fuel Cells** Ulrike Krewer, Christine Weinzierl; TU Braunschweig, Institute of Energy and Process Systems Engineering, Braunschweig/Germany	A1304	**Fuel cell electric vehicle-to-grid: emergency and balancing power for a 100% renewable hospital** Vincent Oldenbroek, Lennart Nordin, Ad van Wijk; Energy Technology Section, Department of Process and Energy, Delft University of Technology, Delft/The Netherlands	B1304

12:00	**A New Model of PEMFCs: Process Identification from Physics-based EIS Simulation** Georg Futter (1), Arnulf Latz (1,2), Thomas Jahnke (1); (1) German Aerospace Center (DLR), Stuttgart/Germany, (2) Helmholtz Institute Ulm for Electrochemical Energy Storage (HIU), Ulm/Germany	A1305	**Long Term Field Testing of PEM Fuel Cell Backup Applications in the Field of Communication** Ulrike Trachte, Peter Sollberger; Lucerne School of Engineering and Architecture, Horw/Switzerland	B1305
12:15	**Examining the Effect of the Secondary ('Forgotten') Flow Field during Polymer Electrolyte Membrane Fuel Cell Operation** N. Kulkarni, Q. Meyer, P.R. Shearing, D.J.L. Brett; Electrochemical Innovation Lab, Department of Chemical Engineering, London/UK	A1306*	**Advances in Non-Flow-Through PEM Fuel Cells for Aerospace Applications** William Smith; Infinity Fuel Cell and Hydrogen, Inc., Windsor/USA	B1306
12:30	**Lunch - 2nd Floor on the Terrace** **Coffee - Ground + First Floor in the Exhibition & 2nd Floor on the Terrace**			

Afternoon **Afternoon**

Friday, July 7, 2017

	Auditorium		**Convention Foyer**	
13:30	**Bridge to Products: From material to cells & stacks**	**A14**	**Electrolysers & FCs - Implementation & Expectations**	**B14**
13:30	**Opportunities and challenges for de-alloyed PtNi cathode catalysts for automotive applications** Geoff Spikes, Dash Fongalland, Jonathan Sharman, Alex Martinez; Johnson Matthey Technology Centre, Reading/UK	A1401	**H2FUTURE - Hydrogen from Electrolysis for Low Carbon Steelmaking** Karl Anton Zach (1), Thomas Buergler (2), Klaus Scheffer (3), Irmela Kofler (4), Ronald Engelmair (5), Marcel Weeda (6); (1) VERBUND Solutions GmbH, Vienna/Austria, (2) voestalpine Stahl GmbH, Linz/Austria, (3) Siemens AG, Erlangen/Germany, (4) K1-MET GmbH, Linz/Austria, (5) Austrian Power Grid AG, Vienna/Austria, (6) ECN, Amsterdam/The Netherlands	B1401

13:45	**MATISSE - MAnufacTuring of Improved Stack with textured Surface Electrodes for Stationary and CHP applications** S. Escribano, C. Nayoze, J. Cren (1), J. Hunger, F. Wilhelm, A. Kabza (2), A. Rakotondrainibe, S. Besse (3), S. Theuring, C. Hildebrandt (4), C. VanAken (5); (1) Atomic Energy Commission (CEA), Grenoble/France, (2) Zentrum für Sonnenenergie- und Wasserstoff- Forschung Baden-Württemberg, Ulm/Germany, (3) AREVA Energy Storage, Aix-en-Provence/France, (4) inhouse engineering GmbH, Berlin/Germany, (5) Nedstack fuel cell technology B.V., ED Arnhem/The Netherlands	A1402	**Application of Water Electrolyzers in the Swiss Ancillary Services Market** Christoph Imboden (1), Aby Chacko (2), Daniel Schneider (1); (1) Lucerne University of Applied Sciences, Horw/Switzerland, (2) Swissgrid AG, Laufenburg/Switzerland	B1402
14:00	**Concepts and Technologies for Production and Qualification of Automotive Fuel cells** Angelika Heinzel, Peter Beckhaus, Jörg Karstedt; The Fuel Cell Research Center, Duisburg/Germany	A1403	**Cost-efficiency of a CHP hydrogen fuel cell** Andreas Herrmann (1), Fabian Rosenheimer (1), Corina Dorn (1), Christoph Hildebrandt (2), Hartmut Krause (1); (1) TU Bergakademie Freiberg, Institute of Thermal Engineering, Freiberg/Germany, (2) Inhouse engineering GmbH, Berlin Germany	B1403*
14:15	**Durability Tests of PEM-Fuel Cell Stacks based on harmonized Test Procedures** Ludwig Jörissen, Alexander Kabza, Jürgen Hunger; Zentrum für Sonnenenergie- und Wasserstoff- Forschung Baden-Württemberg, Ulm/Germany	A1404	**Impact of Dynamic Load from Renewable Energy Sources on PEM Electrolyzer Lifetime** Frans van Berkel (1), Arend de Groot (1), Sander ten Hoopen (2); (1) Energy Research Centre of The Netherlands ECN, Petten/The Netherlands, (2) Hydron Energy, Noordwijkerhout/The Netherlands	B1404
14:30	**The effect of cation contamination the performance and lifetime of the MEA** Ahmad El-kharouf; Centre for Fuel Cell and Hydrogen Research, University of Birmingham, Birmingham/UK	A1405*	**Hydrogen Mobility Europe (H2ME) – Creating the European Vision for Hydrogen Transportation** Lisa Ruf, Madeline Ojakovoh, Ben Madden; Element Energy, London/United Kingdom	B1405
14:45	**Highly efficient and long-term stable fuel cell micro-energy systems based on ceramic multilayer technology**	A1406	**Improved performance of modular HT-PEM based CHP systems considering seasonal effects and degradation effects**	B1406*

	Adrian Goldberg (1), Lars Röntzsch (2), Carsten Pohlmann (3), Christian Freitag (1), Ariel Thierry Tagne Saha (1), Steffen Ziesche (1), Uwe Partsch (1); (1) Fraunhofer IKTS, Dresden/Germany, (2) Fraunhofer IFAM, Dresden/Germany, (3) Aaqius & Aaqius, Paris/France		Elmar Pohl, David Diarra; OWI – Oel-Waerme-Institut GmbH, Herzogenrath/Germany	
15:00	**5 Min to change from B14 Session to Auditorium for A15 Session**			

Afternoon **Afternoon**

Friday, July 7, 2017

Auditorium

15:05	**P5: Closing Ceremony & Keynote by the Gold Medal of Honour Winner 2017**	**A15**
15:05	**Summary by the Chairladies** Isotta Cerri (2), Angelika Heinzel (1); (1) ZBT GmbH, Duisburg/Germany, (2) Advanced Technology Division, Production Engineering Group, Toyota Motor Europe, Zaventem/Belgium	A1501
15:20	**Information on Next EFCF 2018 + 2019** Olivier Bucheli (1), Hubert Gasteiger (2), Michael Spirig (1); (1) European Fuel Cell Forum, Lucerne/Switzerland, (2) Technical Electrochemistry, Department of Chemistry and Catalysis Research Center, Technical University of Munich, Garching/Germany	A1502
15:30	**Christian Friedrich Schönbein Award for the Best Poster, Best Science Contribution, Medal of Honour** Angelika Heinzel (1), Isotta Cerri (2); (1) ZBT GmbH, Duisburg/Germany, (2) Advanced Technology Division, Production Engineering Group, Toyota Motor Europe, Zaventem/Belgium	A1503
15:40	**Gold Medal Winner Keynote 2017 "FCEVs Fueled by Renewable H2 - Remaining Challenges"** Hubert Gasteiger; Technical Electrochemistry, Department of Chemistry and Catalysis Research Center, Technical University of Munich, Garching/Germany Technical Electrochemistry, Department of Chemistry and Catalysis Research Center, Technical University of Munich, Garching/Germany	A1504
16:05	**Thank you and Closing by the Organizers** Michael Spirig, Olivier Bucheli; European Fuel Cell Forum, Lucerne/Switzerland	A1505
16:15	**End of Sessions - End of Conference** **Goodbye coffee and travel refreshment in front of the Luzerner Saal**	

Special Sessions Programme

Friday, July 7, 2017

Club Room

09:00	**Photoelectrochemical Water Splitting - Microbial & Direct Formic Acid Fuel Cells**	**C12**
09:00	**Photoelectrochemical Water Splitting in Separate Hydrogen and Oxygen Cells** Avigail Landman (1), Hen Dotan (2), Gennady E. Shter (3), Gideon S. Grader (3), Avner Rothschild (2); (1) The Nancy & Stephen Grand Technion Energy Program (GTEP), Technion – Israel Institute of Technology, Haifa Israel, (2) Department of Materials Science and Engineering, Technion – Israel Institute of Technology, Haifa/Israel, (3) Department of Chemical Engineering, Technion – Israel Institute of Technology, Haifa/Israel	C1201
09:15	**Solar Water Splitting: Beating the Efficiency of PV-Electrolysis with Tandem Cell Photoelectrolysis** Avner Rothschild, Hen Dotan; Department of Materials Science and Engineering, Technion – Israel Institute of Technology, Haifa/Israel	C1202
09:30	**The PECSYS Project: Demonstration of a solar driven electrochemical hydrogen generation system with an area > 10 m^2** S. Calnan (1), R. Schlatmann (1), M. Edoff (2), T. Edvinsson (2), P. Neretnieks (3), L. Stolt (3), S. Haas (4), M. Langemann(4), M. Mueller (4), B. Turan (4), A. Battaglia (5), S. A. Lombardo (6); (1) PVcomB, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin/Germany, (2) 3SUN SRL, Catania/Italy, (3) Uppsala Universitet, Uppsala/Sweden, (4) Forschungszentrum Juelich GmBH, Juelich/Germany, (5) Consiglio Nazionale Delle Ricerche CNR-IMM, Catania/Italy, (6) Solibro Research AB, Uppsala/Sweden	C1203
09:45	**Enhanced Electron Transfer by a Magnetic Self-assembled Conductive Fe3O4/Carbon Nanocomposites in E. coli-Catalyzed Mediator-less Microbial Fuel Cells** In Ho Park, Kee Suk Nahm; School of Chemical Engineering, Chobnuk National University, Jeonju/Republic of Korea	C1204
10:00	**Bioelectrochemical systems as tools to steer anaerobic digestion processes** Annemarie Schmidt (1), Anna Prokhorova (1), André Weber (2), Elena Kipf (3), Sven Kerzenmacher (3), Marc Gauert (4), Andreas Lemmer (5), Padma Priya Ravi (5), Johannes Gescher (1); (1) Institute for Applied Biosciences (IAB), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany, (2) Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), Karlsruhe/Germany, (3) Laboratory for MEMS Applications, IMTEK - Department of Microsystems Engineering, University of Freiburg, Freiburg/Germany, (4) B.R.A.I.N AG, Zwingenberg/Germany, (5) State Institute of Agricultural Engineering and Bioenergy, University of Hohenheim, Stuttgart/Germany	C1205
10:15	**Microbial Fuel Cells: A Platform Technology for Multiple Applications** Ioannis A. Ieropoulos, Jiseon You, Iwona Gajda, John Greenman; Bristol BioEnergy Centre, Bristol Robotics Lab, Faculty of Environment & Technology, Bristol/UK	C1206
10:30	**Break - Ground + First Floor in the Exhibition**	

Club Room **S-Chairs: Günther G. Scherer, Olaf Conrad**

11:00	**Similarities & Differences: FC - Redox Flow Batteries (RFB) I**	**C13**
11:00	**PEM Fuel Cells and Redox Flow Batteries – Differences, similarities and common problems** Rüdiger Schweiss; SGL Carbon GmbH, Meitingen/Germany	C1301
12:00	**Catalytic Properties of Carbon in the All-Vanadium-Redox-Flow-Batteries (aVRFB)** Jochen Friedl, Ulrich Stimming; School of Chemistry, Newcastle University, Newcastle upon Tyne/United Kingdom	C1303
12:30	**Lunch - 2nd Floor on the Terrace** **Coffee - Ground + First Floor in the Exhibition & 2nd Floor on the Terrace**	

Club Room **S-Chairs: Günther G. Scherer, Jochen Friedl**

13:30	**Similarities & Differences: FC - Redox Flow Batteries (RFB) II**	**C14**
13:30	**All-Polymer-Redox-Flow-Batteries (aPRFB)** Olaf Conrad; JenaBatteries GmbH, Jena/Germany	C1401
14:00	**Progress in miniaturized redox flow batteries** Patrick Ruch (1), Neil Ebejer (1), Julian Marschewski (2), Lorenz Brenner (2), Kleber Marques Lisboa (2), Dimos Poulikakos (2), Bruno Michel (1); (1) IBM Research - Zurich, Zuerich/Switzerland, (2) ETH Zürich, Zuerich/Switzerland	C1402
14:30	**Electrolytes for bromine/bromide cathode in hydrogen-bromine Redox-Flow-Battery (RFB** Michael Küttinger, Paulette Loichet, Emeline Meyer, Peter Fischer, Karsten Pinkwart, Jens Tübke; Applied Electrochemistry, Fraunhofer Institute for Chemical Technology, Pfinztal/Germany	C1403
14:45	**Local characterization and 3D simulation of mass transport issues in Vanadium-Redox-Flow-Batteries (VRFB)** Matteo Zago, Mirko Messaggi, Claudio Rabissi, Andrea Baricci, Riccardo Mereu, Fabio Inzoli, Andrea Casalegno; Politecnico di Milano, Department of Energy, Milan/Italy	C1404
15:00	**Design and upscaling of a AQDS-bromine based Redox Cell** Simone Amicabile (1), Matteo Testi (1), Luigi Crema (1, 2); (1) Fondazione Bruno Kessler, Trento/Italy, (2) Green Energy storage, Trento/Italy	C1405
15:15	**Summary and Discussion on future common Exchange-Activities FC-RFB (ca. 10min)**	
15:25	**For participants of the EFCF conference 5min to change from C14 Session to Auditorium and to jump in the Closing Session A15 with Keynote from Prof. Hubert Gasteiger TUM, Conference Summary and Award Ceremony**	

Auditorium Foyer

A03 Poster Session I with all Session Topics Wednesday, 5 July 2017 13.15 - 14:30

A09 Poster Session II with all Session Topics Thursday, 6 July 2017 13.15 - 14:30

Poster Session

Membranes & MEAs	A08
Investigation and Quantification of Acid Condensation and Cell Conductivity within HT-PEMFC Hans Becker (1), Lars N. Cleemann (1), Kasper Enemark-Rasmussen(2), Jens Oluf Jensen (1), Qingfeng Li (1); (1) DTU Energy, Technical University of Denmark, Kgs. Lyngby/Denmark, (2) DTU Chemistry, Technical University of Denmark, Kgs. Lyngby/Denmark	A0807
Effect of the spirobiindane group in sulfonated poly(arylene ether sulfone) as a polymer electrolyte binder for fuel cell application Ji Eon Chae, Hyoung-Juhn Kim, Sung Jong Yoo, Jong Hyun Jang, So Young Lee*; Fuel Cell Research Center, Korea Institute of Science and Technology (KIST), Seoul/Korea	A0808
Coating grid metallic contacts with electrosprayed carbon layers J.J. Conde, M.A. Folgado, P. Ferreira-Aparicio, A.M. Chaparro; Dep. of Energy, CIEMAT, Madrid/Spain	A0809
Additive Effect in PFSA Electrolytes Je-Deok Kim (1,2);	A0812

Non-precious metal catalysts	B02
Composition-Stability Relations for Non-Noble Metal Catalysts for Polymer Electrolyte Fuel Cell Cathodes (see B0202) <--	B0207
Effects of surfactant on the structure of nanomaterials for low temperature fuel cell application Njoku Chima (1,2), Patrick Ndungu (1,3); (1) University of KwaZulu-Natal, Durban/South Africa, (2) Durban University of technology, Durban/South Africa, (3) University of Johannesburg, Johannesburg/South Africa	B0209

Pt-Catalysts and supports	B04
Adhesion Behavior of Nafion Solution at Disperse Phase Boundaries Schulz Anne (1), Stähler Markus (1), Lühmann Nicole(2), Lehnert Werner (1,3); (1) Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research IEK-3: Electrochemical Process Engineering, Jülich/Germany, (2) Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science JCNS-1/, Jülich/Germany, (3) Modeling in Electrochemical Process Engineering, RWTH Aachen University, Aachen/Germany	B0407
Ultra-Low Pt Content Stabilises Fe-N-C Catalysts in PEM Fuel Cell Cathodes	B0408

Stability of Highly Sulfonated Polyphenylsulfone Membrane (I) A0813

Je-Deok Kim (1,2);

(1) Hydrogen Production Materials Group, Center for Green Research on Energy and Environmental Materials, National Institute for Materials Science, , (2) Polymer Electrolyte Fuel Cell Group, Global Research Center for Environmental and Energy based on Nanomaterials Science (GREEN), NIMS, Ibaraki/Japan

Characterisation of materials & degradation A10

The water vapor equilibrium in the phosphoric acid – water system A1007

Jürgen Giffin (1), Fosca Conti (2,3), Carsten Korte (1), Werner Lehnert (1,4);

(1) Institute of Energy and Climate Research: Electrochemical Process Engineering, Jülich/Germany, (2) University of Padova, Department of Chemical Sciences, Padova/Italy, (3) Institute of Innovative Mobility (MOREA), Technische Hochschule Ingolstadt, Ingolstadt/Germany, (4) Modelling in Electrochemical Process Engineering, RWTH Aachen University, Aachen/Germany

Investigation of PEMFC damage mechanisms due to cyclic freeze-thaw attack A1008

Stanislav Gorelkov, Susanne Palecki, Georg Dura, Jens Wartmann, Angelika Heinzel;

The Fuel Cell Research Center, Duisburg/Germany

Effect of mechanical degradation and chemical degradation on PEMFC stability A1009

Nastaran Ranjbar-Sahraie, Moulay Sougrati, Deborah Jones, Frédéric Jaouen;

Institut Charles Gerhardt Montpellier, Université de Montpellier, Montpellier/France

Hydrogen and Oxygen Evolution on Alloys of Transition Metals of Period 4 B0409

Alejandro N. Colli, Heron Vrubel, Hubert H. Girault;

Laboratoire d'Electrochimie Physique et Analytique Ecole Polytechnique Fédérale de Lausanne, Sion/Switzerland

Evaluation of binary catalyst performance by computational quantum mechanics B0410

Hung-Hsiao Liu (1), Kan-Lin Hsueh (2), Che-Wun Hong (1);

(1) Department of Power Mechanical Engineering, National Tsing Hua University, Hsinchu/Taiwan, (2) Department of Energy Engineering, National United University, Miaoli/Taiwan

Highly active heteroatom doped carbon supported palladium for oxidation of formate B0412

Sohaeng Kim (1), Myounghoon Choun (1), Jaeyoung Lee (1,2);

(1) Electrochemical Reaction and Technology Laboratory (ERTL), School of Environmental Science and Engineering, Gwangju Institute of Science and Technology (GIST), Gwangju/South Korea, (2) Ertl Center for Electrochemistry and Catalysis, Gwangju Institute of Science and Technology (GIST),

Oriented Electrode for Polymer Electrolyte Fuel Cells B0413

Hongmei Yu;

Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian/China

Investigation of (La1-X,CaX)(Ni0.25Fe0.25Cr0.25Co0.25)O3 for Solid Oxide Fuel Cells Cathode Materials A1010

Sai R. Gajjala, Rasit Koc;

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

Transport phenomena limitation A11

The effect of cation contamination the performance and lifetime of the MEA (see A1405) <-- A1107

Analysis of Roughness Induced Hydrophobicity in Electrospray Deposited Microporous Layer on Carbon Fiber Paper used in PEMFC Membrane Electrode Assembly A1108

Carmencita Lumban (1), Armando Somintac (1) (2), Manolo Mena (3), Henry Ramos (4);

University of the Philippines, Diliman, (1) Materials Science and Engineering Program, College of Science, Quezon City/Philippines, (2) National Institute of Physics, College of Science, , (3) Department of Mining, Metallurgical and Materials Engineering, College of Engineering, , (4) Technology Management Center, Philippines,

Why an OCV of 1.23 Volt cannot be obtained A1111

Ulf Bossel;

Fuel Cell Consultant, Oberrohrdorf/Switzerland

Laboratory of Fuel Cells, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian/China

H2 from Electrolysers: Concepts & costs B05

Vibration Disassociation of H2O molecule B0507

Sonya Davidson;

H2 Energy Now, Beer Sheva/Israel

Developments for Alkaline Electrolysis: From materials to laboratory electrolysers (see B1003) <-- B0509

Hydrogen Production from Zinc Dissolution in Saline Formation Water B0510

M. A. Deyab;

Egyptian Petroleum Research Institute (EPRI), Cairo/Egypt

Densification of gadolinium-doped ceria diffusion barriers for solid oxide electrolysis cells B0511

Hyun-Jong Choi, Doo-Won Seo, Sang-Kuk Woo, Sun-Dong Kim;

Korea Institute of Energy Research, Daejeon/Republic of Korea

Effect of ozone pretreatment on biohydrogen production from complex biomethanated distillery wastewater B0512

Sameena. N. Malik (1,3), Prakash. C. Ghosh (3), Atul. N. Vaidya (1), Vishal Waindeskar (2), Sandeep N. Mudliar (1)*;

Durability, testing & optimisation for operation

A12

A1207 **Advanced Materials for High-Temperature PEM Fuel Cells (see A1201) <--**

A1208 **Advanced Materials for High-Temperature PEM Fuel Cells (see B0704) <--**

A1209 **Effect of operating conditions temperature on low temperature PEFC under aeronautical conditions**
Noluntu Dyantyi, Sivakumar Pasupathi, Adrian Parsons, Cordellia Sita;
HySA Systems, University of the Western Cape, Bellville/South Africa

A1210 **Long term Durability of High Temperature-Polymer Electrolyte Membrane Fuel Cells based on Acid Doped Polybenzimidazole**
Arvind Kannan, Lars N Cleemann, Qingfeng Li, Jens Oluf Jensen;
Department of Energy Conversion and Storage, Technical University of Denmark, Kgs. Lyngby/Denmark

Diagnostics and Simulations

A13

(1) CSIR – National Environmental & Engineering Research Institute,, Maharashtra/India, (2) Ozone Research and Application (I) Pvt Ltd, Maharashtra/India, (3) Department of Energy Science & Engineering, Indian Institute of Technology, Maharashtra/India

H2 Storage: Concepts & systems

B07

B0707 **Hydrogen Blending into the Gas Distribution Grid: The Case Study of a Small Municipality (see B0704) <--**

B0708 **Modelling and Simulation of a Two-dimensional Hydrogen Storage Reactor Including Effects of Expansion Volume**
Mahvash Afzal, Pratibha Sharma;
Department of Energy Science and Engineering, Maharashtra/India

B0709 **Evaluation of phenomena occurring in a Regenerative Solid Oxide Cell System for energy storage**
Bruno Conti (1,2), Marco Graziadio (1,3), Stephen John McPhail (1), Maurizio Carlini (3), Barbara Bosio (1);
(1) Department of Energetic technology,CR-ENEA, Casaccia(Rome)/Italy, (2) University of Genoa, Dept. Civil,Chemical and Enviromental Engineering, Genoa/Italy, (3) University of Tuscia, DAFNE/Italy

Modelling & Diagnostics of Pt-Catalysis

B08

B0807 **Molecular Analysis of Oxygen Permeation Properties in Ionomer on Pt Surface in PEMFC**

Two-Dimensional, Non-Isothermal Simulation Model of an Alkaline Fuel Cell (AFC): Effect of Temperature on the Polarization Curve (see B0803) <-- A1307

Industrial achievements & inventions B13

Investigation of 2 MW PEMFC power plant for hydrogen recovery from chlor-alkali industry (see B1301) <-- B1307

Cost-efficiency of a CHP hydrogen fuel cell (see B1403) <-- B1308

Improved performance of modular HT-PEM based CHP systems considering seasonal effects and degradation effects (see B1406) <-- B1309

Fuel Cell Electric Vehicle-to-Grid: Experimental feasibility and operational performance B1310

Vincent Oldenbroek (1), Victor Hamoen (1), Samrudh Alva (1), Carla Robledo (1), Leendert Verhoef (2), Ad van Wijk (1);

(1) Energy Technology Section, Department of Process and Energy, Delft University of Technology, Delft/The Netherlands, (2) Green Office, Delft University of Technology, Delft/The Netherlands

Increasing the efficiency of biogas CHP with simultaneous emission reduction B1311

Florian Rau (1), Andreas Herrmann (1), Hartmut Krause (1);

TU Bergakademie Freiberg (TUBAF), Institute of Thermal Engineering, Freiberg/Germany

Yuya Kurihara (1), Takuya Mabuchi (2), Takashi Tokumasu (2);

(1) Graduate School of Engineering, Tohoku University, Miyagi/Japan, (2) Institute of Fluid Science, Tohoku University, Miyagi/Japan

Physical Modeling of the Proton Density in Catalyst Layer Nanopores of PEM Fuel Cells (see B0805) <-- B0808

Fuel processing, purification & compression B11

Advancement in Palladium Membranes Hydrogen Purification B1107

Marco Succi, Giorgio Macchi;

SAES Getters SpA, Lainate (Mi)/Italy

High Temperature Electrochemical Hydrogen Pumping B1109

Tomasz Rojek (1), Thomas J. Schmidt (1,2), Lorenz Gubler (1);

(1) Paul Scherrer Institut, Villigen PSI/Switzerland, (2) ETH Zürich, Laboratory of Physical Chemistry,

Performance and Degradation Study of Pt-Ru Catalysts for Hydrogen Production from Commercial Diesel B1110

Jaemyung Lee, Jiwoo Oh, Joongmyeon Bae*;

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

Low Pressure Hydrodesulfurization Processes for Gaseous Fuels B1111

Thomas Optenhostert (1), Christian Spitta (1), Michael Steffen (1), Wolfgang Schmidt (2), Sissy Puthenkalam (2);

(1) ZBT GmbH, Duisburg/Germany, (2) Max-Planck-Institut für Kohlenforschung, Mülheim an der Ruhr/Germany

Study on Start-up Control of Diesel Autothermal Reformer for 1 kWe Solid Oxide Fuel Cell System B1112

Minseok Bae (1), Jiwoo Oh (1), Dongyeon Kim (1), Joongmyeon Bae (1), Sai P. Katikaneni (2);

(1) Dept. of Mechanical Engineering, KAIST, Daejeon/South Korea, (2) Research and Development Center, Saudi Aramco , Dhahran/Saudi Arabia

Electrolysers & FCs - Implementation & Expectations B14

QualyGridS – Standardized qualifying tests of electrolysers for grid services B1407

Regine Reissner (1), Anders Søreng (2), Nick van Dijk (3), Laura Abadía (4), Cyril Bourasseau (5), Shi You (6), Chresten Træholt (6), Francoise de Jong (7), Pablo Marcuello (8), Christoph Imboden (9), M. Spirig (10) et al.;

(1) German Aerospace Center (DLR), Institute of Engineering Thermodynamics, , Stuttgart/Germany, (2) NEW NEL HYDROGEN AS, Notodden/Norway, (3) ITM POWER, Sheffield/UK, (4) Aragon Hydrogen foundation, Huesca/ES, (5) CEA , Grenoble/FR, (6) Danmarks Tekniske Universitet (DTU), Lyngby/DK, (7) Stichting Nederlands Normalisatie Instituut (NEN), Delft AX/NL, (8) IHT Industrie Haute Technologie SA (IHT) AG , Monthey/CH, (9) Lucerne University of Applied Sciences and Arts (HSLU), Horw/CH, (10) European Fuel Cell Forum AG, Adligenswil/CH

Innovative Approach for Nano-structured Electrode of Solid Oxide Cells B1408

Jae-ha Myung* (1,2), Dragos Negue (2), John Irvine (2);

(1) Korea Institue of Energy Research, Daejeon/Korea, (2) School of Chemistry, University of St Andrews, St Andrews/UK

Similarities & Differences: FC - Redox Flow Batteries (RFB) C13 C14

Spatially resolved OCV distribution for studying flow behavior in Vanadium-Redox-Flow-Batteries (VRFB) (C1407) C1407

Arjun Bhattarai (1), Nyunt Wai (1), Rüdiger Schweiss (2), Adam Whitehead (3), Günther G. Scherer (4), Purna C. Ghimire (1), Huey Hoon Hng (1);

(1) Nanyang Technological University, Singapore/Singapore, (2) SGL Carbon GmbH, Meitingen/Germany, (3) Gildemeister energy storage GmbH, Wr. Neudorf/Austria, (4) TUM CREATE, Singapore/Singapore

6th EUROPEAN PEFC & Electrolyser Forum 2017

4 – 7 July 2017
Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

Chaired by

Prof. Dr. Angelika Heinzel
ZBT GmbH Uni Duisburg-Essen Germany
Dr. Isotta Cerri
Toyota Motor Europe Belgium

Abstracts of all Oral and Poster Contributions

Legend:

Abstracts are identified and preliminarily sorted by presentation number (= EFCF-ID) e.g. A0504, B1205, etc. first all A , then B, then C. However some very similar session topics were grouped to chapters, which correspond to the chapters of the proceedings (see web link and www.EFCF.com/Lib)

- Oral abstracts consist of numbers where last two digits are lower than 07
- Poster abstracts are linked to related sessions by letter and first two digits: e.g. A05.., B10, …etc
- Due to late changes some numbers (second two digits) are missing or changed.

Chapter-Session-Overview

Chapter 01 - Sessions A01, A02, A06, A15

A01 Plenary 1: Opening Session - The bridge to the Hydrogen Economy
A02 Plenary 2: Automotive OEM Status
A06 Plenary 3: Keynote: Green Power for Green Hydrogen
A15 Plenary 4: Keynote by the Gold Medal of Honour Winner 2017: Prof. Hubert Gasteiger

Content **Page A01, A02, A06, A15 - ..**

A0101 (Plenary, no Abstract)

Welcome by the Organizers

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

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

A0102 (Plenary, no Abstract)

Welcome by the Chairladies

Angelika Heinzel (1), Isotta Cerri (2);
(1) ZBT GmbH, Duisburg/Germany
(2) Advanced Technology Division, Production Engineering Group, Toyota Motor Europe, Zaventem/Belgium
angelika.heinzel@uni-due.de; Isotta.Cerri@toyota-europe.com

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A0103 (Plenary, no Abstract)

Welcome to Switzerland

Stefan Oberholzer, Rolf Schmitz, Benoît Revaz
Swiss Federal Office of Energy; Bern/Switzerland
stefan.oberholzer@bfe.admin.ch J.Chatzimarkakis@hydrogeneurope.eu

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

A0104 (Keynote, no Abstract)

Who is building the bridge to the hydrogen economy update on industry status challenging next step (EU)

Jorgo Chatzimarkakis;
Hydrogen Europe, Brussels/Belgium
J.Chatzimarkakis@hydrogeneurope.eu

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A0105 (Keynote, no Abstract)

Expectations - Evaluation of the FCH Technologies

Olivier Bishop;
Shell (Switzerland) AG, Baar/Switzerland
Oliver.Bishop@shell.com

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A0201 (Status Report, no Abstract)

Toyota Vehicle Strategy and Development (A0201)

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A0203 (Status Report, no Abstract)

FCV Development - Vision and Status (A0203)

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A0204 (published elsewhere)

New fuel cell stack and development method for the Fuel Cell System of the Honda CLARITY FUEL CELL and Honda's activity towards the Hydrogen Society

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Abstract

Honda started to lease the world's first fuel cell vehicle (FCV) in December 2002 and has provided FCVs with advanced new technologies continuously to customers.
And then, Honda leased the newly developed fuel cell vehicle, the CLARITY FUEL CELL, in March 2016.
A downsized fuel cell system with high performance and durability has been realized by evolved structure of fuel cell stack and controlling water content distribution in the catalyst coated membrane applying fundamental technologies to predict the fuel cell lifetime as follows:

- Performance degradation of catalyst
- Mechanical degradation of electrolyte membrane
- Chemical degradation of electrolyte membrane
- Water content optimization for catalyst coated membrane

As a result, fuel cell system, voltage control unit and motor unit are integrated into one fuel cell powertrain system. This highly integrated design allowed the CLARITY FUEL CELL becoming the world's first production five-seater fuel cell sedan to install the entire fuel cell powertrain system under the front hood of the car.
In order to popularize fuel cells, continuous efforts for cost reduction (the development of specifications and processes) will be essential.
Moreover, Honda is pursuing hydrogen society actively under the key concept "generate", "use" and "get connected" for realization of a recycling-based society.

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A0205 (Abstract only)

Engineering and validation of a cryo-compressed hydrogen storage system to maximize driving range in automotive zero emissions driving applications.

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Abstract

In order to contribute to fulfilling the world´s greenhouse gas reduction targets, as set by our governments at COP21, BMW has developed a zero emission vehicle strategy. As our customers want the same driving pleasure, while the vehicles must be as easy to use and as safe as nowadays, they are also expecting to spend only a minor mark-up for achieving zero emissions. BMW has two complementing offers for zero emission vehicles, namely the battery electric vehicle (BEV) and the fuel cell electric vehicle (FCEV). The FCEV will be the large vehicle option for long distances and continuous driving.

During the FCEV 5 series GT demonstrator development phase, BMW has conceived, built and validated two onboard systems for hydrogen storage. While the 70 MPa gaseous H2 storage is the mainstream technology for hydrogen storage, BMW has developed the 35 MPa cryo-compressed storage and associated refueling technology, as it could become an option for extended drive range applications. Durability in the field, customer day-to-day usability and range expectations of the cryo-compressed storage system have been confirmed through extensive drive testing in hot and cold climates. The presentation will show BMW´s cryo-compressed technology principles, technical challenges and solutions, as well as results of testing the system onboard fuel cell electric vehicles.

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A0206 (Abstract only)

Audi h-tron Strategy

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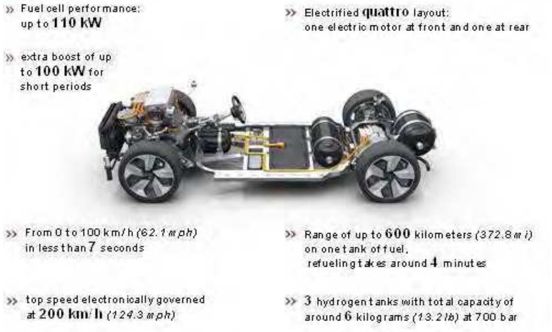
Abstract

Sustainable mobility with ZERO local and global emissions will play a key role in the future of the automotive industry. The Audi strategy to achieve the worldwide emission targets includes highly efficient combustion engines, plug-in-hybrids, battery electric vehicles and fuel cell electric vehicles. Beginning with the Audi A2H2 Fuel Cell in 2004 Audi and the Volkswagen Group have a long history in the development of fuel cell vehicles. Using hydrogen produced with renewable energy (green hydrogen) the Audi fuel cell electric vehicles are real ZERO emission vehicles with high range, swift refueling and sporty road performance. Like a car with combustion engine, refueling takes about four minutes., therefore the customer does not need to change his habits.

The biggest challenge for the success of fuel cell electric vehicles are the availability of a hydrogen infrastructure and the cost reduction of fuel cell systems. In Germany the Clean Energy Partnership, one of Europe's biggest initiatives between politics and industry, will provide 400 hydrogen fueling stations until 2023.

At the Detroit Motor Show 2016 the Audi h-tron quattro concept has been presented for the first time. With the 5th generation fuel cell system it combines a highly efficient fuel cell achieving an output of up to 110 kW with a powerful battery that can provide a temporary boost of 100 kW. With an efficiency rating in excess of 60 percent, the fuel cell now surpasses any combustion engine. The "stack" comprising 330 individual cells is housed in the forward structure. The car can be fully refueled with hydrogen in around four minutes, and is then ready to drive for up to 600 kilometers. The three hydrogen tanks are located beneath the passenger compartment and luggage compartment but do not impinge on the interior.



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A0601 (Keynote, no Abstract)

Wind – Electrolysers – Hydrogen – Fuel Cells – Market partnership with prospects (A0601)

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A1501, A1502, A1503, A1505 (Plenaries, no Abstracts)

Summary by the Chairladies (A1501)

Isotta Cerri, Angelika Heinzel

Information on Next EFCF (A1502):

13th European SOFC & SOE Forum 2018

7th European Low-Temp.Fuel Cells/Electrolysers & H2 Processing Forum 2019

Olivier Bucheli, Hubert Gasteiger, Michael Spirig

Christian Friedrich Schönbein Award (A1503) for the Best Poster, Best Science Contribution, Medal of Honour

Angelika Heinzel, Isotta Cerri

Thank you and Closing by the Organizers (A1505)

Michael Spirig, Olivier Bucheli

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A1504 (Gold Medal Winner Keynote 2017, Abstract only)

FCEVs Fueled by Renewable H_2 - Remaining Challenges

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Abstract

To meet the 2021 EU target of 95 g_{CO2}/km fleet average for new cars requires a substantial fraction of either battery electric vehicles (BEVs) and/or of fuel cell electric vehicles (FCEVs) based on proton exchange membrane fuel cells (PEMFCs) and fueled by renewable hydrogen [1]. While short-range BEVs have been shown to be commercially viable, their market penetration is still limited and likely can only be increased by providing longer-range BEVs with fast charging capability. On the other hand, the commercial availability of FCEVs is still limited to small numbers provided by very few car companies, with very few hydrogen filling stations being available to date. Furthermore, both vehicle technologies are currently substantially more expensive than conventional vehicles.

After a brief review of the current technological and economic constraints for BEVs [2], this presentation will focus on the fuel cell materials/design options to reduce the amount of the costly and resource limited platinum catalyst. Owing to its high activity for the H_2 oxidation reaction [3], the platinum loading in fuel cell anodes has already been reduced to very low levels, so that a substantial reduction of the amount of platinum in FCEVs hinges on the development and implementation of improved oxygen reduction catalysts [2] in order to reach the <0.1 g_{Pt}/kW DOE target. While this was originally thought to require novel platinum based catalysts with a 10-fold higher mass activity (or Pt-free catalysts), it will be shown that recent advances in increasing the operating current density can also be a significant in the roadmap towards the <0.1 g_{Pt}/kW target.

The final part of this presentation will examine the feasibility of the large-scale generation of renewable hydrogen by PEM water electrolysis, particularly in view of the required amount of the resource-limited iridium catalyst for the oxygen reduction reaction [4]. The materials and design development challenges will be examined in view of our current understanding of the efficiency losses in PEM water electrolyzers [5].

[1] U. Eberle, B. Müller, R. von Helmolt; "Fuel cell electric vehicles and hydrogen infrastructure: status 2012"; *Energy Environ. Sci. 5* (2012) 8780.
[2] O. Gröger, H.A. Gasteiger, J.-P. Suchsland; "Electromobility: Batteries or Fuel Cells?"; *J. Electrochem. Soc. 162* (2015) A2605.
[3] J. Durst, C. Simon, F. Hasché, H.A. Gasteiger; "Hydrogen Oxidation and Evolution Reaction Kinetics on Carbon Supported Pt, Ir, Rh, and Pd Electrocatalysts in Acidic Media"; *J. Electrochem. Soc. 162* (2015) F190.
[4] U. Babic, M. Suermann, F.N. Büchi, L. Gubler, T.J. Schmidt; "Review – Identifying Critical Gaps for Polymer Electrolyte Water Electrolysis Development"; *J. Electrochem. Soc. 164* (2017) F387.
[5] M. Bernt, H.A. Gasteiger; "Influence of Ionomer Content in IrO_2/TiO_2 Electrodes on PEM Water Electrolyzer Performance"; *J. Electrochem. Soc. 163* (2015) F3179.

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Chapter 02 - Sessions A08, A10, B02, B04

A08 Membranes & MEAs
A10 Characterisation of materials & degradation
B02 Non-precious metal catalysts
B04 Pt-Catalysts and supports

Content **Page A08, A10, B02, B04 - ..**

A0801 (Abstract only, published elsewhere)

PBI Membranes for Fuel Cells and Electrolyzers

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Abstract

Polybenzimidazole (PBI) polymers have been extensively studied for high temperature PEM fuel cells operating at 100-200˚C . As part of our work in developing and using the sol-gel PPA process, we have been exploring the effects of chemical structure on the basic membrane properties, as well as issues of membrane stability and durability. Membranes produced from this process showed the ability to maintain high levels of phosphoric acid (PA) and high proton conductivities while simultaneously exhibiting low levels of PA loss during operation in many simulated duty cycles. We have been interested in understanding possible membrane failure modes as a gateway to making extremely long lifetime membranes. Membrane creep was identified as one possibility and for the past several years, testing and mitigation strategies were investigated that have been successful in significantly lowering membrane creep at high temperature using alternate membrane chemistries. Simultaneously with these efforts, it appeared to us that new PBI chemistries were needed to fully satisfy the membrane needs for various electrolyzer devices. In this presentation, we will present some of our initial efforts to tailor the PBI chemistry for electrolyzer devices such as hydrogen pumps and hybrid sulfur cycles. Extensive cell testing results supports our premise that tailoring the PBI chemistry for the particular operating environment of the device provides an attractive pathway for successful device design.

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A0802

Understanding the degradation of High-Temperature PEM Fuel Cells

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Abstract

High Temperature Proton Exchange Membrane Fuel Cells (PEMFC) run at temperatures between 120 °C and 180 °C. The higher operation temperature comes with many advantages, e.g. the higher temperature increases the kinetics, gives a higher tolerance towards CO poisoning, and by designing a fuel cell that runs at high temperatures we remove the need for cooling the components, which simplifies the design process and lowers the cost. The higher CO tolerance makes it possible to rely on hydrogen formed from methanol or reformate, which increases the flexibility of these devices.

At Danish Power Systems (DPS) we develop and manufacture state of the art Membrane Electrode Assembly (MEA) for PBI-based HT-PEMFC that operate at temperatures between 120 °C and 180 °C. These cells have a low degradation rate of 4 µV/h over 13.000 h. This degradation test was performed at T=160 °C at a current density of 300 mA/cm^2. The degradation is mainly a consequence of loss of phosphoric acid and loss of surface area of the catalysts due to sintering and Ostwald ripening. To understand the causes of the degradation, the MEAs have been studied using various characterization techniques before the testing and post mortem. X-ray diffraction experiments and Transmission Electron Microscopy were performed to study the growth of the platinum nanoparticles on the different electrodes. These experiments revealed that the increase in Pt particle size was significantly larger on the cathode than on the anode. Scanning Electron Microscopy has been performed to study the corrosion of the electrodes [3], and X-ray computer tomography was used to determine the distribution of the platinum particles in the electrode layers and the distribution of phosphoric acid.

A0803 (Abstract only)

A comparison of HT-PEM MEA performance within the German project QUALIFIX

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Abstract

In order to meet current market requirements for fuel cell systems a quality management needs to be established. The main focus in this quality management is to reduce the production-related failures of such systems, by involving all companies along the value chain and thus to further improve the long-term stability of the products, starting with the supplier of membrane electrode assemblies, the production of the bipolar plates and the manufacturer of the total fuel cell system. This task is approached within the project QUALIFIX, funded by the German Federal Ministry for Economic Affairs and Energy, with the participation of the industry to deliver a High Temperature PEM Fuel Cell (HT-PEMFC) based auxiliary power system with 5 kW output power. A large number of tests, as well as the development of new test methods and their linking with known technology are necessary to determine and verify relevant quality features like efficiency or lifetime. The investigations also include short-term tests that cause aging under defined stressing conditions, such as start-stop cycling, and are compared with constant load results from other short- and long-term tests. Through the use of HT-PEMFC-MEAs from different manufacturers, investigated under the same conditions, a large pool of data is generated, from which findings can be drawn about the lifetime and quality features. Results from such measurements will be discussed in the presentation and linked to the underlying question: How can quality be described in terms of fuel cells?

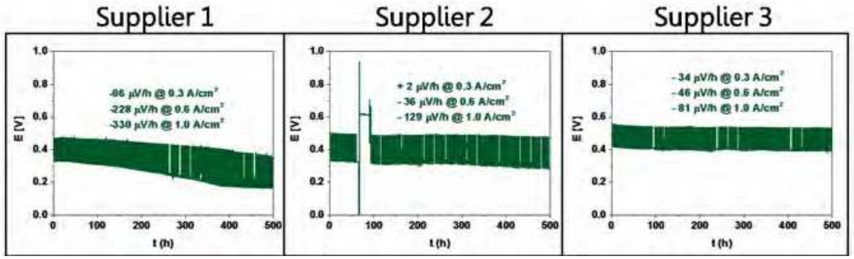

Figure 1: Comparison of three different HT-PEMFC-MEAs from various suppliers

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A0804

Proton Conducting Ionic Liquids as Non-Aqueous Electrolytes in HT-PEFCs – Interaction with PBI-type Polymers and ORR Kinetics

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Abstract

High temperature PEM fuel cells (HT-PEFCs) are currently based on phosphoric acid (H_3PO_4) doped polybenzimidazole (PBI). Due to the high operation temperature in the range of 120 – 180°C there are several advantages for the system design compared to low temperature PEFCs, as a simplified water management, a recovery of high-grade waste heat, a more compact cooling system and a higher CO tolerance. A major drawback is the slow oxygen reduction reaction (ORR) kinetics at the cathode in presence of H_3PO_4. This is (mainly) caused by i) a poisoning of active sites on the platinum catalyst due to a specific adsorption of H_3PO_4 species, ii) a low solubility of oxygen and iii) a slow diffusion of oxygen through the H_3PO_4 film which covers the platinum catalyst.

The uptake of protic electrolyte molecules by a PBI-type polymer depends on their acidity. Generally, the basic groups of the polymer chains are protonated in a first step, resulting in strong coulombic forces to the electrolyte anions. The increased osmotic pressure due to the formation of a “polymer salt” induces the further uptake of neutral electrolyte molecules by H-bonds to the chains and other electrolyte molecules [1].

Ionic liquids (ILs) have attracted interest for their use as non-aqueous and non-volatile solvents. Thus, proton conducting ionic liquids (PIL) with acidic cations are promising candidates as alternative non-aqueous electrolytes in PEFCs for operation temperatures above 100 °C. An alternative electrolyte should have an acidity high enough to protonate PBI, a sufficient protonic conductivity and only negligible specific adsorption on Pt.

In this contribution we want to present our first results on the ionic conductivity, the ORR kinetics up to a temperature of 100°C and on the interaction with PBI of a new type of highly acidic PILs with a sulfoethylammonium cation [2]. We have studied 2-Sulfoethylammonium triflate [2-SeA][TfO] and 2-Sulfoethylmethylammonium triflate [2-SeMA][TfO]. There is a slow uptake of [2-SeMA][TfO] by *m*-PBI ($D \approx 10^{-11}$ cm s^{-1}), resulting in a weight increase of ~100 wt%. The conductivity depends highly on the concentration of residual water. Virtually water-free [2-SeMA][TfO] has a conductivity of 4 mS cm^{-1} at 100 °C and with 6 wt% water of 11 mS cm^{-1}. The ORR current density on Pt in [2-SeMA][TfO] with 5 wt% water exceeds the value of H_3PO_4 with the same water content by a factor of 3.

[1] C. Korte, F. Conti, J. Wackerl, P. Dams, A. Majerus, W. Lehnert, *J. Appl. Electrochem.* **45**, 857 (2015)
[2] K. Wippermann, J. Wackerl, W. Lehnert, B. Huber, C. Korte, *J. Electrochem. Soc.* **163**, F25 (2016)

A0805

Stable Aquivion® based MEAs: investigation on catalyst and ionomer

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Abstract

The large scale application of polymer electrolyte membrane (PEM) fuel cell technology requires a reduction of its high cost as well as the improvement of performance and stability. In particular, the automotive fuel cells market needs the PEM fuel cell works under harsh conditions, for an easy thermal and water management, such as high temperatures (i.e. 110 °C or above) and low relative humidification (R.H.) (less than 50%), maintaining a good performance level and low degradation. These operative conditions permit to mitigate the constraints concerning thermal and water management allowing both a simplification and a volume reduction the of the system inside the car with a strong impact on costs and reliability. These extreme conditions require the development of catalysts with a proper resilience to sintering and corrosion. With these aims, the research activities carried out in the last years were focused on the development of various platinum-based eletrocatalysts characterized by a good performance and resistance to corrosion. At the same time, the use of PFSA polymers with shorter side chains and lower equivalent weight (EW), such as Aquivion® PFSA ionomers, represents a valid alternative to improve fuel cell performance and stability under these harsh operative conditions.

In this work, the activity dealing with the cathode catalysts development has regarded the synthesis of Pt-Co/C catalysts with an ordered cubic primitive structure and characterized by Pt segregation in the outermost surface layers to achieve a superior electrocatalytic activity and stability. An optimization of the composition of the catalytic ink was carried out, according to the different ionomer characteristics, with the aim to select the ionomer with the most suitable EW to be used in the catalytic layer in order to reduce the degradation level using a MEA based on Aquivion® polymer with low Pt loading. With this aim, electrochemical characterisations in a single cell of 25 cm^2 and different accelerated stress test procedures were performed. At first, a test was performed in H_2/O_2 at 80°C, 100% RH and 1.5 bar, by cycling the cell potential between 0.6 and 0.9 V for about 10^4 cycles, in order to assess the electrocatalyst stability. Afterwards, an additional accelerated stress test, regarded an open circuit voltage operation in H_2/air, at 80°C, 100% RH and 1.5 bar for about 90 hours, was carried out, with the aim of evaluate the stability of MEA based on Aquivion® polymer with different EW. The stability was assessed by taking into account the variations of performance (I-V curve) and electrochemical parameters such as electrochemical surface area (ECSA) and mass activity (j_m) at the beginning (BoT) and the end (EoT) of accelerated stress test procedures.

A0806

Poly(arylene ether sulfone) containing spirobiindane moieties for electrode binder in solid alkaline exchange membrane fuel cells

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Abstract

Poly(arylene ether sulfones) is robust polymer but have difficulties to control gas permeation properties. In this study, we investigate PES containing spirobiindane groups using a monomer that could form a structure similar to that of polymers with intrinsic microporosity (PIMs). The effect of the spiro-moieties on gas permeability are measured by time-lag method. Compared with poly(arylene ether sulfone) that contain biphenyl moieties instead of spirobiindane moieties, the spirobiindane-based PES shows high gas permeability due to increased fractional free volume, which are related to internal void volume of spirobiindane unit. For anion-conducting electrode binder material, a series of poly(arylene ether sulfone) containing spirobiindane moieties and tetra(quaternary ammonium) pendant groups are also prepared. The products are characterized by ^1H NMR, GPC, and water uptake. The membrane electrode assemblies (MEAs) are prepared by a spray method and single cell performance is evaluated. In a solid alkaline membrane fuel cell test under H_2 and O_2, spirobiindane-based QOH60-SBI40 represented higher current density values in mass transport region and 1.2 times higher power density values than biphenyl-based QOH60-BPS40. The maximum power density of 223 mW cm^{-2} is achieved for the MEA using QOH60-SBI40.

A0807

Investigation and Quantification of Acid Condensation and Cell Conductivity within HT-PEMFC

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Abstract

High-Temperature Polymer Electrolyte Membrane Fuel Cell (HT-PEMFC) utilizes the moderately high conductivity and low volatility of phosphoric acid to be able to operate at heightened temperatures (160 °C). Phosphoric acid doped polybenzimidazole membrane is the most common electrolyte membrane employed for HT-PEMFC. It is a known issue that above its boiling point, phosphoric acid will get lower conductivity due to condensation to higher chain acid. Water formation on the cathode side is believed to shift the condensation equilibrium to the reactant side by humidifying the whole electrolyte system. Yet how far will the phosphoric acid condensation inhibited during HT-PEMFC operation is still unknown. 1D ^{31}P NMR is developed to measure the electrolyte concentration after steady state condition is reached.

In equilibrium condition, phosphoric acid with concentration above 95 wt. % possesses a measurable amount of pyrophosphoric acid. The area ratio of pyrophosphoric acid against ortho-phosphoric acid was recorded using 1D ^{31}P NMR and correlated to concentration inside the membrane. Impedance spectroscopy will be used before the sample is taken to investigate the cell conductivity at every concentration. Influence of various parameters such as cell temperature, current density, and air stoichiometry will be studied.

A0808 (Abstract only, published elsewhere)

Effect of the spirobiindane group in sulfonated poly(arylene ether sulfone) as a polymer electrolyte binder for fuel cell application

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Abstract

Electrode properties determine the membrane-electrode assembly (MEA) performance of fuel cells and are influenced by the materials and processing. A high-performance electrode requires good adhesion between the membrane and catalyst, excellent gas permeability, and good ion conduction. In this work, sulfonated poly(arylene ether sulfone) (SPAES) containing a bulky spirobiindane (Spiro) group is proposed as a new hydrocarbon electrode binder for MEAs. The effect of the Spiro group on MEA performance was compared to that of the common biphenylsulfone. The structural differences between the two binders affected the mass transport region of the current-voltage polarization (related to gas permeation). Also, the degree of sulfonation of the electrode binder contributed to the Ohmic region of the i-V curve. The Ohmic resistance of these hydrocarbon binders was similar to that of commercial Nafion binder. However, the charge transfer resistance of our binders was higher than that of Nafion due to insufficient gas permeability and low proton conductivity. The details will be discussed in presentation.

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A0809

Coating grid metallic contacts with electrosprayed carbon layers

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Abstract

Grid metallic contacts are used as current collectors for some fuel cell and battery types. In proton exchange membrane fuel cells (PEMFC) operated with passive ambient air (air breathing fuel cells), the grid contact is placed at the back of the air breathing cathode in order to collect the current while allowing for the exchange of air and water with the ambient. This type of fuel cell is very appropriate for small portable applications and electronic devices requiring high autonomy. The surface of the metallic grid must be properly coated to avoid dissolution and growth of oxides causing loss of conductivity and ions that may contaminate the catalyst and the membrane. At the same time, the coating should improve water transport to the ambient. Coatings with high hydrophobicity and conductivity are most appropriate to accomplish with these requirements.

This communication shows a study of coatings of carbon layers on metal surfaces deposited by the electrospray deposition technique. The electrosprayed carbon layers are adherent and have highly porous structure that renders them very hydrophobic. Hydrophobicity and good conductivity provide stable electronic contact and fast water transport for passive air breathing PEMFCs. Results are presented of the properties of electrosprayed carbon layers, and their electrochemical stability in contact with sulfuric aqueous electrolyte.

Keywords – contact, carbon, coating, electrospray, corrosion, hydrophobicity

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A0812 (Abstract only)

Additive Effect in PFSA Electrolytes

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Abstract

Polymer electrolyte membrane fuel cells (EMFCs) have been high attracting attention as a next-generation power generation device. The current study is in the high performance with the understanding of the material itself. Perfluorosulfonic acid polymer membrane such as Nafion has high proton conductivity in the humidified condition. A cluster structure in the polymer membrane gives the high conducting path. Proton transport property depends on the degree of sulfonation and mobility in the polymer and on the relative humidity (RH). It is required an electrolyte membrane having high proton conductivity in the low RH and high temperature. The conductivity depends on the density and proton mobility of the sulfonic acid groups in electrolyte membranes. It is known that Nafion membranes have cluster structures (Fig. 1)1) and that they exhibit high conductivities of 0.1 S/cm under highly humidified conditions. If the random cluster structure can be converted into a straight structure, such as a 1D or layer-by-layer structure, the proton conductivity should increase due to an increase in the density and mobility in the straight structure area. Various bases, such as 2-undecylimidazole, 1,2,3-triazole, 1,2,4-triazole, and benziimidazole, can be incorporated into the nanostructure of the Nafion membrane. If they can be removed, the polymer structure will reorganize at the interface between the sulfonic acid groups and the base (Fig. 2).

We prepared a modified membrane using the compound of perfluorosulfonic acid and a heterocyclic material. The heterocyclic material can change a nanostructure in the bulk polymer. After the reorganization of polymer membrane, the heterocyclic material was removed, then a modified membrane was obtained. The proton conductivity and cell performance of the modified membrane were higher than that of bulk PFSA electrolyte membranes. We will discuss about this interesting result in the conference.

Acknowledgments
This work was partially supported by the MEXT program for Development of Environmental Technology using Nanotechnology from Ministry of Education, Culture, Sports, Science and Technology, Japan.

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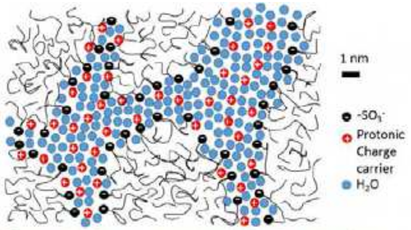

Figure 1. Cluster structure in Nafion membrane.

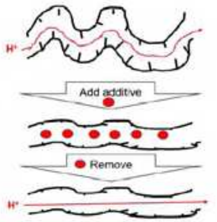

Figure 2. Reorganization of polymer structure using a base additive.

A0813 (Abstract only)

Stability of Highly Sulfonated Polyphenylsulfone Membrane (I)

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Abstract

Polymer electrolyte membrane fuel cells (EMFCs) have been high attracting attention as a next-generation power generation device. Recently, the fluorine-free aromatic-type proton exchange membranes have been developed intensively as alternatives to cutting-edge perfluorinated ionomer membranes such as Nafion, since perfluorinated ionomer membranes suffer from moderate operation temperature and high production cost1).

As a cheap polymer, we are studying a sulfonated polyphenylsulfone (SPPSU) material2-4). High proton conductivity and thermal stability was obtained by the high sulfonation of PPSU polymer and thermal crosslinking processing. However, the mechanical and chemical stabilities in the membrane was not enough. In this paper, to increase the stability in the membranes a composite membrane was investigated.

Acknowledgments

This work was partially supported by the MEXT program for Development of Environmental Technology using Nanotechnology from Ministry of Education, Culture, Sports, Science and Technology, Japan.

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A1001

A Systematic Approach for Fuel Cell Characterization

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Abstract

Characterization of various components, materials, operating conditions and systems is of paramount importance in any research field. This is especially true in the field of fuel cells, where so many material and operating parameters influence the cell performance. The dilemma faced by experimental researchers is twofold; on one hand reliable results are desired and on the other hand the experimental effort needs to be optimized to minimize the required resources.

The one factor at a time (OFAT) method requires holding all input variables (factors) constant except one, whose effect on the output variable (response) is desired to be evaluated. As the number of factors increases, the required experimental effort increases exponentially, thus making it difficult to conduct an experimental campaign for a large number of factors due to limited time and resources. Also, an inherent assumption of the OFAT method, that the output variable is not sensitive to the level at which the constant factors are held, is not always true. When this is the case, the results from the OFAT method can be misleading. The design of experiments (DoE) method not only reduces the experimental effort required by planning the experiments in a systematic way, but also evaluates the main effects (effect of the factor considered in isolation) and factor interactions (effect of factor considered in regard to the level of another factor) for the considered factors. Factor interactions quantify the effect of the level at which the constant factors are held on other factors. Interactions could be very important and cannot be evaluated using OFAT method. The DoE, therefore, optimizes the experimental process itself by reducing experimental effort and improving the reliability of the results. It is the ideal method to use when a screening of large number of factors is desired.

In this work, we quantify and compare the effects of various operating conditions such as anode and cathode gas stoichiometries, operating temperature and current density on single cell performance for four commercially available high temperature polymer electrolyte membrane fuel cell membrane electrode assemblies (HT-PEMFC MEA). DoE is utilized to evaluate the main effects and factor interactions of the above mentioned four factors on the cell voltage (response). Statistical models for the response of each MEA based on the statistically significant main effects and factor interactions are developed using linear regression analysis [1].

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A1002 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Challenges and Possibilities of EIS on PEMEC

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Abstract

Electrochemical impedance spectroscopy (EIS) has been proven a very strong electrochemical characterization tool in electrochemical research in general and in the areas of fuel cell and battery research in particular. However, this is not the case for polymer electrolyte membrane electrolysis cells (PEMEC), for which relatively few reports on the application of systematic EIS studies are available. Asking experienced researchers in the field about why, the answer has often been that these cells reveals too much electrical noise to obtain EIS with acceptable quality due to O_2 and H_2 bubble formation.

Our view of the ideal structure of a PEMEC is that there ought not to be any effect of gas bubbles on the EIS as the current paths should not be disturbed by bubbles. However, we also see noise in our spectra, but the level of noise varies very much from one cell type to another. We have studied noise on three types of PEMEC and two type of alkaline electrolysis cell (AEC) for comparison. A characteristic feature of the studied PEMEC is that there is no or very little noise seen in the EIS in the frequency range above ca. 500 Hz and again not much noise below 5 Hz.

Our hypothesis is that this phenomenon is related to bubbles that are adhering to active sites of the electrocatalyst. When the catalyst layer is subjected to alternating current (AC) during the EIS then, in the PEMEC case, the O_2 pressure and volume of the bubbles growing on the catalyst layer will oscillate with the frequency of the AC. The volume change will naturally change with the frequency. The longer the wave period (the lower the frequency) is, the bigger is the change in the amount of O_2 production during an AC period. In other words, a vibration of the O_2 bubble size and internal pressure must be induced by the AC current. Thus, we imagine that at some low frequency, the bubbles adhering to the catalytic layer get more unstable and detach with an uneven rate from the catalyst surface. This causes the noise observed.
Presumably, the structure and the properties of the interface of the catalyst to the liquid aqueous phase as well as the operation parameter will affect the frequency range and the size of noise in the EIS.

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A1003

Multilayer Coating for Aluminium Plates in Polymer Electrolyte Fuel Cells

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Abstract

Portable power systems up to 100 watts, including for example chargers for outdoor applications have to meet stringent requirements regarding volumetric as well as gravimetric power density.
Bipolar plates constitute the main share of the total stack weight, volume and costs. Aluminium as bipolar plate material is one of the most attractive metals among all other metallic-based alternatives, due to its light weight, its high mechanic strength as well as its low electric bulk resistance. However, one major disadvantage can be found in the low corrosion resistance of this material.

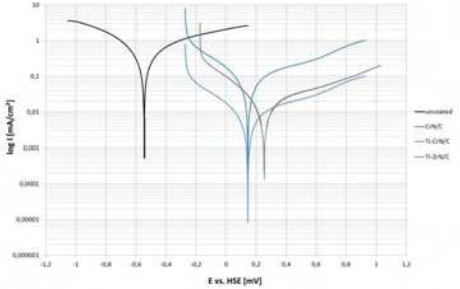

Figure 1: Potentiodynamic curves for bare and coated 1050A

The goal of this study is the development of a multi-layered coating for the surface of aluminium by physical vapour deposition (PVD) which exhibits high electrical conductivity and corrosion resistance. The coatings were analysed with the help of electrochemical methods as linear sweep voltammetrie (LSV) (Figure 1) as well as an in-house contact resistance measurement apparatus.

A1004

Performance analysis of lab-scale Polymer Electrolyte Fuel Cells at various operation parameters

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Abstract

The performance of a polymer electrolyte fuel cell (PEFC) is strongly influenced by its actual operating conditions, i.e. temperature, fuel flow, fuel utilization and relative humidity. Electrochemical impedance spectroscopy (EIS) has proven its applicability for recording polarization processes with different time constants. However, the deconvolution of different processes overlapping in the frequency domain and the identification of the underlying physicochemical mechanisms remains challenging. Systematic and comprehensive parameter variations combined with high resolution deconvolution techniques such as the distribution of relaxation times (DRT) are required to resolve the polarization processes and set up physicochemical meaningful models. The benefits of this approach have been successfully demonstrated for high temperature fuel cells and lithium-ion batteries [1],[2].

For the first time, we will present this approach for low-temperature PEFCs. Impedance measurements in a wide frequency range (100 mHz to 1 MHz) have been conducted on 1 cm² commercial MEAs (Greenerity H500EL2). The impedance data quality was ensured by an improved Kramers-Kronig validity test [3]. The combination of small active electrode areas (1 cm²) and high gas flow rates (200 ml/min) eliminates lateral gradients in temperature, gas composition and current density. Hence, we trigger a homogenous operational state over the entire cell area during one measurement, sharpening the peaks in the DRT and increasing the resolvability of individual processes in the impedance spectrum. Stepwise variations of single operating parameters as current density, temperature, humidity and gas composition at anode and cathode provide information about the parameter dependencies of the polarization processes.

A1005

Electron Paramagnetic Resonance Spectroscopy Studies of Transition Metal Ion-Chelating Ordered Mesoporous Carbons for Oxygen Reduction Catalysis

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Abstract

We systematically compare EPR spectra for a series of iron-chelating ordered mesoporous nitrogen-functionalized carbon (Fe-OMC) catalysts. This type of catalyst has shown considerable activity for the oxygen reduction reaction (ORR) in PEMFCs[1] and the active site is believed to consist of iron-nitrogen (Fe-N_x) chelates bound to the carbon matrix.[2-3] We are able to distinguish different features in the EPR spectra and correlate these with results obtained by complementary methods such as EXAFS and fuel cell tests of their catalytic activity.

A1006

Effect of Platinum Oxides on Reversible and Irreversible Degradation in Polymer Electrolyte Fuel Cells

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Abstract

At the current state of art in Polymer Electrolyte Fuel Cell (PEFC) technology, there is no competitive alternative to Platinum or Platinum alloys as electrocatalyst materials to promote sluggish oxygen reduction reaction (ORR). However, Platinum materials tend to form oxides above 0.70 V vs RHE, which are suspected to affect ORR electrochemical activity and long-term stability [1]. Several studies have been dedicated in the past to the analysis of Platinum oxides [2], suggesting a high level of complexity.

In the first part of this work, experimental analysis in membrane electrode assembly (MEA) is performed to get insight into the effect of Platinum oxides on ORR activity. First, experimental analysis is performed in inert environment (fully saturated Nitrogen). Oxides are formed via potential holding at 0.85V vs RHE or via potential cycling between 0.7V and 0.85V vs RHE, according to [3]. Oxide charge is quantified by linear sweep voltammetry in the potential range between 0.85V and 0.4V vs RHE. Results indicate the presence of two dominant families of Pt oxides. Additionally, a procedure is obtained to selectively form each type of oxide, by adopting potential holding or cycling. In a second step, the experimental setup is improved to quantify the effect of Platinum oxides on ORR activity and the following procedure is adopted. Oxides are formed in inert atmosphere, consequently air is enabled at the cathode side and potential is set to 0.85V. ORR current is recorded for 600s, after which the operation is switched to nitrogen again and oxides are measured via linear potential sweep. It is observed that oxide formation does not depend on oxygen concentration. Additionally, the selective effect of main oxide families on ORR is quantified.

In the last part of the work, different accelerated stress tests for electrocatalyst degradation based on potential cycling are compared, with the intent to distinguish the effect of each type of Platinum oxide on stability. Standard DOE test (triangular sweep between 0.6V and 1.0V at 50 mV s^{-1}) is thus modified for this scope.

This work was supported by the FCH-JU FP7 project Second ACT (EC GA 621216).

A1007

The water vapor equilibrium in the phosphoric acid – water system

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Abstract

For high temperature polymer electrolyte fuel cells (HT-PEFCs), phosphoric acid (PA, H_3PO_4) is still the state-of-the-art electrolyte material, since it shows excellent proton conductivity [1] in the temperature range between 373 K and 473 K. Another advantage is the chemical compatibility with polymers which is exceptional considering the acidity of the acid (pH < 0 unless highly diluted). However, care has to be taken that strongly dehydrating conditions have to be avoided when using PA in HT-PEFCs, since enhanced degradation of the catalyst [2] appears for these conditions. This can be explained with the formation of PA condensates [3], which are formed at low water contents and high temperatures, typically above 390 K. It is therefore crucial to avoid the formation of PA condensates by adjusting the operating conditions of a HT-PEFC.

In this work, PA is exposed at a constant water vapor pressure of 10 kPa until equilibration is reached at different temperatures in the range between 333 K and 433 K. The equilibration time and the evolution of the electrical parameters during the equilibration process are discussed with respect to the water content at the end of the tests. The results not only show the formation of PA condensates for temperatures above 413 K, but also indicate the existence of a local PA hemihydrate structure occurring in the liquid before condensation occurs.

Keywords- Phosphoric acid, conductivity, water vapor pressure, electrode polarization

A1008

Investigation of PEMFC damage mechanisms due to cyclic freeze-thaw attack

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Abstract

During cyclic frost exposure the remaining product water within fuel cells after shutdown can form ice lenses, which for their part could lead to various damage phenomena within the membrane electrode assemblies (MEA). Generally, a MEA could be considered as a single multilayer system with a different pore structure and a pore size distribution that could range from a few nanometers (membrane) to several tens of micrometers (gas diffusion layer - GDL) (Figure 1 - *left*). This has a significant impact on the moisture distribution inside the MEA itself and furthermore, affects the freezing point of the pore water depending on the pore size distribution. Thus, the residual water can exist at sub-zero temperatures in different modifications simultaneously. With increasing number of freeze-thaw cycles (FTC) further redistribution of the liquid water takes place. Those water movements could lead to additional formation of ice lenses and thereby cause frost damages such as frost heaves, delamination effects of the MEA as well as physical damages of the membrane (Figure 1 - *right*). This conform with considerable performance loses of the fuel cell stack and might be observed already after only a few FTC.

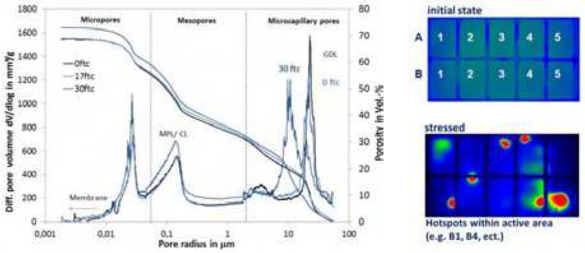

Figure 1: *left*: Pore size distribution of a MEA after different FTC´s; *right*: IR-Screened MEAs

The main aim of this study is therefore not only to identify the frost induced failure models and damage patterns of the MEA but also to receive a better understanding of its underlying mechanisms. The results could contribute to a reduction the complexity of shutdown procedure preventing freezing in today's fuel cell cars according to the state-of-the-art.

A1009 (Abstract only, published elsewhere)

Effect of mechanical degradation and chemical degradation on PEMFC stability

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Abstract

Lifetime of PEMFC is critical issue for its application, which is related with the stability of key materials, electrode structure, water management and also operation condition. This work is mainly focused on the investigation of MEA decay concluding mechanical degradation and chemical degradation. Long time operation of fuel cell under different relative humidity is conducted to analyze the membrane mechanical intension, and how to eliminate the mechanism degradation is disclosed initially through lifetime experiments. Chemical degradation of MEA under accelerated stress test is studied and some strategies to mitigate the attack from free radical are attempted, such as adding free radical scavengers to membrane and catalyst layer.

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A1010 (Abstract only)

INVESTIGATION OF $(La_{1-X},Ca_X)(Ni_{0.25}Fe_{0.25}Cr_{0.25}Co_{0.25})O_3$ FOR SOLID OXIDE FUEL CELLS CATHODE MATERIALS

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Abstract

Solid Oxide Fuel Cells (SOFCs) have gained tremendous amount of attraction as an alternate source of electrical energy in the recent decades. The purpose of this research is to develop cathode material for use in low temperature solid oxide fuel cells which demonstrates desired properties of high electrical conductivity, excellent chemical stability, desirable thermal expansion characteristics and which can be easily manufactured by sintering in conditions acceptable with other cell components. In the present research, stoichiometry's of $La_{1-x}Ca_x(Fe_{0.25}Co_{0.25}Ni_{0.25}Cr_{0.25})O_3$ (x=0,0.1,0.2,0.3) (LCFCNC) were synthesized by using polymerizable precursor method proposed by Pechini. The structure and morphology of the samples were characterized by X-ray diffraction and Scanning Electron Microscopy. X-ray diffraction results revealed the formation of single phase orthorhombic distorted perovskite structure in all the samples. SEM analysis showed the densification of the pellets with the addition of calcium which was in accordance with the sintered density calculations at 1100°C. Electrical conductivity of the material samples was measured in air in the temperature range of 100-900°C. Study of this data showed an increasing trend in electrical conductivity with the increase in amount of calcium doped on A-site up to 20mol% and the sample doped with 30mol% of calcium showed sharp increase in electrical conductivity reaching a maximum of 50 S/cm at 800°C, showing that the developed materials can be used as cathode materials in low temperature SOFC.

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B0201 (Abstract only, published elsewhere)

Oxygen Electrocatalysis on Transition Metal Spinel Oxides

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Abstract

Exploring efficient and low cost oxygen electrocatalysts for ORR and OER is critical for developing renewable energy technologies like fuel cells, metal-air batteries, and water electrolyzers. This presentation will presents a systematic study on oxygen electrocatalysis (ORR and OER) of transition metal spinel oxides.[1] Starting with a model system of Mn-Co spinel, the presentation will introduce the correlation of oxygen catalytic activities of these oxides and their intrinsic chemical properties. The catalytic activity was measured by rotating disk technique and the intrinsic chemical properties were probed by synchrotron X-ray absorption techniques. It was found that molecular orbital theory is able to well-explain their activities.[2,3] The attention was further extended from cubic Mn-Co spinels to tetragonal Mn-Co spinels and it was found that the molecular theory is again dominant in determining the catalytic activies. This mechanistic principle is further applied to explain the ORR/OER activities of other spinels containing other transition metals (Fe, Ni, Zn, Li, and etc.).

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

B0202

Composition-Stability Relations for Non-Noble Metal Catalysts for Polymer Electrolyte Fuel Cell Cathodes

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Abstract

Polymer electrolyte fuel cell (PEFC) commercialization would be significantly enhanced if the Pt-based catalysts needed to catalyze the oxygen reduction reaction (ORR) at the cell's cathode were substituted with inexpensive materials based on abundant metals. Such non-noble metal catalysts (NNMCs) have been studied since the 1960s, and the ongoing refinement of their syntheses has recently led to ORR-activities and high-current performances commensurate with those of Pt-catalysts. However, these qualities are accompanied by a poorly understood, fast deactivation that ultimately prevents NNMCs' device implementation. In order to shed light on the relative impact of the different mechanisms discussed in the literature (e.g., radical attack, demetallation) on the overall instability and their likely relation with the materials' composition, there is an urgent need to develop synthesis strategies allowing for a fine control of the catalyst's speciation.

With this motivation, we have developed a novel NNMC-preparation approach in which an inexpensive precursor and polyacrylonitrile are used as the porous template and C- / N-precursor, respectively, and a complex of Fe^{2+} with 1,10-phenanthroline acts as the metal source. The initial mixing of all precursors is followed by heat treatment and acid washing, along with a second heat treatment that improves the catalyst's ORR-activity (assessed by rotating disc electrode voltammetry). Tuning of the synthesis parameters (e.g., precursors' ratios, heat treatment temperature) results in catalysts with different (micro-)porous- and N-contents, unveiling the importance of these variables on the corresponding ORR-activity. Finally, polymer electrolyte fuel cell tests unveil that the most active NNMC displays a promising, initial ORR-activity ($\approx 10\ A \cdot g_{NNMC}^{-1}$ at 0.8 V) that promptly decays during a potentiostatic test at 0.5 V – a behavior that is tentatively assigned to the flooding of the excessively-microporous NNMC catalyst layer.

B0203 (Abstract only, published elsewhere)

Insights into Perovskite Nano-Catalysts as Oxygen Electrodes for the Electrochemical Splitting of Water

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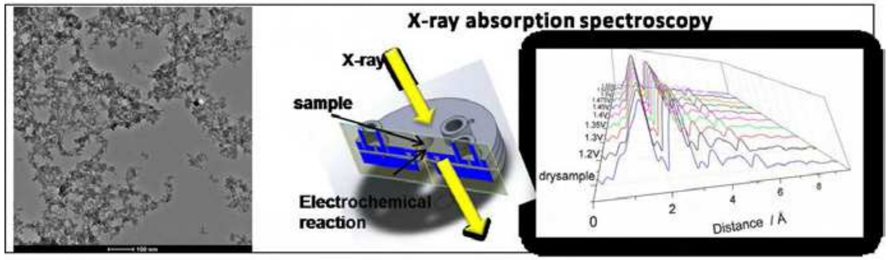
Abstract

In recent years, electricity-driven hydrogen production by electrochemical splitting of water has received particular attention because of its potential applicability in decentralized energy storage concepts.(1) Most of the efforts have been focused on the electrochemical reaction occurring at the anode side (2), the oxygen evolution reaction (OER), since it is source of large overpotentials.

Advances in computational studies and in in situ characterizations can now offer novel insights into the OER mechanism, revealing new perspective in the search for advanced materials. In this study, we couple a cutting-edge synthesis method to produce highly active OER nano-catalysts with time resolved X-ray absorption spectroscopy (XAS) measurements able to capture dynamics of the catalyst electronic and local structure during operando conditions. The use of nano-catalysts not only allows achieving outstanding performance, but also reveals electronic and structural changes at the catalysts surface (given the high surface to bulk ratio of nanoparticles) never observed before (3-5).

At present most of the fundamental studies on OER catalysts have been conducted using bulk techniques and materials with low surface area, which is a questionable approach considering that the OER is a near-surface reaction. In here we show that substantial and mostly irreversible chemical and structural changes take place on the catalyst surface at potentials where the OER occurs, opening new views on the OER mechanism.



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B0204 (Abstract only, published elsewhere)

Polymer derived Fe-N/C Electrocatalysts for the Oxygen Reduction Reaction

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Abstract

Fe-N/C catalysts are alternative catalyst materials for the oxygen reduction reaction (ORR) in basic and acidic environment. However, further development is required in order to improve both their activity and stability. In this context, identification of the active sites in these materials is of outmost importance in order to develop strategies for a) active site accumulation during synthesis and b) active site stabilization under electrochemical conditions.

In this study, several mesoporous Fe-N/C materials showing different ORR activities have been synthesized. The materials are in terms of composition and structure characterized by several techniques including scanning electron microscopy, transmission electron microscopy, energy dispersive X-ray spectroscopy, X-ray photoelectron spectroscopy, nitrogen physisorption, X-ray diffraction and elemental analysis. ORR activity was determined by RDE experiments. In a first step, underlying composition-structure-activity correlations were determined revealing significant structural differences between the different Fe-N/C materials. In a second step, the coordination and electronic structure of the Fe present in the materials was investigated by X-ray absorptions spectroscopy at the C and N K- edge as well as at the Fe L2,3-edge. The data confirm the presence of different Fe species in the Fe-N/C catalysts and their influence on the ORR is discussed.

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B0205 (Abstract only)

Graphene Hybrid Electrodes for PEM Fuel Cells

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Abstract

The increase on the Platinum (Pt) catalyst efficiency in Polymer Electrolyte Membrane (PEM) fuel cells is the one key factor for a commercial introduction of fuel cells to the transportation systems. In the state of the art, the Pt loading for the cathode electrode varies between 0.4-0.5 mg/cm^2 and the maximum Pt efficiency is 2 kW/gPt. In this work, carbon nanotube (CNT), carbon black (CB) and carbon nanofiber (CNF) were mechanically mixed and decorated with Pt nanoparticles by chemical polyol process as the catalyst substrate for PEM fuel cell electrode. XRD, TEM (Figure 1a) and electrochemical measurements such as cyclic voltammetry (CV) (Figure 1b) and hydrodynamic oxygen reduction reaction were evaluated as the ex-situ characterizations. Membrane electrode assemblies were prepared by hot pressing with Nafion® 212 membrane and commercial anodes. We succeeded in increasing the Pt efficiency up to 3 kW/gPt.

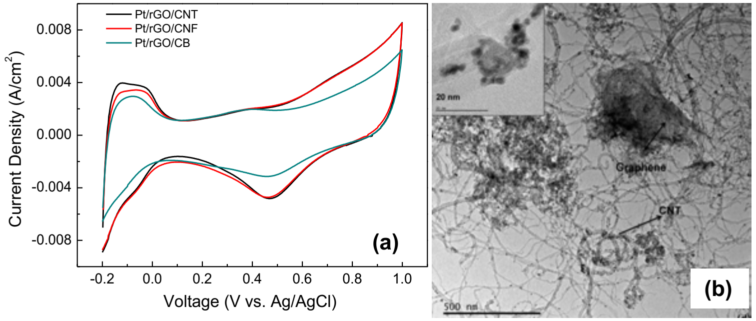

Figure1. a) CV votammograms ofPt hybrid electrocatalyst b) TEM image of Pt/CNT electrocatalyst

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B0206

Graphene and Graphene Oxide in low temperature fuel cells for enhanced performance

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Abstract

The barrier and electrical properties of graphene and graphene oxide have been well documented with significant discussion around their efficacy as additives in low temperature PEM fuel cells. Graphene oxide has been demonstrated to be an ionic conductor but impermeable to dry gases and electrons. Graphene is an excellent in-plane electronic conductor but impermeable to all species apart from protons through the plane.
Here we will describe the work carried out at Manchester University incorporating Graphene, Reduced Graphene Oxide (RGO) and Graphene Oxide into PEM fuel cell Membrane Electrode Assemblies (MEA's).
Reduced Graphene Oxide and boron and nitrogen doped RGO has been added to/replaced the carbon in the microporous layer adjacent to the cathode catalyst and provides enhanced fuel cell performance (up to 84% improvement in power density) due to greater electrical conductivity.
Graphene Oxide (GO) has been added to the Nafion binding layer in a Direct Methanol Fuel Cell (DMFC) providing additional tortuosity and hence reduced methanol permeability, the optimisation of the GO loading has led to superior performance(up to 50% improvement in power density) when compared to a standard DMFC (Figure 1).
The addition of CVD graphene onto the MEA of a DMFC has demonstrated no change in proton conductivity but lower methanol permeability, supporting the hypothesis of CVD graphene as a proton conductor and again increasing the power density achievable (30% in the initial experiment) by a DMFC.

B0207 (see B0202)

B0209 (Abstract only)

Effects of surfactant on the structure of nanomaterials for low temperature fuel cell application

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Abstract

The sol-gel technique is a versatile and relatively simple method easily adapted to synthesize complex metal oxide formulations. The sol-gel technique takes advantage of the structural directing properties and templating characteristics of non-ionic, anionic and cationic surfactant to produce porous Iridium oxide, with samarium doped ceria (SDC) nanoparticles. The nano-powders were calcined at a temperature of 950 °C, and the crystalline nanostructures and compositions were characterized by high resolution transmission electron microscopy and X-ray diffraction. Textural characteristics and particle morphology were respectively characterized by Nitrogen sorption at 77.5 K and scanning electron microscopy. The electrochemical properties were characterised by using a Kittec squadro muffle furnace and a SOFC testing equipment, with air and hydrogen as the gases used. The nature of the surfactant influenced particle morphology, pore diameter, pore size, crystallite size, surface area and electrochemical properties.

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

B0401

Oxygen Reduction Activity and Durability of Nanoparticulate Pt Supported on Boron Carbide

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Abstract

Using standard deposition techniques, we have catalysed high surface area carbon-rich boron carbide (BC) powders with Pt nano-particles and characterised them for ORR activity and stability. Electrochemical characterisation includes ORR activity as assessed by RDE measurements and accelerated durability testing in aqueous electrolyte.

RDE measurements provide evidence that Pt/BC provided roughly twice the activity towards ORR at high potentials when compared to Pt/C, whilst simultaneously showing significantly improved cycle stability within the operational voltage window of a PEMFC.

Advanced x-ray characterisation (XANES, EXAFS, XPS) were utilised to further elucidate the increase in ORR activity for Pt/BC. EXAFS measurements confirmed that the morphology of Pt/BC is similar to Pt/C, while XPS unveiled a relative shift between C 1s and Pt 4f core levels, which indicates a stronger electronic interaction between catalyst and support, and XANES was used to determine the Pt d-band occupancy of the supported catalysts in electrochemical environment.

B0402 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Electrochemical characterization of pre-conditioning processes of electrospun nanofiber electrodes in polymer electrolyte fuel cells

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Abstract

Structure innovation and optimization of polymer electrolyte fuel cell (PEFC) catalyst layers is instrumental to improve catalyst utilization and effectiveness. Electrospinning technique has been recently used to fabricate nanofiber electrodes for PEFCs; and improved performance compared to conventionally electrosprayed electrodes has been reported. However, working details of electrospun nanofiber electrodes and underlying causes of the performance improvement are incompletely understood yet. Here, we investigate the change of the electrochemically active surface area (ECSA) and electrochemical impedance spectroscopy (EIS) during the pre-conditioning process, and compare steady-state performance of electrospun nanofiber electrodes with conventionally electrosprayed electrodes at wide range of operating conditions. During the pre-conditioning process, ECSA of electrospun nanofiber electrodes increases, and both mass transfer resistance and charge transfer resistance decrease monotonically. At steady state, electrospun nanofiber electrodes outperform conventionally electrosprayed electrodes (both electrodes have a Pt loading of 0.1 $mg.cm^{-2}$ at anode and cathode) at 80°C due to lower activation and mass transport losses. In contrast, conventional electrodes have higher cell voltages at high current densities at 60°C and 70°C in high RH range, in which case electrospun nanofiber electrodes have larger mass transport losses.

Keywords: Polymer electrolyte fuel cell, electrospun electrodes, pre-conditioning, voltage losses.

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B0403 (Abstract only)

Oxide-supported PEFC Electrocatalysts

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Abstract

Even after the start of the commercialization of fuel cell vehicles, further improvement of electrocatalysts is still desired for the next-generation PEFCs. While the Pt-based electrocatalyst supported on carbon black is commonly used, development using alternative electrocatalyst support materials is helpful especially to improve the durability of electrocatalysts. Among various degradation mechanisms, start-stop-cycle up to a high potential can cause carbon corrosion related degradation, one of the major degradation mechanisms of PEFCs. This paper gives an overview on the materials design principles to tailor oxide-supported PEFC electrocatalysts. In general, as thermochemically calculated, oxides such as SnO_2 and TiO_2 could be alternative support materials to the conventional carbon black [1-5]. It has been revealed that doped SnO_2 is a promising electrocatalyst support material with the 60,000-cycle durability between 1.0 and 1.5 V_{RHE}, which has been verified for electrocatalysts and MEAs. Recently, we have expanded this concept to apply various oxide-based electrocatalysts. "Core-shell support" concept has been demonstrated using Ti-containing complex oxides. Alloy electrocatalysts such as Pt-Co and Pt-Ni could be successfully prepared on such oxide supports. Conductive fillers including vapor-grown carbon fibers and carbon nano-tubes (CNT) have been successfully applied to improve both electrochemical performance and voltage cycle durability. Design concepts using oxide support materials are compiled and proposed to tailor robust and active PEFC electrocatalysts.

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B0404 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Investigation of Carbon Nanofiber Supported Platinum Electrocatalysts for the Use in PEM Fuel Cells

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Abstract

In this work, an optimized preparation process, which results in polymer electrolyte membrane fuel cell (PEMFC) electrodes with ultra-low platinum loading is presented. High and stable PEMFC performance is achieved, while the anode Pt loading is reduced to 10 $\mu g_{Pt}.cm^{-2}$. All tested anodes, cathodes (except Quintech) and MEAs were self-prepared by using Nafion 212 membranes and Freudenberg H23C8 gas diffusion layers. The anodes catalyst deposition was prepared via pulse electrodeposition process on a plasma pretreated corrosion stable carbon nanofiber (CNF) support (2% Pt/CNF). These anodes are compared to the anodes prepared with a commercial 10% Pt/Vulcan XC72R (HiSPEC 2000, Johnson Matthey). The cathodes used for both types of anodes were Quintech (BC-H225-10F) with 1 $mg_{Pt}.cm^{-2}$ and the more active self-prepared cathodes with a commercial catalyst 40% Pt/Vulcan XC72R (HiSPEC 4000, Johnson Matthey) at 0.36 $mg_{Pt}.cm^{-2}$. In-situ performance tests, cyclic voltammetry (CV) to determine the electrochemical active surface area and electrochemical impedance spectroscopy to analyze the electrode characteristics were carried out. An accelerated stress test (AST) of the anodes (1000 triangular cycles E = 0.4 – 1.4 V vs. reversible hydrogen electrode (RHE) at a rate of 1 $V.s^{-1}$) reveals that Pt/CNF preserve and even enhance their performance due to catalyst poisoning, which was gradually removed during AST, while the anodes with a commercial catalyst degraded severely. Pt/CNF anodes started to decrease their electrochemical active surface area (ECSA) when a cleaning procedure was applied preliminary to AST.

Keywords- PEM fuel cell, electrode preparation, pulse electrodeposition, carbon nanofibers, catalyst, accelerated stress test, cyclic voltammetry, electrochemical impedance spectroscopy

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B0405

Carbon support modification for high performance low Pt loaded cathodes

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Abstract

Reducing the platinum loading in fuel cell catalyst layers is critical for mass market commercialization of hydrogen powered vehicles. However, at low platinum cathode loadings of about 0.1 mg_{Pt}/cm^2_{geo}, it is assumed that various kinetic and transport resistances limit the performance of the fuel cell at high current density. The origin of these voltage losses has not been unambiguously resolved so far.

In this study, we present that the modification of commercially available Vulcan type carbon with NH_x groups significantly improves ionomer distribution during electrode preparation. The in-house prepared catalysts on modified and pristine carbon are fully characterized by TEM, TGA, XPS and elemental analysis. By rotating disc electrode measurements, we show that the surface modification does not affect the intrinsic ORR activity of the catalysts. The pressure independent oxygen transport resistance, which is mainly attributed to oxygen transport in the ionomer film, is determined from limiting current measurements and reveals a lower resistance for the modified support. By systematically decreasing the ionomer to carbon ratio (I/C) from 0.65 to 0.25 we find a maximum H_2/air performance at 0.4, where an optimum between ionomer thick-ness and proton resistance is obtained.

This work shows that not only ionomer thickness - but more importantly - ionomer distribution is the key to high performance low Pt loaded electrodes.

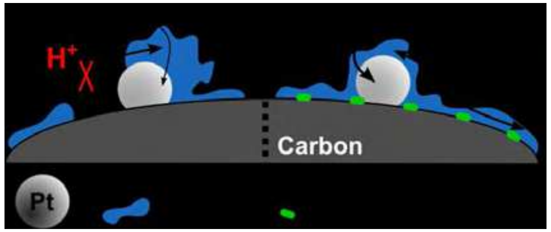

Figure 2. Illustration of the ionomer distribution in the cathode. Inhomogeneous ionomer distribution with bad proton transport and high local oxygen transport resistance (A). Carbon functionalization leading to a better ionomer distribution with improved proton conductivity and lower O_2 mass transport resistance (B).

B0406 (Abstract only)

Recent Developments of Electrocatalysts and Membrane Electrode Assembly in DICP

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Abstract

Owning to the virtue of high efficiency, no pollutant emission, low operating temperature, Proton Exchange Membrane Fuel Cells (PEMFCs) have drawn massive attention recently. However, the cost and durability still remain the thresholds to the commercialization of PEMFCs. To reduce the cost and expand the lifetime both while, DICP DNL 0301 has devoted much effort in the electrocatalysts and membrane electrode assembly (MEA). Aimed at increasing the activity and stability of state-of-the-art Pt/C electrocatalyst, Hollow PtCu nanoparticles of about 6.9 nm supported on Vulcan XC-72 were synthesized by a one-pot method in the absence of surfactants. The enhanced ORR performance was attributed to the reduced adsorption strength of OH_{ads} on surface of PtCu nanostructures resulted from the hollow-induced lattice compression and subsurface alloy effect. Besides, Pd@Pt nanostructure was fabricated through the reduction of K_2PtCl_4 by dissociated hydrogen at room temperature without the assistance of either surfactant or high-boiling point solvent. The remarkable electrocatalytic performance was attributed to the lattice compression effect and electron transfter impact between Pd_{core} and Pt_{shell}. Further, the ordered electrodes were prepared to decrease the Pt loading of MEA. TiO_2 nanorod arrays (NRs) were hydrothermally grown on carbon paper and converted into TiO_2-C NRs by heat treatment at 900^oC under methane atmosphere. Then, platinum nanoparticles were sputtered onto the TiO_2 NRs by physical vapor deposition to produce Pt-TiO_2-C. The single cell can generate power of 11.9 kW g_{Pt}^{-1} when the as-prepared electrode with ultra-low platinum loading (28.67μg cm^{-2}) is employed as the cathode. Meanwhile, a nanostructured ultrathin catalyst layer (CL) based on open walled cobalt-doped Pt nanotube arrays (NTAs) has been constructed through a hydrothermal and physical vapor deposition method. Serving as cathode, a maximum power density of 14.38 kW g_{Pt}^{-1} was achieved with a cathodic Pt loading of 52.7 μg cm^{-2}, which is 1.7 fold higher than the conventional CCM. Moreover, the electrospun electrode was prepared with 5 wt. % polytetrafluoroethylene (PTFE), and the maximum power density of the electrospun (E_spun) electrode can reach 696 mW cm^{-2} at Pt loading of 87 μg cm^{-2}. The enhanced performance was attributed to the optimized triple phase boundary in the porous electrode. In addition, electrostatic spraying technology was developed to fabricate MEA, and the corresponding H_2-Air PEMFC can obtain the average voltage of 0.67V and at 1 A cm^{-2}.

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B0407

Adhesion Behavior of Nafion Solution at Dispersive Phase Boundaries

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Abstract

A key component of proton exchange membrane (PEM) electrolyzers (EL) and PEM fuel cells (FC) is the membrane electrode assembly (MEA). The electrodes, which consist basically of precious metal and Nafion polymer, are produced by means of different manufacturing processes. Each of these processes has an impact on the electrode structure which is important for the electrode efficiency. One approach of the current research is to increase the efficiency by increasing the level of structure. But the dependencies between the electrode structure and the molecular interactions during the manufacturing process which form this structure are still not fully understood. One aspect of this structure formation is the adherence behavior of Nafion solution at dispersive phase boundaries. In this work the adhesion behavior of aqueous-alcoholic Nafion solutions at different phase boundaries was researched by measuring the static and dynamic surface tension as well as the receding angle. In addition, ATR-IR, and ^{19}F-NMR measurements were performed to obtain detailed information about the molecular interactions. A Nafion free solution shows no adherence on a Polytetrafluorethylene layer (PTFE). However, a Nafion containing solution shows a clear adhesion on the same layer (but only at a critical alcohol concentration). The application of the before mentioned methods provides an understanding of the interaction between Nafion and alcohol and an idea of the adhesion between dispersion and PTFE. These are important information to get a better understanding of the adhesion behavior of Nafion at a dispersive phase boundary, for example during the coating process for manufacturing MEAs.

B0408 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Ultra-Low Pt Stabilises Fe-N-C PEM Fuel Cell Cathode Catalysts

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Abstract

Keywords: Hybrid cathode catalyst, stabilisation of Fe-N-C, PEM fuel cells

Currently, Pt and Pt-alloy nanoparticle electrocatalysts supported on high surface area carbon are used to accelerate the reaction rates at the cathode and anode of PEMFCs. The high cost and restricted resources of Pt must be taken into account for the large-scale deployment of PEMFCs, and the strong reduction or replacement of Pt (and platinum group metals, PGM) by more abundant elements for catalysing the ORR would have a large positive impact on the cost and sustainability of PEMFCs. Recently, several breakthroughs have been reported in the field of non-PGM catalysts made from iron (cobalt), nitrogen and carbon, with much improved activity and power performance at their beginning-of-life. Their durability in an operating fuel cell is, however, still insufficient, and to bring these novel non-PGM catalysts into viable PEMFC stacks, the highest activity reported must be combined with a stable behaviour for thousands of hours in an operating PEMFC.

In recent work, we functionalised Fe-based non-PGM catalysts with an ultra-low content (1-2wt %) of Pt in various ways and investigated the resulting hybrid catalysts for their activity and durability. One specific approach for such Fe-N-C@Pt hybrid catalysts already showed improved stability [1]. This approach was further investigated, using different Pt salts and Pt-salt reduction strategies in order to optimise the catalytic activity and/or stability of Fe-N-C@Pt hybrid materials.

Typically, a Fe-N-C material was first synthesised via pyrolysis of Fe-acetate, phenanthroline and ZIF-8 [2]. Hybrid catalysts were prepared by depositing 1-2wt. % Pt and further treatment in H2 atmosphere. We specifically studied the influence of H2 concentration during the Pt reduction step on the ORR activity and stability of this series of hybrid catalysts, and successfully correlate the H2 concentration and their activity/stability. For example, the activity of an optimised hybrid Fe-NC catalyst with 2wt% Pt shows no activity decrease after 200 h at 0.5 V. In another approach, the thermal reduction of Pt salts in H2/N2 was replaced by a chemical reduction, using formic acid [3]. The iron speciation, key to the activity of Fe based catalysts, was investigated with Mössbauer spectroscopy. Pt or Fe coordination and oxidation states as well as particle size were characterised by XANES, XPS, XRD and SEM. The reducing method as well as the Pt precursor strongly influence the oxidation state of the Pt, which in turn impacts the performance and stability of the hybrid catalysts.

Acknowledgements

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B0409 (Abstract only, published elsewhere)

Hydrogen and Oxygen Evolution on Alloys of Transition Metals of Period 4

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Abstract

The electrocatalytic activity of alloys of transition metals of period 4, such as Nickel, Copper, Cobalt and Zinc used for the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) in an alkaline media was studied. In this study, different alloys from alkaline and acidic solution were electrochemically deposited and tested for long term electrolysis. A wide alloy composition range was achieved by controlling the applied current and bath composition. One of the problems observed during the usage of Ni-based materials for water electrolysis is the loss of activity as indicated by the time variation of the cathode potential, It is well know that some electrocatalyst absorbs atomic hydrogen that depresses the surface M-H bond strength, thus giving rise to time-dependent performance which can generate erroneous conclusions about the performance when comparing polarization curves (Tafel plots). As in the case of the H_2 cathodes, some anodes also exhibit potential variation with time. Then, galvanostatic experiments were carried out at room temperature using 6 M of KOH as supporting electrolyte whilst the applied current density was 200 mA/cm^2, as is the case of industrial practice. XRD patterns were also obtained in order to characterize the atomic and molecular structure of the alloy coated electrodes. It was found that the cell potential of the cell was stable over 240 hs electrolysis. We also found that the cell potential, and as a consequence, the overpotential of HER and OER were lower than observed for Nickel 99.99 %, the traditional material used in alkaline electrolzsers. The alloy coating good electrocatalytic activity for HER and OER in alkaline medium can be related to the porosity as well as synergistic interaction of transition metals of period 4.

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B0410

Evaluation of Catalyst Performance by Computational Quantum Mechanics and Experiment.

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Abstract

Non-precious metals, such as Ni, have been widely used as the cathode catalyst for alkaline fuel cell, metal-air batteries etc. The reaction mechanism at atomic scale is not well understood. This paper is aiming to calculate the catalytic ability of nickel atom on carbon nanotube. The computational quantum mechanics (CQM) based on Density Functional Theory (DFT) was used to calculate the binding energies and activities of Ni with different weight-percentage (wt%). The oxygen reduction reaction (ORR) is used as the electrochemical reaction taking placed on the catalyst. Calculation results are verified by experimental measurements, such as rotating disc electrode (RDE) for catalytic activity and X-ray photoelectron spectroscopy (XPS) for binding energy.

Keywords: XPS, ORR, RDE, CQM, Catalyst

B0412

Highly active heteroatom doped carbon supported palladium for oxidation of formate

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Abstract

Valuable compounds such as carbon monoxide (CO), ethanol (C2H5OH), ethylene (C2H4), and formate (HCOO-) can be environmentally friendly produced by electroreduction of CO2. Among them, HCOO-, which can be produced electroreduction of CO2 with high faradaic efficiency, is preferred to alkaline fuel cell due to its fast oxidation kinetics compared to the other small organic molecules such as methanol, ethanol, etc. Pd, which is relatively cheaper than Pt equivalently used in fuel cell field, is known as the best electrocatalyst for oxidation of HCOO- in alkaline media. According to the literatures, in formate oxidation mechanism, oxidation for adsorption of hydrogen (Had) is known as rate determine step. In addition, it is reported that lowering adsorption energy of hydrogen on the surface of Pd induced by electron transfer to Pd can be improve the oxidation kinetics of Had leading to highly catalytic activity for HCOO- oxidation. Therefore, in this study, carbon doped with atom like B, P, or N is utilized as carbon support to synthesize the highly metallic Pd, which has great catalytic activity toward oxidation of Had, and to control particle size of Pd. The prepared Pd catalysts with various heteroatom doped carbon are intensively characterized by physicochemical analysis. Furthermore, the catalytic activities of the prepared Pd catalysts for formate oxidation are investigated by various electrochemical methods and their single cell performances are presented as well.

B0413 (Abstract only, published elsewhere)

Oriented Electrode for Polymer Electrolyte Fuel Cells

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Abstract

Proton exchange membrane fuel cells should be improved and lower platinum loading. High activity membrane electrode assembly (MEA), low ohmic polarization and mass transfer polarization are required. Different oriented structured MEAs have been prepared in our group. For proton-conductor free oriented MEA, the mechanism of proton transport is a new challenge. Based on electrical conductive and non-conductive oriented structure, the characteristics of the prepared oriented electrodes are investigated. In the microstructure of the oriented MEA, the active surface of electrocatalyst, proton conductor, three phase interface, have important impact on the transport, absorption, desorption and electrochemical reaction process. The utilization of precious metal catalyst were improved. The high efficient mass transfer passages and reactive interface should be constructed for PEMFC high current density operation, which is the requirement for high power density fuel cell. High performance, long durability and stability can be expected for the new MEA.

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Chapter 03 - Sessions A07, A11, A05, A12

A07 Analysis & evaluation of system components
A11 Transport phenomena limitation
A05 Durability, testing & degradation mitigation
A12 Durability, testing & optimisation for operation

Content **Page A07, A11, A05, A12 - ..**

A0701 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Novel concept for evaporative cooling of fuel cells: an experimental study based on neutron imaging

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Abstract

Polymer Electrolyte Fuel Cells (PEFC), although a promising technology for carbon free production of electricity, are penalized by system complexity, partly due to cooling and humidifying systems. These systems are necessary to avoid the heating up and drying of the membrane, which stop the electrochemical reaction. Here we present an evaporative cooling concept for PEFC developed at Paul Scherrer Institute. Unlike other concepts, our approach does not require any additional layer in the cell structure. Water flows through dedicated flowfields channels, parallel to the gas channels, and is distributed over the cell area thanks to a modified gas diffusion layer (GDL). A synthesis method developed at PSI [1,2] transforms some portions of the GDL into hydrophilic patterns, which wick the water from the supply channels at low capillary pressure. These hydrophilic areas, parallel and equally spaced, define pathways for liquid water separated from the gases, which avoids flooding (Figure 1).

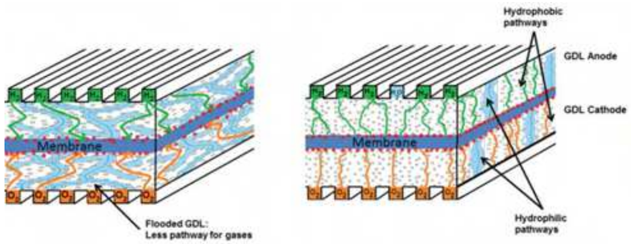

***Figure 1**: Concept of evaporative cooling with patterned GDLs compared to a classic GDL*

A test cell was built to investigate both water transport with the help of neutron radiography and heat transport thanks to integrated heat flux sensors. Here, we will present how the evaporation can be controlled by the mass flow rates, temperatures, pressures of gases and the geometry of the hydrophilic lines.

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A0702

Analysis of water distribution and evaporation rate in gas diffusion layers

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Abstract

Improved water management in the membrane electrode assembly (MEA) of polymer electrolyte fuel cells (PEFCs), especially at high current densities, is an important step towards the economic viability of PEFCs. Water removal by evaporation is not only an important water management technique but also enables simultaneous cooling of the cell and can therefore also be used as an effective heat management technique. However, despite the critical role of evaporation in heat and water management in PEFCs, evaporation in the gas diffusion layer (GDL), an integral part of the MEA, is a topic that has received scant attention in literature [1,2]. This study focuses on understanding the correlation of liquid water distribution in GDL to the evaporation rate in GDL under different thermodynamic conditions. This is achieved by combining evaporation experiments with X-ray CT imaging in order to correlate global properties such as evaporation flux with local properties such as saturation distribution. The experimental parameters are systematically varied over a wide range of boundary conditions (airflow temperature, flow rate etc.) to determine the influence of water distribution and vapor diffusion on the evaporation rate.

A0703 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

PEFC Catalyst Layer Modeling in CFD Simulations: From Interface to Agglomerate Models

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Abstract

The polymer electrolyte fuel cell (PEFC) catalyst layer model implemented in a commercial computational fluid dynamics (CFD) code is extended from a 0D interface treatment to a 3D agglomerate approach. The extended model fully accounts for reactant diffusion into the agglomerates and local electrochemical reactions inside the agglomerates. Simulation results obtained with agglomerate and interface model are compared to polarization curves of a 50 cm^2 serpentine channel cell measured under various operating conditions. Both models show good agreement with the measurements at a qualitative level, whereas the agglomerate model, in addition, predicts the experimental data at a quantitative level, even in the low voltage range. 3D results in the membrane and gas diffusion layers obtained with both models are compared to each other. Additionally, 3D results in the membrane and the catalyst layers are analyzed in detail for the different operating conditions.

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A0704 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Tailoring electrosprayed carbon layers

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Abstract

Electrosprayed films prepared from carbon and Nafion are of great interest for proton exchange membrane fuel cells (PEMFC). Their particular properties in comparison with those of conventional deposits having the same composition allow them to be applied as microporous layers and protective coatings for of a number of components in PEMFCs. The electrospray deposition of the carbon-polymer inks is a complex process which depends on several factors related to the ink, the substrate, and the applied voltage. In order to gain insight into the factors influencing the characteristics of electrosprayed films, the effect of some parameters has been analyzed. The solvent nature, the Nafion/C ratio in the ink, the ionization voltage (positive or negative) and the polymer distribution on the carbon surface are some of the studied variables. By analyzing the ions formed from the ionomer solution by electrospray ionization in positive and negative modes, a very different fragmentation pattern has been observed for the ionomer. As a matter of fact, the microstructure of the resulting carbon-polymer layers by applying positive or negative ionization modes reflects a different microstructure in the formed aggregates. Surface characterization of these layers has been performed by using a number of techniques such as XPS, SEM or ATR to obtain detailed information that allow tailoring electrosprayed structures.

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A1101 (Abstract only)

Understanding performance limitations in anion-exchange membrane fuel cells

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Abstract

The development of anion-exchange membrane fuel cells (AEMFCs) is very rapid. However, for the further progress of the field it is important to obtain a better understanding of the electrode processes and the performance limitations in operating cells. Previous studies on Pt/C catalysts [1, 2] show that electrode and cell behaviour are different in AEMFC compared to PEMFC, due to the alkaline environment and altered ionomer and membrane properties. Earlier studies indicate that both the oxygen and hydrogen electrodes affect the performance in an AEMFC, and further limitations arise due to water management, as water is produced at the anode, and may cause flooding, and consumed at the cathode, and where it may cause drying [3].

In this study the performance of operating AEMFCs is investigated and the limitations are found to be attributed to different physical and electrode kinetic phenomena, including charge transfer, transport processes of reactants, and electric and ionic conduction. The limiting processes are studied experimentally by electrochemical characterization in small laboratory scale full cells employing anion exchange membranes, porous gas diffusion electrodes and model thin-film electrodes. Operating parameters such as oxygen and hydrogen partial pressure, relative humidity and temperature are varied. The porous structure of the electrodes is examined e.g. using SEM. The thin-film model electrodes are used to eliminate electrode structural influences on the cell behaviour. To complement the experimental study the electrochemical and structural data will be used to formulate a chemical and physical based mathematical model for AEMFC. This model will include effects of the porous morphology of the electrodes as well as water transport.

Our preliminary results show that the cathode is limiting at lower current densities, while the anode influences the performance significantly at higher current densities. Thus for a complete description of an operating AEMFC, the cathode as well as the anode behaviour need to be included in the model. The combination of experimental work and mathematical modelling is found crucial for further understanding of performance limitations in AEMFC systems.

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A1102

Gas transport in PEFC gas diffusion layers and its analysis for upscaling

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Abstract

The gas diffusion layer (GDL) with its geometric structure on meso scale connects the electrodes with the feeding channels of the bipolar plate on the cell and stack scale. This is more or less identical for all polymer electrolyte fuel cells of the type PEFC, DMFC and HT-PEFC. The GDL also provides electric contact to the bipolar plates. They are often made from carbon fibers, e.g., paper, woven and non-woven textiles.
The structure of non-woven and paper-type GDLs in real fuel cells was analyzed by X-ray synchrotron tomography under various compression levels. Gas transport is simulated with the Lattice Boltzmann method in compressed and uncompressed microstructures in through-plane and in-plane directions of the GDL, both in real structures and in stochastic equivalent geometries. Effective properties calculated from the simulation results provide model parameters for homogenized approaches in cell scale simulations. The simulated through-plane gas flow at the exit layer of the GDL will be presented. 70 % of the gas is leaving the GDL at less than 30 % of the surface area. Stochastic methods provide substantiated properties suitable for connecting the meso scale to larger spatial scales and to design virtual GDL materials with improved transport properties.

A1103 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Single Cell Study of Water Transport in PEMFCs with Electrosprayed Catalyst Layers

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Abstract

The electrospray deposition allows for the growth of catalyst layers with high macroporosity and hydrophobicity. Pore volume fraction of electrosprayed layers is normally above 90%, compared to 75-85% of standard catalyst layers with same Pt/C and ionomer phase (Nafion) composition. Such additional porosity is due to a large macropores fraction resulting from the electrospray deposition process. Surface hydrophobicity of the layers determined with the water drop sessile method shows contact angles above 150^o, in the superhydrophobicity range. Single cell studies have shown that macroporosity and hydrophobicity of electrosprayed layers have a positive effect for the performance and durability of a PEMFC. As cathodic layers, they give rise to about 25% increase in maximum power density, compared with standard cells, due to improved water transport in the cell. In addition, lower degradation rate has been found with electrosprayed catalyst layers in cells submitted to start-up and shut-down cycling, reflecting a slowdown of corrosion kinetics that we attribute to the dry conditions imposed by the hydrophobicity of these layers.

In this communication, the performance of electrosprayed catalyst layers is analysed in the light of water transport results in single PEMFCs. First, morphology and hydrophobicity of the layers are analysed with SEM, porosimetry, and sessile water drop. Then, single cells are studied using electrosprayed catalyst layers in cathode, in anode, and in both electrodes. The water transport in the cells is studied by means of water collection experiments. It is shown that the electrosprayed layer in the cathode side increases back diffusion transport of water from the cathode towards the anode. This effect improves anode humidification and avoids cathode flooding, leading to the reported increase in performance and durability. However, when placed in the anode, the electrosprayed layer gives rise to excessive anode drying and limits the membrane lifetime.

Keywords – electrospray, catalyst layer, hydrophobicity, water transport

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A1104

Real time monitoring of water distribution in an operando fuel cell during transient states

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Abstract

The water distribution of an operating proton exchange membrane fuel cell (PEMFC) was monitored in real time by using Small Angle Neutron Scattering (SANS). The formation of liquid water was obtained simultaneously with the evolution of the water content inside the membrane. Measurements were performed when changing current with a time resolution of 10s, providing insights on the kinetics of water management prior to the stationary phase. We confirmed that water distribution is strongly heterogeneous at the scale at of the whole Membrane Electrode Assembly. As already reported, at the local scale there is no straightforward link between the amounts of water present inside and outside the membrane. However, we show that the temporal evolutions of these two parameters are strongly correlated. In particular, the local membrane water content is nearly instantaneously correlated to the total liquid water content, whether it is located at the anode or cathode side. These results can help in optimizing 3D stationary diphasic models used to predict PEMFC water distribution.

A1105

Impact of Microporous Layer Structural Properties on Oxygen Transport in PEM Fuel Cells

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Abstract

A key component of PEM fuel cells is the diffusion medium (DM), which typically consists of a carbon fiber gas diffusion layer (GDL) coated with a microporous layer (MPL) facing the electrodes to enhance the transport of oxygen and the water management. [1]
Conventional MPLs are composed of carbon black particles and PTFE acting as binder and hydrophobic agent [1]. In order to modify the porous structure of the MPL, we follow several approaches: (1) variation of the carbon black type; (2) perforation of the MPL and (3) use of carbon fibers. SEM images of fabricated MPLs are illustrated in **Figure 1**, revealing very different porous structure. The modification strategies yield an increase of the H_2/air fuel cell performance from 2.5 A cm^{-2} for a carbon black I based to 3.5 A cm^{-2} for a carbon fiber based MPL at 0.5 V under fully humidified conditions. The present results indicate different transport pathways of oxygen and liquid water through the porous layer.
We will show the characterization of various MPLs by SEM, porosity analysis and fuel cell testing at different operating conditions. Analysis of the oxygen transport resistance by a limiting current approach in a differential cell setup is used to identify crucial properties for oxygen and water transport. [2,3]

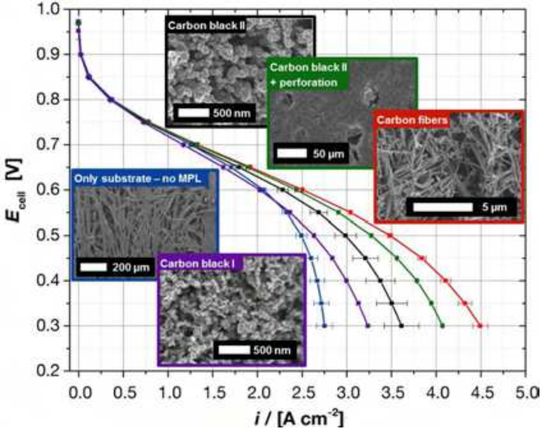

Figure 1: H_2/air polarization curves of different cathode MPLs coated on the same GDL substrate (Freudenberg H1410 I4) at T_{cell} = 50 °C, RH = 120% and p_{abs} = 300 kPa.

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A1106 (Abstract only, published elsewhere)

Porous binder: Contribution to gas transport in fuel cell gas diffusion layers

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Abstract

Carbon paper type gas diffusion layers (GDL) use a carbonaceous binder to ensure the necessary mechanical strength criteria required in polymer electrolyte fuel cells. In some materials the binder is porous, however the contribution of the binder pores to the overall gas diffusion in the GDL has not been yet investigated.
X-ray tomographic microscopy images of a SGL 24BA in different compression states were recorded with a 2.2 um voxel edge length. A specific segmentation of the reconstructed images makes possible to distinguish between fibres, binder and void (Figure 1). However, with the given resolution, the pores in the binder are not resolved and only binder regions can be identified.

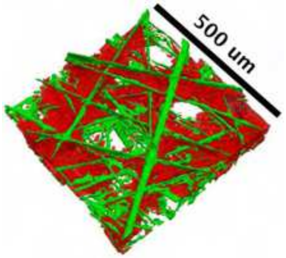

Figure 1: 3D rendering of a ternary segmented SGL 24BA gas diffusion layer; green: fibres, red: binder, white: void.

With the ternary segmented structures (fibres, binder, void), the distributions of the different phases across the GDL thickness are determined and the effective gas transport coefficients are numerically calculated [1] for all compressions and in three orthogonal directions (two in-plane and one through-plane) taking into consideration the gas transport through the binder pores. This latter contribution is significant for the diffusion, increasing the effective diffusion coefficient of the GDL by a factor of 2.

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A1107 (see A1405)

A1108 (Abstract only)

Analysis of Roughness Induced Hydrophobicity in Electrospray Deposited Microporous Layer on Carbon Fiber Paper used in PEMFC Membrane Electrode Assembly

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Abstract

This work demonstrates the application of electrospraying in depositing hydrophobic to super hydrophobic microporous layers (MPL) on carbon fiber substrates and studies the effects of deposition time and amount of 10 wt% Nafion® PFSA dispersion used as binder in the MPL. By sufficiently varying the deposition time from 60 mins. to 160 mins., wider coverage of the deposit on the topmost layers and partial filling of the gaps in between the fibers were achieved. By analyzing the SEM images of the samples, measurements revealed linear increase in the lateral direction of the deposit and yield mean lateral deposition rate of 0.27 µm/min. This indicates that a stable and well controlled deposition process was achieved during electrospraying. By varying the volume of Nafion® binder added in the MPL suspension between 5 vol% and 10 vol%, we were able to produce MPL layers with macro- to mesoporous structures leading to increased surface area. As consequence of this, increased roughness of the surface was achieved and resulted to roughness-induced hydrophobicity on the samples. At best conditions, we were able to observe super hydrophobic behavior using 5 vol% Nafion® binder in the MPL suspension and measured the corresponding BET surface area at 17.45 m^2/g. Based on these findings, the MPL/CFP samples were coated with Pt and used as electrodes to form membrane electrode assembly (MEA) and where characterized using single cell tests with V-I polarization and in-situ EIS measurements. During single cell tests, the H_2 and O_2 feed gas to the anode and cathode were generated on-site using a simple electrolysis device running at 9V DC.

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A1111 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Why an OCV of 1.23 Volt Cannot Be Obtained

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Abstract

According to the accepted theory [1], [2] and [3], the open circuit voltage (OCV) of the electrochemical fuel cell conversion of Hydrogen and Oxygen under standard conditions should be 1.23 Volt. However, this theoretical value has never been experimentally confirmed for low temperature fuel cells. Yet in SOFC experiments above 600°C, the OCVs observed agree closely with the values predicted for high operating temperatures [4]. Also, for ceramic fuel cells, the voltage falls with increasing current along straight lines, indicating Ohmic behavior. For polymer fuel cells such Ohmic behavior is not seen at low currents ("polarization"), but only at higher currents. Apparently, the electrochemical combination of Hydrogen and Oxygen is not the same for both types of fuel cell. It seems that Hydrogen and Oxygen can be combined by the reaction $2H_2 + O_2 \Rightarrow 2H_2O$ only at temperatures above the temperature of spontaneous ignition (also called auto- or self-ignition) of 585°C while at lower temperatures they combine by another path. This is postulated to be the formation of Hydroxyl ions ($H + O \Rightarrow HO^-$). The present work cites and reports evidence for this hypothesis.

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A0501 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Effects, damage characteristics and regeneration potential of traffic-induced nitric oxide emissions in PEM fuel cells under variable operating conditions

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Abstract

Understanding of the influence of traffic-related harmful gases, especially nitrogen oxides, on PEM fuel cells is essential to improve life time and durability of fuel cell vehicles. In a 3-year work, both the damaging mechanism and the influence of the nitrogen oxides, NO and NO_2, on PEM fuel cells under real environmental and operating conditions became more comprehensible. It could be shown that a complete regeneration of previous NO_x contamination can only take place under neat air, which is occasionally rare in urban areas. Furthermore, a negative influence of NO could already be seen at a concentration level of 100 ppb, which is often exceeded in traffic areas. NO leads to significantly faster voltage drops compared to NO_2, so typical NO peaks during rush hour traffic can reduce the fuel cell power within a few seconds. Finally, it is assumed that the course of the voltage loss during contamination, with subsequent attainment of a stable balance state, is related to the surface coverage of the platinum catalyst. With a higher surface coverage, the bonding structure of NO on platinum changes, but during the first strong voltage loss NO is in direct competition to the oxygen reduction reaction.

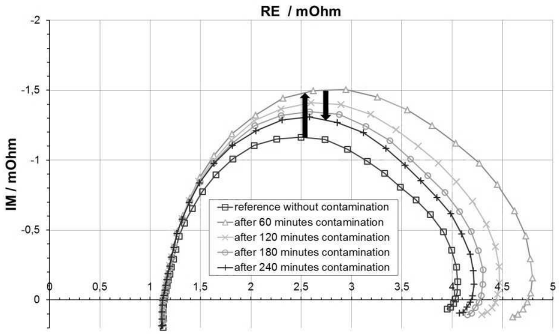

Figure 2: Impedance course in Nyquist plot during contamination with 2 ppm NO

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A0502 (Abstract only, published elsewhere)

A new approach to mitigation of membrane degradation caused by mechanical and chemical stressors

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Abstract

The ionomer membrane responsible for proton conduction and separation of the fuel from the oxidant gas in proton exchange membrane fuel cells (PEM FCs) is one of the most susceptible components of the membrane electrode assembly. The main cause of membrane failure is chemical decomposition of the polymer structure often accelerated by mechanical fatigue due to compression and humidity cycling in the operating cell. Thin membranes (<<20 μm) developed from low equivalent weight perfluorosulfonic acid (PFSA) ionomers are required to achieve industry targets for automotive propulsion application. However, the high performance is achieved at the expense of the accelerated chemical degradation and susceptibility of the high ion exchange capacity membrane to humidity cycles. This work focuses on evaluation of several strategies to mitigate degradation of thin PFSA membranes including incorporation of electrospun mechanical reinforcements and ceria nanoparticle radical scavengers. The benefits and remaining challenges associated with these approaches will be presented and discussed.

Acknowledgement: This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 671465 VOLUMETRIQ. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme.

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A0503 (Abstract only, published elsewhere)

Impact of the operation modes on the reversible and non-reversible degradation mechanisms of a PEMFC

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Abstract

PEMFC systems are considered as promising energy sources for transportation and/or stationary applications. Whereas the overall performances have now reached most of the targeted specifications for integration, the overall durability and cost are still major hurdles to the mass market. Improved understanding of the degradation mechanisms occurring during ageing of PEMFCs is needed to enable durability improvements by the modification of components or by the application of focused operating strategies.

In this work, PEMFC degradation has been studied on short stacks of a few cells submitted to different ageing tests, looking for major causes for reversible or non-reversible degradations. Analyses have been conducted in-situ by electrochemical diagnostics to follow the degradation of the Membrane Electrodes Assemblies (MEA) components with a main focus on the catalyst layers properties. At stack scale, full understanding requires to complete these averaged measurements by local analyses to take into account the correlation of performance degradation and the cell design. Current density distribution maps have been performed using a segmented cell (S++ ®) implemented in the stacks allowing to clearly identify the local issues, particularly near the fuel and air inlets or outlets.

In-situ experimental investigations are completed by modelling and post-ageing analyses by advanced electron microscopy techniques.

Most important performance losses during load cycles or fixed current operation, far from the few µV/h targeted by the applications, are reversible and conduct to the necessary stop and restart of the fuel cell to avoid too low voltage. One major cause of reversible losses was supposed to be related to the formation of Platinum oxides. Results presented clearly show how air starvation can be used as a strategy stabilizing the stack voltage.

In addition to the study of performance losses during nominal operating modes, impact of start-up and shut-down phases has also been investigated on the same PEMFC stacks to identify the specific degradation mechanisms involved. A harsh procedure, creating a hydrogen / air front anode side, was selected to emphasize the issues. These experiments allowed to understand the design-specific losses related to the so-called reverse current mechanism which occurred locally as shown by the current density distribution maps.

Acknowledgment:
This work has been mainly conducted in the frame of the project Second Act supported by the FCH JU in FP7 program (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n°621216.

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A0504 (Abstract only)

EU Harmonised Test Protocols for Automotive Applications

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Abstract

The European Union's transport sector is the second largest energy consumer in Europe being responsible for 33% of the total energy consumption and about 25% of the total European greenhouse gas emissions (GHG) emissions. The European Union is committed to transforming its transport and energy sector as part of a future low carbon economy. It is recognised that Fuel Cell and hydrogen technologies hold great promise for energy and transport applications from the perspective of meeting Europe's energy, environmental and economic goals and are part of the Strategic Energy Technologies (SET) Plan - , which was adopted by the European Union in 2008.

Proton Exchange Fuel Cells due to their high energy density, low operating temperature and high efficiency are considered to be very suitable for vehicle propulsion. In such applications, fuel cells could encounter operating conditions which are severe to the materials involved.

The objective of this paper is to present a set of harmonised operating conditions, testing protocols and procedures for assessing both performance and durability of Polymer Electrolyte or Proton Exchange Membrane Fuel Cells (PEMFCs) in Single Cell configuration for automotive applications to allow fair comparison of test results from various projects and laboratories.

The paper presents a set of reference operating conditions such as temperature, pressure, humidification, gas flow and composition at the fuel and oxidant inlet representative for future automotive applications. A methodology is established to examining the relative influence that the individual operating parameters exert on the MEA performance in single cell configuration.

Fuel cell durability is evaluated through endurance testing by applying a repetitive load profile to the cell and measuring performance degradation in terms of cell voltage decrease as function of operating hours. To assess the cell degradation rate a dynamic load cycle for endurance testing is proposed. The Fuel Cell Dynamic Load Cycle, (FC-DLC) is used in this document and is derived from the New European Driving Cycle (NEDC) modified for fuel cell applications.

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A0505 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

CO_2 Enrichment In Anode Loop And Correlation With CO Poisoning Of Low Pt Anodes In PEM Fuel Cells

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Abstract

In automotive fuel cell systems anode fuel re-circulation is often used to achieve high hydrogen utilization rates which on the one hand reduces the hydrogen consumption of the fuel cell car and on the other hand is an appropriate way to control hydrogen emissions. During fuel cell operation hydrogen is consumed while residual gases increase in the previously mentioned hydrogen loop. Besides nitrogen, which mainly has a diluting effect in the anode loop, we have found that carbon dioxide accumulates in the anode loop and concentrations between 150-350 ppm were measured for varying current densities. We attribute this finding to CO2 crossover from the cathode to the anode and subsequent enrichment in the anode loop.

To study the effect of this relatively small CO_2-concentration on the Cell performance tests were conducted with a PEM single test cell employing “CAT”-hardware by AFCC Automotive Fuel Cell Cooperation with hydrogen/ air feed. The active area of the cell in this setup was about 45 cm² which allowed measurements with almost gradient free conditions for temperature, pressure, stoichiometry and potential. This sub-scale testing equipment with graphite plates with parallel straight channel flow-field design was equipped with a state-of-the-art MEA. Different concentrations of CO_2 were fed into the hydrogen stream: 200 ppm, 400 ppm and 800 ppm representing the range of the expected presence of this species in the anode loop. The data clearly indicate that electrochemical reduction of CO2 to CO takes place which has a significant impact on the cell performance which is due to blocked catalyst sites by CO affecting the current density of the hydrogen oxidation reaction (HOR) taking place on the anode side. The data indicate that about 41% of the anode Pt catalyst surface is covered with CO after exposure to 400 ppm of CO_2 in hydrogen for 24 hours. The measurements with hydrogen contaminated with CO_2 were matched with hydrogen plus CO measurements to quantify the impact and to determine a “CO-equivalent concentration” for CO_2. It is found that a MEA being exposed for one hour to 400 ppm CO_2 in hydrogen and hydrogen containing 0.14 ppm CO face the same reversible degradation.

The influence of electrochemical CO_2 reduction to CO was further confirmed in short stack test. Consequences for the operation strategy of the fuel cell system are given.

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A0506

Durability studies in a unitized regenerative fuel cell

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Abstract

The study underlines the probable reasons of degradation of a unitized regenerative fuel cell (URFC) when run in fuel cell as well as in electrolysis mode at 45 °C. The durability of the URFCs is analyzed on the basis of its catalysts (Pt and IrO_2) and membrane, together with the bipolar plates. The electrolysis mode of operation and its high operating potentials is found to be the dominant cause of failure due to the oxidation of the carbon base of the catalyst, causing agglomeration and loss of catalyst along with delamination of electrode from membrane. Bipolar plates were also found to have deposition of an oxide layer. Electrochemical characterizations together with other visual and chemical analysis help confirm this diagnosis of the URFC.

A0507 (see A0506)

A1201 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Physical modelling and analyses of catalyst degradation in PEM fuel cells

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Abstract

The presented model of catalyst degradation in polymer electrolyte fuel cells expands upon previous models in the literature [1,2]. The basic modeling framework encompasses the main processes at the particle level, namely catalyst dissolution, redeposition, coagulation, and detachment. Moreover, the expanded model accounts for the effluence of Pt content into the polymer electrolyte membrane. Data sets analyzed include information on the change in electrochemically active surface area, evolution of the particle radius distribution and changes in Pt mass distribution including Pt content in the membrane and catalyst layer thickness. Systematic optimization studies using the generalized pattern search algorithm and statistical analyses of the parameter space using Monte Carlo techniques were employed to analyze the data sets, deconvolute degradation mechanisms, and extract parameters of different degradation mechanisms. Optimization techniques reproduced experimental data reasonably well for both *in situ* and *ex situ* data from various groups. Surface tension was seen to increase with upper potential limit at a constant rate of dissolution. The results are consistent with the literature showing that the dissolution kinetics increases significantly with increasing the upper potential limit while the surface tension decreases only slightly. A wider range of experimental data is in the process of being explored and analyzed.

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A1202 (Abstract only)

The Importance of Failure: Understanding degradation mechanisms in PEM electrolysers

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Abstract

In a world in which fossil fuel energy is becoming ever more scarce and expensive and countries are struggling to meet their carbon reduction obligations, hydrogen solutions have finally reached the top of energy agendas. The only industrially applicable zero carbon method to produce hydrogen is via electrolysis utilizing renewable sources of electricity. ITM Power is at the very heart of the initiatives and programmes to adopt hydrogen technology that will reduce both carbon footprints and energy costs. Using its technology and know-how, ITM is aiming to be the world leading supplier of both infrastructure for the production of green hydrogen transport fuel, and products for the generation and storage of hydrogen fuel from intermittent renewable energy sources.

PEM electrolysers have a lifetime of 5-10 years; as such there is difficulty in getting new materials to market. In order to get innovations to market faster the failure mechanisms need to be well understood and methods to accelerate degradation, based on real failure mechanisms need to be developed.

The first step is to understand the mode of operation of electrolysers in the field. The key is electrolysers (almost independent of application) need to be off for long periods of time and need to be able to respond on a subsecond basis. This very different to how most electrolysers are tested in the laboratory steady state and intermittent load following are common practice. The reasons behind this will be explained in more detail.

In addition, the stack failure mechanisms will be discussed and how these are measured in the laboratory. In one such example ITM have used an *in-situ* reference electrode (developed in collaboration with the National Physical Laboratory) to help understand catalyst degradation within the cell. This approach enables separation of the relative contributions of anode and cathode to the overall reaction. During shut down periods, it was observed that the cathode contributes more to changes in the open circuit voltage. This knowledge has been used to show that the majority of the degradation is occurring on the cathode catalyst, which is in contrast to the perceived thought which assumes the anode degrades faster. Changes in the electrochemically active surface area of the platinum cathode as a result of potential cycling were determined *in-situ* via hydrogen underpotential cyclic voltammetry. Scanning electron microscopy and X-ray tomography were used to correlate changes in catalyst morphology with performance degradation of both carbon-supported and unsupported platinum catalysts. These experiments have led to the development of accelerated stress tests, based on cycling of the electrode potential, for PEM electrolyser catalysts. Other such examples will be presented.

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A1203 (Abstract only)

Advanced Materials for High-Temperature PEM Fuel Cells

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Abstract

Proton exchange membrane fuel cells (PEMFC) can be used to convert chemical energy stored in hydrogen into electricity and water. This can provide a safe and stable power supply for stationary as well as mobile devices. PEMFC can run at different temperatures and can be divided into two subgroups; High temperature PEMFC (HT-PEMFC) that typically run at temperatures between 120 °C and 180 °C and low temperature PEMFC (LT-PEMFC) running at temperatures well below 100 °C. These different techniques both have advantages and challenges that we need to overcome before commercialization. The higher operating temperature for HT-PEMFC comes with many advantages; the higher temperature increases the kinetics, gives a higher tolerance towards CO poisoning [1], and by designing a fuel cell that runs at high temperatures, we remove the need for cooling the components, which simplifies the design process and lowers the cost [2]. The higher CO tolerance makes it possible to rely on hydrogen formed from methanol or reformate, which increases the flexibility of these devices. HT-PEMFC has the potential for applications for auxiliary power units or combined heat and power (CHP) applications.

At Danish Power Systems (DPS) we develop and manufacture state of the art Membrane Electrode Assembly (MEA) for PBI-based HT-PEMFC that operates at temperatures between 120 °C and 180 °C. These cells have a low degradation rate of 4 µV/h over 13,000 h. The degradation is mainly a consequence of loss of phosphoric acid and loss of surface area of the catalysts due to sintering and Ostwald ripening [3]. In this presentation, the effect of the choice of catalyst, the loading of the catalyst, and the choice of GDL will be discussed.

Acknowledgements
The funding of this work is gratefully acknowledged from the Danish ForskEL program, the Danish Energy Agency and Innovation Fund Denmark (the joint Danish-Korean KDFuelCell project - http://www.kdfuelcell.net/).

[1]: Li, Q, He, R, Gao, J-A, Jensen, J. O., Bjerrum, N. 2003, 'The CO poisoning effect in PEMFCs operational at temperatures up to 200 °C', *Electrochemical Society. Journal*, vol 150, no. 12, pp. A1599-A1605. DOI: 10.1149/1.1619984
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A1204

Improved durability in DMFC: local optimization of catalyst layers

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Abstract

Direct Methanol Fuel Cell (DMFC) technology's widespread commercialization, among several others technical issues, is still hindered by a strong performance degradation, which is known to have both a temporary and a permanent contribution. Locally resolved measurements and post-mortem analysis revealed a strong heterogeneous components fading. Local inhomogeneity in operating conditions turned out to have a critical impact on early aging of cell components and has to be thoroughly understood and properly mitigated to improve devices' lifetime.
An appositely developed innovative PEM macro-Segmented Fuel Cell setup (m-SFC) has been applied to the investigation of local inhomogeneity both during operation and ex-situ characterization, permitting to point out the main mechanisms determining a heterogeneous performance distribution and degradation. The study pointed out how local water content inhomogeneity and high cathode potential have a strong influence on active layers' localized performance and fading, leading to current redistribution over time.
The design of innovative cathode catalyst layer components permitted to increase homogeneity and stability of performance distribution during operation: particularly, gradient-loaded MEAs have been developed with varying local catalyst layers' formulation from reactant inlet to outlet, optimizing local operating conditions. The developed locally optimized components showed an improved current density distribution over cell active area, reaching a more homogeneous IV performance and revealing very promising effects on MEAs long-term durability.
This work was supported by the FCH-JU FP7 project Second ACT (EC GA 621216).

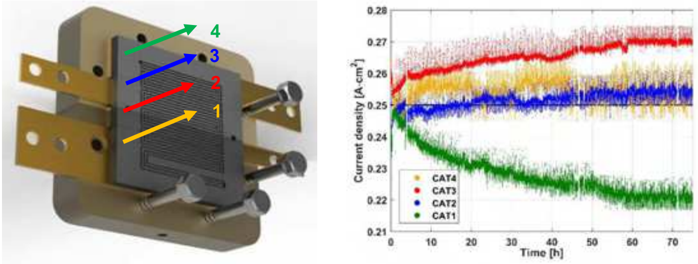

Figure 1: m-SFC setup (A) and local current redistribution during operation (B)

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A1205 (Abstract only, published elsewhere)

Durability Studies of High Temperature PEM Fuel Cells. Operational Parameters, Accelerated Testing and Acid Retention

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Abstract

High temperature PEM fuel cell made from polybenzimidazole doped with phosphoric acid doped have reached a rather mature state of development and early commercialization. However, long term durability is still a challenge [1] and that is the subject for the present study.

A large number of single cells (Dapozol, Danish Power Systems) were tested with hydrogen in multichannel test rigs over several years. Degradation rates as a function of temperature (160 - 200 °C), current load (200 - 800 mA cm^{-2}) and flow rates (up to about lambda 10) were measured. Polarization curves and electrochemical impedance spectra were recorded along the test and post mortem analyses were performed after different periods of time. Based on the data, some clear trends are highlighted.

Accelerated stress testing was performed using a potential cycling protocol. It is shown that humidification during the test has a decisive effect on the outcome and validity of the test.

Finally, cells based on a thermally cured membrane proved a degradation rate of as little as 0.5 μV h^{-1} over an extended period of time. [2] This is, to the authors' knowledge, lower than what is ever reported for high temperature PEMFC.

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

Real time startup simulation of a high temperature PEM fuel cell for combined heat and power generation

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Abstract

System level simulations featuring high level of accuracy, high level of predictiveness and short computational times have become an important tool in the product design process. One of their major advantages is their capability to substantially speed up the exploration of the design space.
The presented newly developed system level model of a high temperature PEM fuel cell in transient operation is based on extending the previously presented innovative Hybrid Analytic-Numerical 3D modelling approach. It features simulation results with coarse 3D resolution at computational times that are well within the real-time constraints.
Predictive capability of the model and its accuracy to spatially resolve fuel cell parameters was first validated against results of the steady-state operating point calculated with the 3D CFD model.
As the operation in off-design points of the steady state operation brings about the largest contributions to fuel cell degradation, such simulations are very beneficial not only for system design but also for design of start-up, shutdown and other transient control strategies. To demonstrate the capabilities of the model a start-up sequence of a fuel cell stack featured in a commercial heat & power generator system has been simulated. Simulation results on the time evolution of the stack's output voltage are compared to the measured data and show good agreement and prove the models predictive capabilities.

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A1207 (see A1201)

A1208 (see A1203)

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

Effect of operating conditions temperature on low temperature PEFC under aeronautical conditions

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Abstract

The factors that influence the life of low-temperature PEFC under aeronautic conditions are studied. Single cell MEAs were tested under simulated real-world conditions to examine effects of operating conditions encountered in aeronautics. The conditions are classified as start/stop cycling, current hold (idling and cruise) and potential cycling (take-off and landing) in comparison to laboratory testing. The MEA have 58.81 m^2g^{-1} ECSA and the IV curve showed relatively acceptable performance for a commercial MEA at Beginning of Life (BoL). The MEAs are further subjected to HRTEM, HRSEM/EDS and XRD to explore the extent and nature of degradation. Ultimately, this study supports efforts to predict fuel cell life under various operating conditions as part of Prognostics and Health Management research campaign in order to provide input to future developments on improving fuel cell reliability and durability for aeronautic applications.

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A1210 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Long term Durability of High Temperature-Polymer Electrolyte Membrane Fuel Cells based on Acid Doped Polybenzimidazole

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Abstract

A PEM fuel cell with an operating temperature above 100°C is desired for increasing the kinetics of reactions, reduced sensitivity to impurities of the fuel, as well as for the reduction of the requirements on thermal and water management systems. High Temperature Polymer Electrolyte Membrane Fuel Cells (HT-PEMFC) can effectively be combined with CHP systems to offer a simple system design and higher overall system efficiencies.

One of the challenges with phosphoric acid doped polybenzimidazole (PBI) membranes is the loss of or changes in phosphoric acid, which controls the proton conductivity, and the long-term endurance of the membrane electrode assembly.

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In this work, Long term durability of a high-temperature proton exchange membrane fuel cell utilizing a phosphoric-acid-doped polybenzimidazole electrolyte is investigated. Fuel cell performance is measured by polarization curves to understand to understand the influence of varied parameters. Electrochemical impedance spectroscopy is employed to characterize the variations in the resistance and polarization losses in the cell. Moreover, Water at the fuel cell exhaust is collected to measure P concentration by inductively coupled plasma - Optical emission spectroscopy.

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Chapter 04 - Sessions A13, B08

A13 Diagnostics and Simulations
B08 Modelling & Diagnostics of Pt-Catalysis

Content **Page A13, B08 - ..**

A1301 (Abstract only, published elsewhere)

Quantification of feature detectability of subsecond X-ray Tomographic Microscopy of PEFC

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Abstract

Recent developments of operando sub-second X-ray tomographic microscopy (XTM) of polymer electrolyte fuel cells have paved the way for 4D imaging studies of the water distribution in the gas diffusion layer (GDL; see Figure 1) [1]. In order to further decrease the scan time towards 0.1 s it is required to quantify the influence of reduced signal to noise ratio in the XTM data and the detectability of small water accumulations and their connecting paths. Here, we present a variation of different imaging parameters (beam energy, radiography exposure time, number of projections) and discuss their consequences on the detectability of the micro-structural features.

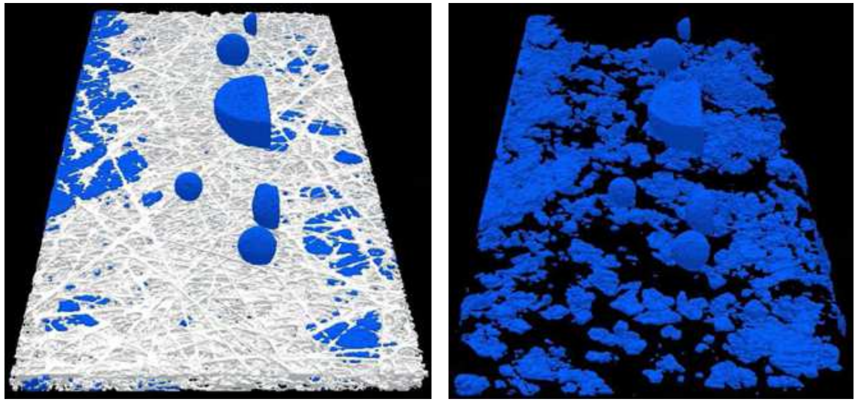

Figure 1: Liquid water saturation in the cathode GDL and flow field. 3D rendering of liquid water and fibrous GDL (left) and liquid only (right). Flow field plate is not shown.

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

A1302 (Abstract only, published elsewhere)

Extracting PEFC electrochemical properties from current interrupt measurement

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Abstract

There are various morphological and material properties that contribute to the dynamics of Polymer Electrolyte Fuel Cells (PEFC). Improving the design of these systems requires understanding of the mutual effect and tradeoffs among the various dynamical processes that determine their response. Quantitative characterization of the properties and processes that contribute to the PEFC’s dynamical response is a vital prerequisite for understanding their basics of operation and improving their design. A lot of research is therefore directed towards developing diagnostic tools that can accurately quantify the properties of these systems.

One of the challenges for tools to acquire diagnostic information about PEFC properties and operation, e.g., using polarization curves, is that they require lengthy procedures for data collection and analytics. In addition, diagnostic tests interfere with other performance and life-cycling testing campaigns conducted on the PEFC. Moreover, hardware required for tests such as Electrochemical Impedance Spectroscopy (EIS) is restricted to stacks with few cells, as the cost of the test hardware scales with the number of cells, diminishing the analytical and predictive value of information extracted.

Current interrupt is rapid diagnostic tools that can be used to characterize fuel cells with minimum interruption to their operation. It works based on sudden interruption of the fuel cell current and observing the evolution of voltage in sub-second time scales. This information is typically used to extract the PEFC membrane resistance during operation. In this work, we use current interrupt data along with a mathematical formulation to extract the exchange current density, Tafel slope, and the double layer capacitance, in addition to membrane resistance. In other words, we show that it is possible to extract the main PEFC parameters that can be obtained from polarization curve and EIS measurements from a relatively simple current interrupt measurement in a fraction of a second when used with first principle mathematical elaborations.

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

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

Understanding of PEMFC Conditioning Behaviors

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Abstract

With zero-emission environmental benefits, the proton exchange membrane fuel cell (PEMFC) technology will play a more important role as an alternative clean energy device in transportation and energy generation industries. Major automotive manufacturers have announced their plans to commercialize PEMFC vehicles between 2017 and 2020. Reducing cost and improving durability are still two major challenges for the commercialization of PEMFC technology in automotive applications. Conditioning is a time-consuming and costly process for PEMFC manufacturing at high production rate.

A conditioning, or break-in, process is usually required for a newly fabricated PEM fuel cell or stack in order to activate the membrane electrode assembly (MEA) and allow the cells reach their designed performances. Typically, conditioning takes from a few hours to tens of hours. Each new fuel cell stack occupies one fuel cell test station or similar device to run conditioning before installing on the vehicle' system. Conditioning protocols vary from one manufacturer/integrator to another, defined from empirical observation of their specific system. No standardized approach has been adopted in industry so far. The conditioning cost is usually negligible for making PEMFCs at R&D or demo stages with several tens of stacks each year. With industry's focus shifting from component development to commercial high volume manufacturing, the conditioning process requires significant additional capital investments and operating cost, thus becoming one of the bottlenecks for PEMFC manufacturing, particularly at a high production volume (>1000 stack/year).

It is intended to study and understand the mechanism and identify the root phenomena behind PEMFC conditioning, for the purpose of reducing conditioning time or even eliminating the conditioning process. The conditioning curves and *in-situ* electrochemical impedance spectroscopy (EIS) diagnosis results for some commercial available membrane/CCM/MEA samples will be presented in this presentation.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

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

Water Management In Alkaline Membrane Direct Methanol Fuel Cells

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Abstract

Alkaline Membrane Fuel Cells are presently intensively researched as they promise a significant reduction in price due to the option of using non-precious catalysts, while still keeping the advantage of solid electrolytes. Especially water management is thought to be much simpler than in liquid electrolyte cells. What is, however, often overseen is that the water balance in these alkaline membrane cells needs to be much more carefully analysed, monitored and controlled, as water is not only product that may lead to two-phase flow, but in contrast to acidic cells it is also a reactant at the cathode. Consumption of each oxygen requires two water molecules and several more due to electroosmotic water drag from cathode to anode. Insufficient supply of water will starve the cell of reactant and thus limit power density; furthermore, flooding may occur at anode.
This talk will elucidate the processes influencing the water balance at anode and cathode and the potential and constraints of obtaining a stable and acceptable water level at the example of the Alkaline Membrane Direct Methanol Fuel Cell (ADMFC). While this cell is yet much less popular than hydrogen fed AMFC, results are transferable also to the latter cell, as the cathode is identical and the ADMFC anode with its ca. 98% water content has strong similarities to a flooded hydrogen electrode.
In a first part, results of a theoretical study are presented which reveal design and operating constraints for establishing a stable water balance at anode and cathode. The study is based on various physico-chemical models tailored for the respective scenario and scans a wide range of material and operating parameters. While humidification of cathode feed is identified as insufficient, diffusion through the membrane is a viable way for cathode side water supply. To prevent accumulation of water at the anode, water removal is needed which may be realised through evaporation on anode side or management via the cathode flow. In a second part, experimental results on diffusion and water uptake of membranes are presented and integrated in a full ADMFC model to allow also for a quantitative assessment of water accumulation and depletion for realistic cells.

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Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1305

A New Model of PEMFCs: Process Identification from Physics-based EIS Simulation

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Abstract

In order to reduce the costs of PEMFCs and to improve their longevity and performance, predictive, macroscopic cell models are needed. With our new modeling framework called NEOPARD-FC we aim to describe the fuel cell behavior under different conditions (e.g. temperatures, pressures, relative humidities,…). It allows transient simulations in 2D or 3D taking into account electrochemical reactions, detailed membrane transport, gas cross-over, multiphase-flow in the porous domains, proton-, electron- and heat transport.
A valuable tool for model validation, apart from polarization curve simulations, is the simulation of electrochemical impedance spectra (EIS). Based on the potential step method [1] the model is able to quickly simulate EIS over a large frequency range, which allows the detailed analysis of processes governing the cell performance.
Experiments often show a significant gap between the total cell resistance measured by EIS and obtained from polarization curves (Fig. 1). This discrepancy can be explained by an additional inductive loop at very low frequencies (~0.01Hz). While these frequencies are not easily accessible in experimental EIS measurements they can be investigated in the EIS simulations. Possible explanations for the occurrence of the inductive feature will be discussed.

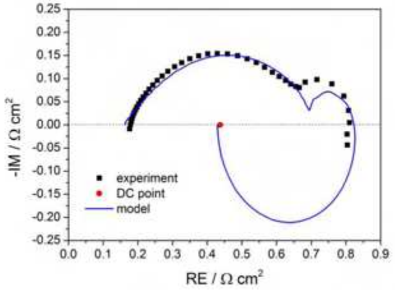

Fig. 1: Nyquist plot of an impedance spectrum at low relative humidity. The red dot denotes the total cell resistance obtained from the slope of the polarization curve

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

Examining the Effect of the Secondary ('Forgotten') Flow Field during Polymer Electrolyte Fuel Cell Operation

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Abstract

Flow fields are key factors in determining the operation of fuel cells. While extensive work has been conducted to develop and optimise the flow and current collection performance of these components, a factor that remains largely unaccounted for. Depending on how a membrane electrode assembly (MEA) is incorporated into a cell, there will often be a small gap between the edge of the gas diffusion layer (GDL) and the seal or bipolar plate. This gap acts as a 'secondary flow field' (SFF) that can bypass the main flow field. Understanding how this affects performance (either positively or adversely) is essential for holistic flow field design. This paper described the issues associated with the 'secondary or forgotten flow field' and describes the results of a 3-D computational model that shows the effect of SFF during dead ended anode (DEA) operation for a fuel cell anode without a macroscopic (conventional) flow field.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

A1307 (see B0803)

B0801

Water Phenomena in PEFC Catalyst Layers as the Origin of the Pt Loading Effect: A Modelling Study

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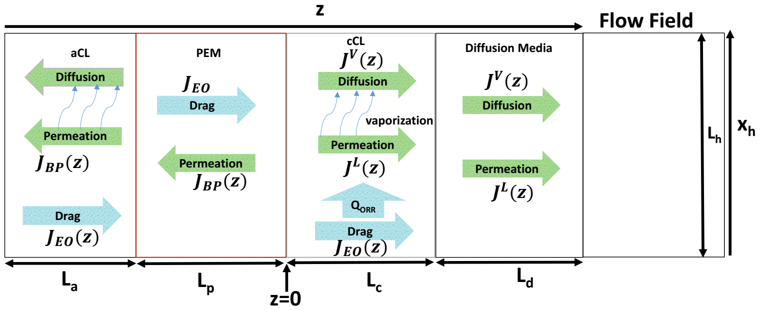
Abstract

The foremost objective of research on polymer electrolyte fuel cells is to design and fabricate catalyst layers with high performance at drastically reduced platinum loading. Achieving this objective demands an understanding of the impact of composition and porous structure on the water balance in the layer [2–4]. Experimental studies have shown a marked increase in the resistance to oxygen diffusion when the Pt content and, correspondingly, the thickness of the catalyst layer were lowered [5–7]. We employ a physical porous electrode model to explain these trends We present a water balance model to explain these trends. Figure 1 illustrates the modeling domain and the processes considered. The set of 1D continuity and flux equations is formulated and solved for the liquid water pressure, vapor pressure, oxygen pressure, liquid water flux and vapor flux. Model solutions reveal the impact of composition, porous structure, and operating conditions on the aforementioned properties. Reducing the Pt loading (i.e. reducing the catalyst layer thickness) results in lowering of the liquid to vapor interfacial area and hence the vaporization capability. Liquid water builds up at the interface of catalyst layer and diffusion medium resulting in poor oxygen diffusivity. Findings of these model should be considered in the efforts to design and fabricate advanced catalyst layers and diffusion media with improved performance.



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B0802 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Dynamic Modelling of Surface Oxide Growth and Reduction at Platinum

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Abstract

We present a physical-mathematical model of oxide formation at Platinum (Pt). The driving motivation stems from the necessity to understand Pt dissolution in cathode catalyst layers of polymer electrolyte fuel cells. As is known, Pt oxide formation and reduction, in particular under transient conditions, are strongly linked to Pt dissolution processes [1], [2]. However, a consistent model to describe these interrelated processes does not exist. We develop an oxide growth and reduction model that implements interfacial exchange processes between Pt and oxygen ions as well as transport mechanisms of oxygen vacancies via diffusion and field-driven migration. The extraction of Pt atoms at the metal-oxide interface transpires as the rate-determining step of oxide growth. Comparison of the oxide growth model with experimental data, allows parameters of the elementary processes at play to be determined. The reduction model is in the early stages of development. The oxide formation and reduction models will then be applied to dissolution studies throughout the literature.

Full article: H. A. Baroody, G. Jerkiewicz, M. E. Eikerling, “Modelling oxide formation and growth on platinum,” *J. Chem. Phys.*, vol. 146, p.144102, 2017.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0803

Two-Dimensional, Non-Isothermal Simulation Model of an Alkaline Fuel Cell (AFC): Effect of Temperature on the Polarization Curve

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Abstract

A two-dimensional model of an alkaline fuel cell (AFC) has been developed with the software COMSOL Muliphysics® which takes into account the transport of mass, momentum, energy, and charge under steady-state conditions. Basically, the model consists of two gas compartments, two porous electrodes, and an electrolyte compartment in which the potassium hydroxide electrolyte solution is circulated. For the transport of species, charge, and electrolyte solution in the porous electrodes macro-homogeneous continua are assumed where all three phases can exist at the same time. Each electrode comprises three layers namely, the stabilizing support layer, the gas diffusion layer (GDL), and the catalyst layer. The hydrophobic GDLs are assumed to prevent any electrolyte flooding completely. The hydrogen oxidation reaction (HOR) and the oxygen reduction reaction (ORR) take place in the respective catalyst layer as this is the place where the liquid electrolyte solution, the gaseous reactants, and the solid catalyst surface form the triple phase boundary (TPB). The catalyst layer is modeled based on the flooded agglomerate model so that hydrogen and oxygen react electrochemically after dissolving in the electrolyte solution covering the catalyst and diffusing to its surface, respectively. Particular attention has been paid to the description of the exchange current density in order to describe the influence of temperature and concentrations accurately. The model has been used for some parameter studies whereas the influence of temperature in the range between 25 and 75 °C will be presented in this publication.

B0804 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Molecular Simulations of Oxygen Scattering and Surface Diffusion on Ionomer Surface

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Abstract

Oxygen transport in catalyst layers (CLs) of polymer electrolyte fuel cells has a significant impact on the overall cell performance. Its mechanism is mainly governed by the Knudsen diffusion because the mean free path of gas molecules is comparable to the characteristic pore size. In this case, the scattering phenomena of gas molecules on the surface play a crucial role for the gas transport in porous structures. The accurate analysis of gas transport requires the scattering model of oxygen molecule to reproduce the scattering phenomena on the surface. Therefore, we have analyzed the scattering behaviors and surface diffusions of oxygen molecules on the ionomer thin film, which covers microporous carbons in CLs.

In this study, molecular dynamics simulations have been carried out to investigate the scattering behavior and surface diffusions of oxygen molecules on ionomer surface. Oxygen molecules were directed to the ionomer surface with a wide range of incident conditions and water contents. Trajectory calculations of impinging oxygen molecules reveal that the fraction of the two distinct scattering behaviors, which are the reflection from the surface directly and the trapping on the surface, depends on the incident temperature and water content. Incident temperature dependence suggests that the energy transfer between oxygen molecules and the ionomer surface occurs during the collision. It was found that the scattering process is affected by the molecular species in the ionomer surface where oxygen molecule collides. Oxygen molecules are more likely to reflect directly on the Nafion chain than on solvent molecules.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0805

Physical Modeling of the Proton Density in Catalyst Layer Nanopores of PEM Fuel Cells

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Abstract

In polymer electrolyte fuel cells, a primary objective is to design highly performing catalyst layer with markedly reduced platinum loading. In this realm, we present a model that explores the impact of ionomer structure and metal charging properties on the proton density distribution in a typical catalyst layer nanopore. The model consists of a cylindrical pore with a solid platinum coated core that is surrounded by an ionomer. The gap region between core and shell is filled with water. The density of charged side chains at the shell exerts a pronounced impact on the surface charge density at the Pt surface and thereby on the activity of the pore for the oxygen reduction reaction. The key parameter controlling the interplay of surface and bulk charging phenomena is the overlap of the Debye lengths of ionomer and metal surfaces in relation to the width of the gap. It allows distinguishing regions with weak and strong correlation between surface charge densities at ionomer shell and Pt core.

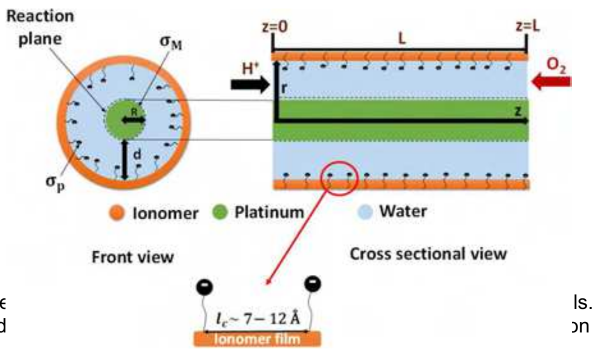

Figure 2. Sche ls. The pore space is
bounded on the other side

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B0806

Pt-Ni Aerogels as Cathode Catalysts in Polymer Electrolyte Fuel Cells

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Abstract

State-of-the-art polymer electrolyte fuel cells (PEFCs) require large amounts of carbon-supported platinum nanoparticle (Pt/C) catalysts (up to 0.4 mg_{Pt}/cm^2_{MEA}) to account for the large overpotential of the cathodic oxygen reduction reaction (ORR) [1]. To reduce these excessive Pt-loadings, the catalysts' ORR activity and durability must be enhanced, e.g. by alloying platinum with other metals like Ni, Cu and Co [2] and by replacing or removing the carbon support that suffers from significant corrosion during the normal operation of PEFCs [3].
To partially overcome these activity and stability issues, un-supported bimetallic Pt-Ni aerogels consisting of nanochains (~ 30 m^2_{ECSA}/g_{Pt}) were synthesized [4]. These materials meet the US Department of Energy ORR activity target for 2017 of 440 A/g_{Pt} at 0.9 V_{RHE} [5] when assessed by the rotating disk electrode technique. Motivated by these results, Pt-Ni aerogels were processed into membrane electrode assemblies (MEAs) and characterized in a differential PEFC.
In this contribution, we will report on the MEA optimization process of un-supported Pt-Ni ORR catalysts and compare their cell performance and durability to a conventional Pt/C benchmark. The experimental results point at the great impact on the PEFC performance of the catalyst layer structure and pore size distribution, which were investigated by focused ion beam - scanning electron microscopy (FIB-SEM). [6]

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B0807 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Molecular Analysis of Oxygen Permeation Properties in Ionomer on Pt Surface on PEMFC

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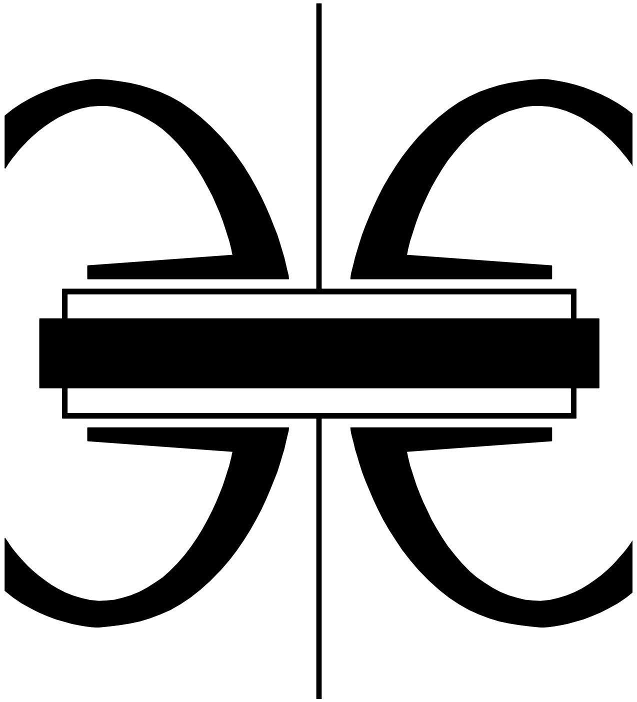
Abstract

In this study, considering the transport resistances and the concentration of adsorbed oxygen molecules in the oxygen permeation through ionomer on a Pt surface, an equation for the oxygen permeation through an ionomer was constructed. Molecular dynamics simulations were performed to analyze the oxygen transport in an ionomer on a Pt surface. The oxygen flux estimated by the new theoretical equation was much closer to the flux evaluated by the simulations, compared with that estimated using the solution-diffusion theory in our previous study. Therefore, our theoretical equation has been improved although the transport resistance is still overestimated. The transport resistance was analyzed at various water contents. As a result, it was found that the diffusion resistance was the dominant factor in the oxygen permeation through the ionomer. Furthermore, the diffusion resistance in the ionomer/gas interface was the largest in the oxygen transport resistance. Both the dissolution and diffusion resistances were smaller at lower water content, which indicates that a lower water content condition is preferable for the oxygen permeation through the ionomer on the Pt surface.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0808 (see B0805)



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Chapter 05 - Sessions A14, A04

A14 Bridge to Products: From material to cells & stacks
A04 Bridge to Products: Stack, system & manufacturing

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A1401 (Abstract only)

Opportunities and challenges for de-alloyed PtNi cathode catalysts for automotive applications

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Abstract

Despite significant improvements over the last few years towards the 2020 US DOE power density target for automotive applications (1 W/cm^2)$^{(1)}$, durability and cost are still the primary challenges for automotive hydrogen fuel cells. Johnson Matthey Fuel Cells, in collaboration with other partners, has demonstrated that de-alloyed PtX_3/C (X=Ni or Co) catalysts are capable of exceeding the DOE 2020 oxygen mass activity and durability targets$^{(2,3)}$. However, despite the excellent activity of these catalysts the performance at high current density and the stability under H_2/Air still needs to be improved. Nevertheless, this approach is currently considered one of the few viable paths towards decreasing the PGM content in fuel cell stacks, which can get very close to the loadings currently used in internal combustion engines (2-8 g Pt/Vehicle).

In this presentation we will show recent strategies that are capable of overcoming the limitations of state of the art PtNi/C de-alloyed catalysts at high power, with formulations capable of reaching specific power densities of 6.5 kW/g_{Pt} at 0.675 V with a total loading of 0.125 g_{Pt}/cm^2. In addition, progress will be shown towards meeting a higher power density target of 1.5 W/cm^2, performed under the EU's FCH JU supported project INSPIRE$^{(4)}$. Results will include advanced characterization techniques that have been applied to reveal the atomic-scale structures and near-surface compositions of de-alloyed PtNi/C catalysts, before and after being exposed to the DOE durability cycling protocol$^{(5,6)}$. These results have helped identify the mechanisms that compromise catalyst stability as well as activity and have allowed the synthesis of new materials that could be capable of thrifting Pt to levels that will help mass commercialization.

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A1402

MATISSE - MAnufacTuring of Improved Stack with textured Surface Electrodes for Stationary and CHP applications

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Abstract

MATISSE is a 36-month project targeting to the development of LT-PEMFC advanced cells and stacks for stationary applications. The consortium of the project consists of 3 industrials and 2 research organizations with CEA in the role of the project-coordinator.

The project methodology includes assessment of stacks incremented with new materials produced and processes developed during the project. Three stack designs are addressed for the stationary fuel cell operating conditions inH2/O2, H2/air and reformate H2/air – mode. MATISSE intends to achieve objectives in terms of stack robustness, lifetime, performance and cost. For this purpose, advanced material solutions are validated as proof of concept for the manufacturability of cells and stacks. The materials are validated based on defined test protocols for functional and durability testing. Applied devices for measuring the current density distribution give valuable information during electrode-development and advanced ex-situ post-mortem-analyzing methods are applied along the evaluation steps.

Textured (non-homogeneous) electrodes are aimed on avoiding electrode flooding or drying to reduce degradation phenomena, previously investigated by ex-situ analysis conducted on reference components. The manufacturability of advanced electrodes is demonstrated by using a continuous screen printing process to make the catalyst layers and by the automation of the membrane electrodes assembly step. This is aimed on reducing costs to meet the market target allowing a large deployment of stationary PEMFC systems. In this context cost assessments are carried out to assess the progression of MATISSE stack technology toward the objectives of the market.

The oral presentation, accompanied with 2 posters, is aimed on giving an overview about the project-progress in the final project-phase, highlighting of some key achievements.

The research leading to these results received funding from the European Union Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant n° 621195.

A1403

Concepts and Technologies for Production and Qualification of Automotive Fuel cells

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Abstract

The development of automotive fuel cell stacks still poses several challenges, despite the high level being already reached in industry. It is important to perform continuous benchmarking of new components becoming available. The development of technologies for the transition from small production volumes to higher volumes and the testing of components, cells and stacks with respect to lifetime under well-defined laboratory conditions as well as the transfer of these results into operational strategies for real driving requirements are continuously required. Especially the development of technologies for the transition to higher component production volumes is focus of current fuel cell engineering activities.

Within the project BREEZE, a complete 30 kW PEMFC stack design with metallic bipolar plates has been developed for a fuel cell range extender application. The stack features a flow field design optimized for dry cathode operation as well as a highly reproducible gasket technology suitable for series production. Power densities of more than 1 W/cm² have been achieved; the stack has been integrated into a compact range extender module and installed into a battery electric car. During the project significant improvements were made with respect to the stack mechanics and the relevant components, especially the gaskets: For stacking of hundreds of cells, a reproducible, automated sealing technology had to be developed and validated. Dispensing and screen printing were evaluated using available paste-like sealing materials. Finally, a dispensing laboratory and application center was established that is being used now for the development and pre-series production of gaskets for automotive and stationary fuel cells.

The joining process of the metallic bipolar plates has been identified as a second important R&D topic: as an alternative to the current state-of-the-art laser welding process, technologies for bonding of metallic bipolar plates are being investigated. They have the potential to significantly reduce cycle time and improve the yield of the production process.

In addition to production technology related R&D, also the testing and qualification of alternative materials and components that enable cost reductions of the fuel cell stack and system are an important focus area of ZBT's research activities. Test environments have been developed that allow the in-situ testing of MEA components, coatings of metallic bipolar plates and gasket materials under realistic operating conditions.

A1404 (Abstract only)

Durability Tests of PEM-Fuel Cell Stacks based on harmonized Test Procedures

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Abstract

Polymer Electrolyte Membrane Fuel Cells (PEMFC) are finding more and more widespread applications in micro CHP, materials handling and vehicle propulsion. To qualify for these applications commonly accepted test procedures need to be available not only at the system level but also on the subsystem and component level with the fuel cell stack being the key component.

In the already completed European project “Stack-Test”, a proposal for a harmonized test methodology was developed to assess performance, endurance and safety properties for PEM fuel cell stacks. Within the project series of test modules and test programs were compiled to address those topics. Test modules are supposed to be combined in test programs to address more complex test situations. Test programs should represent as good as possible the application-specific situation, having in minds some unavoidable differences between the original system and the typical test bench environment for stack testing. The approach of a modular test program is to define each individual step in detail to ensure comparability and reproducibility between different test benches and also different labs. This provides the baseline for benchmarking of stack components. All developed test modules and test programs are public and free to download from the project web page (www.stacktest.zsw-bw.de).

Essential research results achieved led to a New Work Item Proposal for standardization within the IEC technical committee TC105 which was accepted. The European pre-normative research work is now carried on within the framework of IEC standardization.

Stack durability tests for automotive applications should consider fast load-changes and steep load ramps. For that purpose, a *Fuel Cell Dynamic Load Cycle* (FC-DLC) was developed. Performing of the FC-DLC in repetitive mode leads to test-blocks with a specific duration of e.g. 8hrs, followed by a defined shutdown, break and stack recovery. The FC-DLC was successfully applied also in other European projects like “Autostack-Core” and “Impact”.

This contribution, comprising an oral presentation and a poster, is mainly focused on stack durability testing for automotive applications and the challenges associated with it.

The research leading to these results received funding from the European Union Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant n° 303445.

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A1405 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

The effect of cation contamination the performance and lifetime of the MEA

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Abstract

The increased use of metallic bipolar plates for Polymer Electrolyte Fuel Cells (PEFCs) in the automotive industry is driven by the need to increase volumetric power density and to reduce material and manufacturing cost. This, however, increases the risk of membrane contamination and increasing MEA degradation.

The issue of metallic contaminants effect on the membrane is not fully addressed in the literature. Studies showed the presence of cations in the membrane after fuel cell operation resulting in performance and durability reduction. A comparison of the effect of a number of elements; including iron, cupper, and cobalt, is reported in [1]. Iron is reported to have the most significant effect on the membrane through the reduction of protonic conductivity, increase in hydrogen crossover and the degradation of the polymer backbone.

This study looks at the quantification of membrane uptake of iron cations, and the effect of fuel cell environment on the uptake level. The study combines ex-situ and in-situ analysis of the effect on the membrane properties, namely; ion exchange capacity, proton conductivity and MEA performance. The results show extreme deterioration of the MEA and fast growth of pinholes resulting in cell failure; especially in the presence of Pt electrode. Figure 1 shows the deterioration of a contaminated MEA after 24 hour in-situ operation.

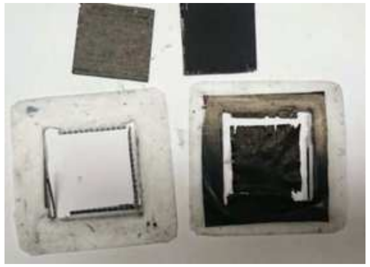

Figure 1: Contaminated MEA degradation during in-situ test

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A1406

Highly efficient and long-term stable fuel cell micro-energy systems based on ceramic multilayer technology

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Abstract

This contribution shows the development of a micro fuel cell system based on the ceramic multilayer technology. All necessary components, like the hydrogen reservoir based on metal hydrides, the planar fuel cell stack, as well as all necessary micro valves were manufactured in ceramic multilayers. The target size of the system is similar to rechargeable lithium button cell batteries (CR2450) and can substitute these. By use of metal hydrides as hydrogen storage medium, a power density of up to 290 Wh / l can be achieved that exceeds the lithium accumulator (CR2450) by more than 50% in combination with extended operating temperatures and increased cycle stability. By the potential of miniaturization of the ceramic energy system and the scalability to the specific application dimensions and performance, completely new possibilities are offered as a long-term stable energy storage, for example, in the field of autonomous sensor systems for the Internet of Things (IoT).

A0401 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Mission accomplished – AutoStack Core delivers top of class automotive FC-technology

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Abstract

“**AutoStack Core**” is a European funded collaborative project with the objective to develop best-of-its-class automotive stack hardware. The project consortium combines the collective expertise of European automotive OEMs, component suppliers, system integrators and research institutes to remove critical disconnects between stakeholders. It includes all core activities of fuel cell stack development from design over component manufacturing and stack assembly to stack performance and durability testing.

The technical concept reflects the system requirements of major automotive OEMs and builds on the **Auto-Stack** assessments carried out under an **FCH JU Grant Agreement from 2010 to 2012**. It suggests a stack platform concept 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. The project thus is addressing one of the most critical challenges of fuel cell commercialization.

Being near to completion, the project has achieved or exceeded all its major technical and cost targets. More than 60 short and full size stacks were built and tested. Results of the validation testing program are confirming robust operation of the stacks under the specified requirements. After 4 years of development, **AutoStack Core** now can provide top of class, viable and affordable automotive stack technology to support the upcoming FCEV commercialization activities.

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A0402 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Cathode Exhaust Gas Recirculation For Polymer Electrolyte Fuel Cell Stack

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Abstract

The integration of Polymer Electrolyte Fuel Cells (PEFC) for electric power supply is a challenging task. Many questions have to be answered to ensure the required reliability and efficiency of the system. According to this, in some situations like aircraft applications the fuel cell must be able to operate even in an emergency case in which the supply of oxidant from the ambient air has to be sealed off. In this case oxygen from a separate gas tank is fed to the fuel cell system.

To prevent the loss of unused oxygen by the exhaust, the cathode gas can be fed back into the fuel cell by cathode gas recirculation while oxygen is injected. Thereby the opportunity to feed back the humidity of the exhaust air for additional fuel cell humidification becomes available.

The humidification of a PEFC and their polymer membranes respectively is essential for ensuring high protonic conductivity and reduction of voltage losses. However, the water content of the inlet gas has to be regulated to prevent the electrodes from flooding and to enable the access of oxygen. To control the humidity of the system the gas flow rate, the temperature of the fuel cell and the temperature of the condenser can be adjusted. In addition, the enhanced water content in the system allows increasing the operating temperatures. This opens further opportunities in terms of scaling of a fuel cell cooling system that is especially important for e.g. aircraft applications.

This work focuses on experimental study of a 12 kW PEFC-System with closed cathode gas recirculation as well as a phenomenological model to optimize the fuel cell humidification depending on the operating parameters. Finally, an outlook on arising prospects of this concept is given.

Keywords- PEFC, cathode gas recirculation, humidification, membrane resitance, fuel cell oxygen supply, phenomenological model

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A0403

Dry start-up performance of PEM fuel cell for pressurized operation

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Abstract

Polymer Electrolyte Membrane Fuel cells need to be humidified sufficiently for proper operation. Generally, a membrane humidifier is used to humidify the supplied gas of the fuel cell. The membrane humidifier has an advantage that no additional power is needed, but disadvantages such as high differential pressure and large volume also exist. To replace the humidifier, the pressurized operation was performed during the start-up process. Segmented cell was used to understand the electrochemical characteristics of the fuel cell locally, and the relative humidity of the discharged gas from fuel cell was compared by using dew point meter at the outlet of the cathode. To modify extreme condition, dehydrated hydrogen and air were used, and the temperature of feed gas was 30°C and 50°C. As a result of the experiment, it was confirmed that when the fuel cell started at low temperature, the chemical reaction rarely occurred at the inlet of the fuel cell when the fuel cell operated at atmospheric pressure, and almost all reactions occurred at the outlet region. In the case of pressurized operation, the reaction was more actively occurred than the case of atmospheric pressure operation, and especially, the reaction more occurred in the middle part of the fuel cell. When the dry start-up process was conducted at high temperature, the overall tendency was similar to the result of low temperature case. However, it was confirmed that the reaction at the atmospheric pressure operation was ineffective as compared with the low temperature start-up operation. From the result of dew point measurement, it is expected that the water generated by chemical reaction vaporized and discharged to the outside rather than accumulated and hydrated the membrane.

A0404

Process Innovation in Electrochemical Power Generation Devices

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Abstract

A combination of the Electrochemical Power Generation Device (EPGD) and the Electric Motor has gained popularity as a main power source to provide vehicle propulsion, aiming to replace the conventional combination of the Internal Combustion Engine (ICE) and the Transmission. However, the diffusion of EPGD powered vehicles is still far lower than that of ICE powered vehicles despite efforts by car manufacturers and governments. In previous papers (Hasegawa 2014, 2015, 2016), we discussed refueling infrastructure and potential demand. In this paper we discuss process innovation and potential productivity per investment.

The changing character of product and process innovation has been studied by Abernathy and Utterback. It is well known as the Abernathy-Utterback model (A-U model). The authors mentioned that *“the shift from radical to revolutionary product innovation is a common thread in these examples. It is related to the development of a dominant product design, and it is accompanied by heightened price competition and increased emphasis process innovation”* (p.6). However, the pattern of product and process innovation of EPGD seems to be different from that of ICEs: Process innovation is mainly transplanted from existing industries, is incremental rather than radical, and has not inherently changed over 20 years.

Our purpose is to propose a framework which will specify and fix problems and attempt to trigger radical innovations in EPGD production, as explained by the A-U model. Our research questions are: why has process innovation of EPGD been stagnant (RQ1), what are the barriers which have been hindering process innovation in EPGD (RQ2), and how can we gain an insight to stop the stagnation and activate the process innovation in EPGD (RQ3).

A0405 (Abstract only, published elsewhere)

Challenges and solutions in the R2R manufacturing of fuel cell membranes

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Abstract

Uniform interface layers of electrode membranes and gas diffusion layers are the most critical part in fuel cell technology for efficient and reliable operation. Yet, mass production remains challenging and competing technologies have emerged during the recent years. Especially the low-cost high-throughput production requires quality improvements for a constant output of uniform electrodes and membranes. During the recent years intense research and development has been directed on the enhancement and safe implementation of critical production steps.

The author provides at first an overview on the roll-to-roll impregnation, coating, membrane washing, drying and lamination process of membranes and electrodes. Subsequently, an insight into the practical realization of the manufacturing is presented. Latest updates in coating and drying technology and exemplary results are discussed.

A deeper look is taken into precision coating and uniform catalyst impregnation by knife coating, continuous and interrupted slot die coating, patterned coating by screen printing, membrane washing and technologies for uniform drying and selective lamination for reliable fuel cell manufacturing. Practical experiences and specific issues are addressed in order to share lessons learned and implemented solutions.

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A0406

Experimental plant balancing and cell voltage analysis of a high temperature proton exchange membrane fuel cell stack with natural gas fuel processor

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Abstract

With operating temperatures of about 160°C, the thermal integration of HT-PEM fuel cells is ideal for combined heat and power applications. In the European joint research project CISTEM, the performance of a new generation HT-PEM based modular CHP unit is analyzed. The CHP concept is using a flexible fuel input with hydrogen and syngas from natural gas steam reforming, promising high electrical efficiencies and low performance losses.
In a first step, the natural gas fired fuel processor performance is examined at different temperatures, steam to carbon ratios and fuel input. In a second step the performance of the fuel cell stack is described. A short stack with 7 cells and a full stack with 80 cells were constructed. The short stack is used to determine degradation rates. The 80 cell full stack performance at begin of life is analyzed including statistical analysis of single cell voltage behavior under hydrogen and syngas operation at different load points. In a third step, the complete system performance is described including electrical, thermal and overall efficiencies for each operation mode.
The experimental results show a degradation rate of 6.59 µV/h over a period of 1,100 h on short stack level with 7 cells. The materials used on short stack level are identical to the ones used on full stack level with 80 cells. The statistical analysis of the cell voltage behavior of the 80 cell stack shows variances in hydrogen operation of 8.6 mV and variances in syngas operation of 11.1 mV at nominal operating point (i=0.3 A/cm²). The impact of stoichiometry and gas composition on cell voltage variances is discussed in a parameter study. At nominal operating point electrical system efficiencies of 46 % under hydrogen operation and 31 % under syngas operation could be demonstrated. The heat integration and overall efficiency with natural gas fuel supply is very promising for applications in residential energy supply systems.

The main results of this work are published in: *E. Pohl, F. Beckmann and C. Tregambe, "Experimental characterization of a modular combined heat and power unit based on high temperature proton exchange membrane fuel cells and natural gas fuel processor". Applied Energy (under review). 2017.*

Chapter 06 - Sessions B12, B13, B14

B12 Electrochemical CO_2-Reduction: Overview & potentials
B13 Industrial achievements & inventions
B14 Electrolysers & FCs - Implementation & Expectations

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B1201

Scale-up of direct Electrochemical Reduction of concentrated CO_2 in Aqueous Systems

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Abstract

Carbon Dioxide (CO_2) is a product unavoidably coupled to the energy production for electricity generation or transport based on fossil fuels, since it constitutes the lowest energetic state of carbon atoms. The increased availability of renewable energies with competitive pricing will allow the utilisation of this CO_2 as the carbon source to generate valuable molecules. A prerequisite is especially that CO_2 is not diluted in air but is available in concentrated form, which can be achieved by extracting the CO_2 from exhaust gases of fossil combustion by carbon capture technologies that become increasingly available. To transform the CO_2 into valuable products we pursue a direct wet electrochemical approach, where energy in form of electricity is needed.

The research activities hereby focus on the single step electrochemical conversion of CO_2 into basic chemical feedstock and subsequently fuels. CO_2 gas is fed to the liquid electrolyte. Energy in form of electricity (electrons) goes to one electrode, where a three phase boundary is formed with the electrolyte and the CO_2 by the usage of a gas diffusion electrode. This three phase boundary is prerequisite to allow the electrolysis at industrially relevant current densities which is at least several 100mA/cm^2. Scaling up to the kW range is ongoing with an optimisation of electrolytes.

Using an Ag based catalyst as cathode, the majority of the electrons (>90%) can be used to generate CO. At the counter electrode, water is reduced to O_2. Lifetimes are currently tested in the 1000h range. Besides the usage of Ag catalyst for the generation of CO or syngas, Cu based catalysts systems are investigated that are able to directly generate a variety of hydrocarbons including C2 and C3 components out of CO_2 by a combination of reaction intermediates on the catalyst surface.

B1204 (Abstract only, published elsewhere)

Study of modified Cu thin films for electrochemical reduction of carbon dioxide

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Abstract

Heat-trapping emissions that we are putting into the atmosphere must be significantly reduced in order to effectively address global warming. One of the attractive and sustainable ways to do it is electrochemical conversion of CO_2 into useful carbon neutral fuels using renewable energy sources[1]. For example, excess electricity generated by wind or solar power systems can be coupled with an electrolytic device to be an ideal mean of achieving high-density renewable energy storage. In order to make this process economically valuable, several challenges have to be resolved, that is: reduction of high overpotentials, increasing of overall faradaic efficiencies (FE) and product selectivities[2,3]. FEs and selectivities directly connected to the catalyst improvement due to multiple proton-coupled electron transfer steps of CO_2 reduction reaction. Among the large variety of CO_2 reduction products methanol and ethanol appears to be especially useful as a liquid fuel for instance in direct methanol fuel cells (DMFCs) or in modified diesel engines.

Most heavily investigated metal catalyst for CO_2 electro-reduction is Cu, since it can produce hydrocarbons with reasonable FE[4]. However, it is unselective and produces more than 16 different CO_2 reduction products. Cu has low efficiencies and poor selectivities for products, such as methanol and ethanol, which are targeted in the present study. However, recent experimental studies on Cu electrodes have shown that higher CO_2 and CO reduction efficiencies could be achieved by modifying these metallic electrodes[5, 6]. For example, Cu thin films prepared by electrochemically reducing thermally grown Cu oxide (Cu_2O) layers exhibit dramatically improved selectivity and up to 50% efficiency towards ethanol at -0.35 V[6].

Inspired by these studies, our present contribution will examine the behavior of modified Cu based thin film electrodes fabricated by reactive sputter deposition on a Si (100) substrates. Thin films were subsequently modified by heat treatment varying the temperature and time of exposure. Electrochemical reduction of CO_2 is performed in 0.05 M Cs_2CO_3 using a custom made parallel plate electrochemical plate cell configuration[4]. Reaction products are analyzed by gas chromatography, nuclear magnetic resonance spectroscopy and ionic chromatography. The surface chemistry and crystal structure of pristine and modified electrodes studied in detail before and after electro-reduction via X-ray photoelectron spectroscopy, grazing angle X-ray diffraction, respectively and scanning electron microscopy among other technics.

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B1205

Co-electrolysis of CO_2 and Water in a Polymer Electrolyte Membrane Cell

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Abstract

Sustainable CO_2 recycling through electrochemical reduction using energy from renewable power sources has recently attracted large interest as one of the possible means to mitigate greenhouse gas emissions. Conversion of CO_2 to value fuels in electrochemical processes can be driven by modulating both the potential and reaction temperature. Low temperature carbon dioxide reduction in solid polymer electrolyte co-electrolysis systems is an attractive process because CO_2 reaction and water oxidation occur on electrodes separated by an ion-exchange membrane. This reduces the occurrence of recombination phenomena that may decrease the current efficiency of the process while allowing for the direct production of fuels or feed-stock chemicals. The low temperature process offers more flexibility with respect to the solid oxide co-electrolysis since the overall reaction process does not necessarily require passing through syngas production as intermediate step. Moreover, the low temperature electrolysis system is characterized by rapid response thus offering a useful solution for grid-balancing service to manage the issues associated to the intermittent behaviour of renewable sources. On the other hand, low temperature CO_2 electro-reduction requires noble metal catalysts to occur at significant rates and with high voltage efficiency. In the present work, the co-electrolysis of CO_2 and water to produce alcohol fuels in a polymer electrolyte membrane system was investigated. Carbon-supported noble metal catalyst of various formulations catalysts were prepared and utilized in gas-diffusion electrodes for CO_2 reduction in the presence of water. The CO_2 reduction catalysts consisted of 2 nm average size metal nanoparticles dispersed on Vulcan® XC72. The polymer electrolyte electrolysis system was equipped with a perfluorosulfonic acid polymer electrolyte and it was operated in a wide temperature range. Electrochemical experiments clearly evidenced a direct CO_2 reaction together with hydrogen evolution at relatively low cell voltages corresponding to a high enthalpy efficiency for the process. Different type of alcohols were obtained for the various catalyst formulations with the productivity increasing as function of temperature and catalyst loading.

B1206 (Abstract only, published elsewhere)

Heat-treated Cobalt-Copper Electrodes for Formic Acid Production from Carbon Dioxide

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Abstract

The product selectivity is a key issue in electrochemical reduction of carbo dioxide to hydrocarbons.[1] Here, we report an approach to improve the formic acid selectivity of Cu electrodes. The Cu thin film electrode was first deposited with Co electrochemically. Then heat-treatments was applied to the electrodes. The deposition time was varied and thus the amount of Co can be tuned. The conditions, like temperature and gas environment, of heat-treatments were tuned as well. It was found that the heat-treatment in air is essential for promoting the formic acid selectivity. XPS, SEM, EDS, etc. characterizations show that the thin film surface was oxidized during the heat-treatment in air. The Co should be in oxide form. Although the oxidized Co should be reduced to metallic Co during electrochemical reduction of CO_2. Interestingly, it is different from directly using the deposited metallic Co, which promoted hydrogen production. The experiments showed that the Faradic efficiency (FE) of formic acid can be achieved as high as 80% on properly treated Co/Cu electrodes. Probably oxidized cobalt may modify the Cu surface towards a better stabilization of the HCOO*,[2] which is believed an important intermediate for formic acid production. The presentation will show the attempts to understand the mechanism and discuss possible reaction pathways.

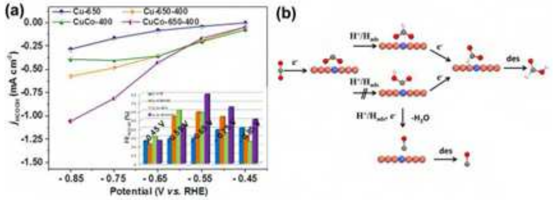

Figure (a) The HCOOH current density comparison of four kinds of catalysts, inset show the FE of HCOOH in different potentials, reduction condition: 0.1 M CO_2 saturated $KHCO_3$ aq, 1 h vs. potentials; (b) The proposed mechanism of CO_2/HCOOH on CuCo-650-400.

References

[1] Hori, Y. Electrochemical CO2 Reduction on Metal Electrodes. In Modern Aspects of Electrochemistry; Vayenas, C., White, R., Gamboa-Aldeco, M., Eds.; Springer: New York, 2008; Vol. 42, pp 89-189.
[3] Ruban, A.; Hammer, B.; Stoltze, P.; Skriver, H. L.; Nørskov, J.K. J. Mol. Catal. A. 1997, 115, 421–429.

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

B1301 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Investigation of 2 MW PEMFC power plant for hydrogen recovery from chlor-alkali industry

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Abstract

In the framework of DEMCOPEM-2MW project, the world's largest PEMFC power plant, rated at 2 MW DC electric power, has been installed inside a chlor-alkali facility in Liaoning province, China. The chlor-alki plant requires both electricity and heat as energy input and produces high purity hydrogen as a byproduct. Hydrogen recovery and conversion through PEMFC allows up to 20% of electricity saving in the chemical process. The power plant includes the modular assembly of fuel cells, the reactant supply and humidification systems, the heat recovery system. The plant has been investigated by simulations with Aspen Plus®. A model of PEMFC has been developed by fitting i-V curves of the cells at different fuel and air stoichiometry while keeping constant temperature, pressure and relative humidity, therefore the model performs steady-state mass and energy balances at different operative conditions typical of stationary applications. The voltage decay due to cells ageing is also included in the model with a simplified correlation: a constant voltage drop per hour is assumed, obtained by fitting i-V curves of the cells operated in steady state conditions for about 20000 hours in the pilot plant in Delfzijl, rated at 70 kW. The model of the complete PEMFC power plant was firstly validated against field data collected from a similar plant rated at 1 MW DC electricity output that was operated at Solvay facility in Lillo, Belgium. The model is now validated also against the data collected in the new 2 MW installation in China. It well predicts the performance of the plant in nominal conditions, while further work is on-going to model off-design conditions.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B1302 (Abstract only)

Energy analyses of fuel cell electric vehicles (FCEVs) under European weather conditions and various driving behaviours

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Abstract

To achieve holistic analyses of the energy balance it is essential to investigate the increasing influence of the auxiliaries' energy consumption. In this study the influence of the auxiliary load on the efficiency of the drivetrain FCEV is investigated. By regarding the driving behaviours and European environmental conditions the holistic energy consumption is analysed. Therefor the user behaviour is analysed with the study "Mobilität in Deutschland". For realistic boundary conditions five starting times are defined to match various situations of the everyday life. The starting times determine the corresponding weather conditions, which are obtained through a clustering, analysing the European climate regarding the ambient temperature, solar flux and humidity. With these inputs realistic auxiliary consumptions are calculated using a complete vehicle simulation. Figure 1 shows the method for Germany, respectively. With the developed methodology the auxiliary loads' impact as well as the dependency on the driving performance of specific users are analysed. A significant influence and the need to investigate solutions to reduce the auxiliary loads` consumption in future works are demonstrated.

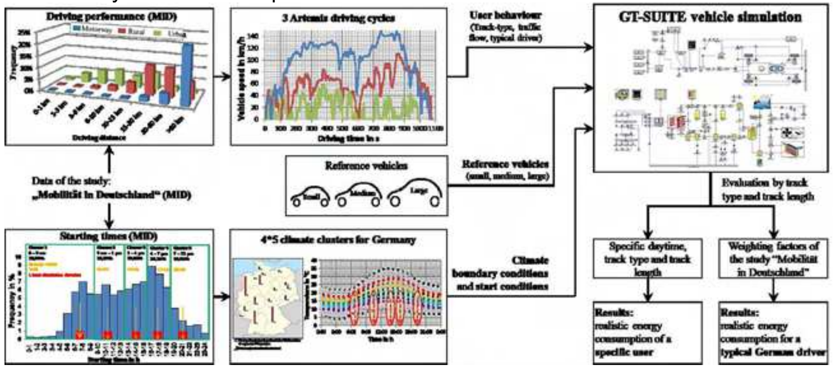

Figure1: Methodology to obtain realistic energy consumptions (with German weather conditions)

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

B1303 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

PEMFC operation with reformate gas in a micro-CHP system based on membrane-assisted reformer

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Abstract

A micro-CHP system fueled with bio-ethanol, rated at 5 kWel, based on a membrane-assisted reformer and a LT-PEM fuel cell is studied. The water-ethanol-air feed undergoes auto-thermal reforming reactions inside the fluidized bed membrane reactor where hydrogen is removed by Pd-based membranes. In principle, Pd-based membranes can produce high-purity hydrogen (99.99%, i.e. selectivity=10^4). However, the selectivity may decrease, determining low-purity hydrogen (e.g. 99% with >100 ppm CO, i.e. selectivity=10^2). Hydrogen quality affects the cell voltage and the overall system performance, therefore fuel cell control strategies must be investigated. Build-up of inert and poisoning species in the hydrogen recirculation loop is limited by venting a fraction of the anodic off-gas, whose amount can be optimized. A dynamic model has been developed to simulate the cell, including the poisoning effect of CO on Pt-Ru catalyst. An experimental campaign was performed to characterize the fuel cell operation with reformate gas. The impact of operative conditions (pressure and relative humidity) and fuel composition, containing up to 20% of inert gases and up to 40 ppm of CO, was analyzed on the overall stack performance as well as on the current density distribution along the cell surface. Experimental data constituted a valuable source for the validation of the model.

The model of the fuel cell is then integrated with the auxiliary components of the PEM-subsystem, which includes the air blower and humidifier, the anode off-gas blower and vent system. Results of the simulations of this section are presented in this work. Finally the PEM-subsystem is integrated into the complete m-CHP system, which includes the innovative membrane reformer and the heat exchangers network for feed pre-heating and heat recovery for cogeneration purposes. The part/over load operation of the system is still under investigation.

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B1304 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Fuel cell electric vehicle-to-grid: emergency and balancing power for a 100% renewable hospital

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Abstract

Hospitals are one of the most energy demanding buildings and require high reliability of energy supply. This work answer the question whether for an all-electric hospital, (urban) solar, wind and municipal wastewater biogas together with grid connected FCEVs and hydrogen as an energy carrier, can provide a 100% renewable and reliable energy system for power, heat and transport in a Mid Century (~2050) scenario. An integrated transport and energy system for a 530 bed hospital is designed based on European statistics and real energy consumption data of a newly built hospital (Figure 1). Year round energy supply is guaranteed by biogas from the city waste water treatment plant (WWTP), wind turbines at the WWTP location and rooftop solar panels on the hospital building and car park. Temporary surplus electricity is converted via water electrolysis into hydrogen. Less than 250 V2G connected FCEVs are required to balance the system al all times by generating electricity from the produced hydrogen in times of low energy supply by the intermittent renewables. The 500 place counting car park can easily host these cars. Hydrogen also serves as a fuel for the hospital vehicle fleet, consisting of only FCEVs. Seasonal inbalance of hydrogen is solved by exchange with other hydrogen consumers and producers. The emergency power system of the hospital could be replaced by grid connected FCEVs, a high pressure hydrogen storage tank at the hydrogen fueling station and hydrogen tube trailers providing an autonomy of six days during an electricity outage.

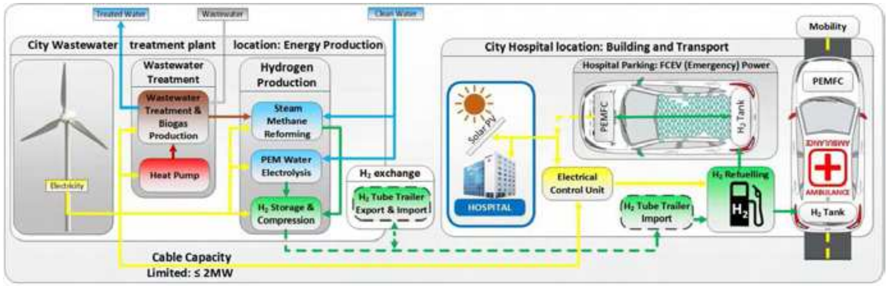

Figure 1. Key elements and functional energy performance of the fully autonomous hospital integrated transport and energy system.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'

B1305

Long Term Field Testing of PEM Fuel Cell Backup Applications in the Field of Communication

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Abstract

Communication service devices as mobile communication and security radio network for emergency aid like police and fire services are important infrastructures to ensure daily life and health services. They are even more important in potential critical situations such as accidents and thunderstorms. In case of grid failures reliable and long standing backup solutions are crucial.
Conventional backup systems for short outages are batteries. In combination with diesel generators longer outages can be handled. Diesel generators are noisy and emit carbon dioxide. In the course of ecologically friendly politics clean solutions without local emissions are demanded. In this field fuel cell systems are promising ecological and additional technical benefits and make first steps towards market entry. However, it is still difficult to get a wide spread acceptance in the field of potential end users in Switzerland. Long-term testing results and more experience with the new technology are required.

Lucerne School of Engineering and Architecture is testing five market-ready PEM fuel cell based backup systems for communication infrastructures in Switzerland. All systems are installed in the field. In accordance with end user demands there are different operational concepts: Small batteries only for the startup of the fuel cell system or big batteries where the fuel cell works as range extender after 8 hours grid off. One system is equipped with a supercapacitor startup unit. All systems work in a power range from 2 to 6 kilowatt. Hydrogen is supplied by 50 liter pressure cylinders at 200 bar.
During a testing period of two years, remotely triggered grid failures were performed on a regular basis. The system data is continuously logged and analysed.

In this work we focus on the different operational concepts, the reliability and the technical readiness of the systems. The application will be evaluated technically and economically.

The research is funded by the Swiss National Federal Office.

B1306

Advances in Non-Flow-Through PEM Fuel Cells for Aerospace Applications

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Abstract

Recent advancements in more-electric aerospace and undersea vehicles have created renewed interest in the use of air-independent fuel cells to meet power requirements. These include fuel cells for spacecraft, regenerative fuel cells for long endurance solar powered aircraft and new generation undersea drones. Similar systems have previously been developed by General Electric, United Technologies and Siemens among others. The attraction for such systems has been the potential for high performance, long life and high energy density allowing for extended mission operations and simple recharge.

A limitation of such systems, to date, has been the relatively complicated balance of plant required for system operation. This typically requires circulation of one or both reactants to remove product water and distribute reactants. These parasitic systems can reduce the overall efficiency of the system, create noise and inhibit or prevent certain missions.

Under the sponsorship of various U.S. government entities, including NASA, Infinity has been developing a non-flow-through Advanced Product Water Removal (APWR) Proton Exchange Membrane fuel cell technology that eliminates the need to actively circulate reactants and can remove water directly from the reaction site within each cell. This low temperature, compact, lightweight technology projects to a system with the operational simplicity and reliability of a battery but with the performance and rapid recharge capability of fuel cells. Its simplicity and robust design also supports lightweight integration into regenerative fuel cell systems.

This paper will report on the operational characteristics and benefits of Infinity's APWR fuel cell and present an update on development status and availability.

B1307 (see B1301)

B1308 (see B1403)

B1309 (see B1406)

B1310 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Fuel Cell Electric Vehicle-to-Grid: Experimental feasibility and operational performance

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Abstract

Future energy supply will contain intermittent renewables such as solar and wind power. To guarantee reliability of energy supply, fast reacting, dispatchable and renewable back-up power plants are required. A promising alternative are parked and grid-connected, so called 'Vehicle-to-Grid' (V2G), hydrogen powered Fuel Cell Electric Vehicles (FCEVs). To evaluate such V2G connection, a commercial FCEV was modified and a 9.5 kW three phase alternating current (AC) grid connection was installed, as shown in Figure 1. The experimental verification of such set-up shows that the FCEV can be used for mobility as well as power, when parked. By virtue of the parallel connection of the high voltage direct current battery and the fuel cell stack in the present-day fuel cell vehicles, grid connected FCEVs can respond to high load gradients in the range of -76 kW/s to +73 kW/s. Virtual power plants, composed of grid connected FCEVs could perform higher power gradients than existing fast reacting thermal power plants. Hydrogen consumption in 9.5 kW AC grid-connected mode was 0.55 kg/h, resulting in a Tank-To-AC-Grid efficiency of 43% on a Higher Heating Value basis (51% on a Lower Heating Value basis). Direct current (DC) to alternating current (AC) efficiency is 95%. In idling, equivalent to spinning reserve, in power grid terminology, hydrogen consumption was found to be 0.04 kg/h. In case FCEVs would be used for driving and V2G services all the time, start-up and shutdowns could be eliminated.

Figure 1. Experimental Fuel Cell Electric Vehicle-to-Grid (FCEV2G) set-up at The Green Village, Delft University of Technology, Delft, The Netherlands.

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B1311 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Increasing the efficiency of biogas CHP with simultaneous emission reduction

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Abstract

At present, the limit values for emissions from biogas CHP (cogeneration plant) are massively tightened. In addition to the emission limits for carbon monoxide and nitrogen oxides, which are known from the automobile sector, significantly more combustion products are now limited. These include, for example, formaldehyde, total carbon from organic substances, ammonia, chlorine and hydrogen sulphide. At the same time, formaldehyde was classified as "probably human carcinogenic". The consequence of this classification is that a limit value of 5 mg/m³ is valid, according to the latest technical instructions for the air purification in Germany.

The, in some cases, relatively high methane, carbon and formaldehyde emissions from CHPs [2] are indicators for incomplete combustion of biogas. Currently, these emissions are reduced by two complex exhaust gas aftertreatment processes (oxidation catalyst, thermal afterburning). The new limit values of the German technical instruction require finance investments at the biogas plants and causes, that these plants can no longer be operated economically. This may lead to the dismantling of the plant.

In order to counteract this problem, the reduction of the pollutant output with simultaneous efficiency advantage is examined by the addition of a combustion moderator to the fuel-air mixture into the internal combustion engine. In terms of a biogas plant, hydrogen can be used as a combustion moderator. It can be produced either by separation of the stages of the fermentation process (separate hydrolysis) or by the conversion of the biogas into a hydrogen-rich gas by the utilization of the waste heat of the CHPs on site (thermochemical recuperation). In addition, hydrogen can be obtained by water electrolysis.

Hydrogen has special combustion properties. The high burning velocity, the small gap width and the high thermal conductivity favour a complete conversion of the fuel-air mixture in the cylinder, which significantly reduces the occurrence of formaldehyde and unburnt hydrocarbons in the exhaust gas. The detailed study of the described question is carried out within the framework of a project funded by the European Social Fund (ESF). The consortium consists of four SMEs and two R&D institutions.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'

B1401

H2FUTURE - Hydrogen from Electrolysis for Low Carbon Steelmaking

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Abstract

The H2FUTURE[1] project aims to make hydrogen sufficiently affordable in the future so it can act as an energy carrier in a low-carbon energy system. In a 4.5-year, €18 million field demonstration project, a consortium, led by Austrian-based utility VERBUND, will construct and operate one of the world's largest proton exchange membrane (PEM) electrolysis plants for producing green hydrogen for the steel industry.

A 6 MW state-of-the-art Siemens electrolyser will be built and operated on the premises of voestalpine in Linz, Austria, and the hydrogen produced will be integrated into regular operations at the steelworks. As such, the project is an innovative step in the development of a route for steelmaking using pure hydrogen, where iron ore is directly reduced by hydrogen in a shaft furnace. By producing hydrogen from electrolysis and using renewable electricity for electrolysis, this process scheme offers a promising route to low-carbon steelmaking.

As part of the project, the electrolyser will be prequalified with the support of Austrian Power Grid (APG), the Austrian transmission system operator, in order to provide grid-balancing services such as primary, secondary or tertiary reserves while utilising the commercial pools of VERBUND. The demonstration is split into five pilot tests and an 18-month quasi-commercial operation to show that the PEM electrolyser is able both to use timely power price opportunities and to attract additional revenues from grid services.

The achievement of capital cost reduction and other technical, economic and environmental performance targets will be analysed by knowledge institutes ECN and K1-MET. This will be done based on data resulting from an extensive pilot plant test programme and an 18 month quasi-commercial operation.

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[1] This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 735503. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and Hydrogen Europe and N.ERGHY.

B1402 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Application of Water Electrolysers in the Swiss Balancing Service Markets

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Abstract

The Swiss balancing service markets support explicit demand side response where industrial installations and micro-units participate as virtual power plants, opening the market to new technologies such as water electrolysers. A research program supported by the Swiss Federal Office of Energy SFOE and the Association of Swiss Electricity Companies VSE analyses the market situation and identifies requirements, opportunities and obstacles for suppliers of balancing services in the Swiss markets.

The article starts with the characterization of the Swiss balancing service markets, then considers the conclusions relevant to water electrolysers and quantifies the financial contribution of balancing energy to the business case. It concludes with an outlook about the FCH research project *Standardized qualifying tests of electrolysers for grid services* QualyGridS, where the considerations are extended to the balancing energy markets of the European member states.

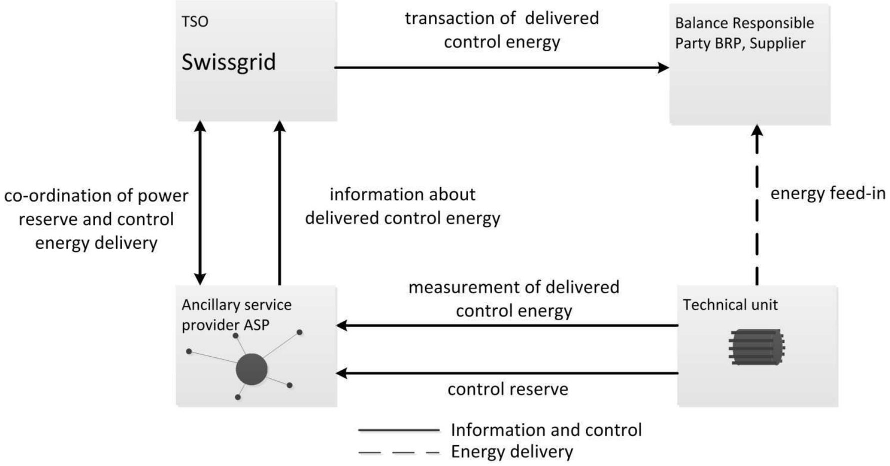

Figure 1: Aggregator model implemented in Switzerland (illustration based on [5])

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B1403 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Cost-efficiency of a CHP hydrogen fuel cell

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Abstract

The project H2home - decentralised energy supply by hydrogen fuel cells - is part of the HYPOS initiative (Hydrogen Power Storage & Solutions East German) and will develop an embedded system suitable for the highly efficient use of electrical, thermal and cooling energy provided by green hydrogen in domestic applications. This system is characterized by a hydrogen CHP plant based on a low temperature PEM fuel cell and a hydrogen-based heat generator module with the application of condensation technology as well as an integrated solution for the use of electrical energy in an AC and DC grid through power electronic components. The electric efficiency of the CHP is higher than 50% and the total efficiency higher than 95%.

The first step was the identification of possible fields of application with the help of the simulation tool TRNSYS. The results showed favourable economic conditions for operation in apartment buildings, hospitals and care centres.

With these simulation results, the parameters of an economical operation were determined by a parametric study based on at least 5.500 full load hours, a private consumption share of electrical energy with more than 80%, full utilization of generated thermal energy, hydrogen cost lower than 0.10 €/kWh as well as the low investment costs. The most relevant parameter is low-cost hydrogen.

The concept and the parameters for an economic commitment will be explained in the present paper.

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B1404

Impact of Dynamic Load from Renewable Energy Sources on PEM Electrolyzer Lifetime

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Abstract

The paper proposes a PEM electrolyzer test protocol for gaining insight into the degradation behavior of the electrolyzer specifically under dynamic load patterns as might occur by varying energy supply of renewable energy. PEM electrolyzer are able to achieve 40,000 hours of lifetime or more. However, this lifetime literally comes at a cost. Long lifetimes can only be achieved using expensive materials. Degradation can be limited by using high catalyst loadings, thicker membranes, complex fabrication technology for the separator plate, etc. But the use of these materials adds excessively to the cost of the electrolyzer stack. Therefore durability has a double impact on the electrolyzer economics. Reduced lifetime increases the capital cost because of depreciation over a shorter period of time. But also because of the need to go to more expensive materials. In addition PEM fuel cell development has extensively shown that degradation may be much quicker under impact of rapid load changes, start-stop cycles and operation close to open cell voltage. Although there are a number of important differences between fuel cells and electrolyzers, durability needs to be assessed both under full-load and under transient and off-design conditions. In particular if the electrolyzer is used to manage a varying supply of renewable energy, it will be operated under varying loads. How these will vary, depends on the application.

Determining durability is challenging, especially when dynamic load patterns are used. It is time-consuming to do a single lifetime measurement and the time required to determine the impact of several variables rapidly becomes an issues. The “holy grail” regarding lifetime is to be able to accelerate degradation in such a way that it allows prediction of the durability of components under real conditions (Accelerated Stress Testing (AST)). Operating at a higher temperature, a higher impurity level or higher current density will accelerate degradation.

In this paper a proposal for an AST test protocols will be given based on an extensive study on degradation mechanisms from literature. The feasibility of the proposed AST-protocols will be validated experimentally.

B1405 (Abstract only)

Hydrogen Mobility Europe (H2ME) – Creating the European Vision for Hydrogen Transportation

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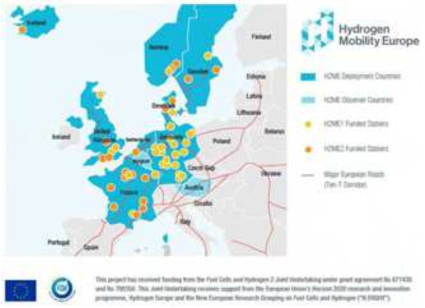
Abstract

The European Commission has identified Hydrogen Fuel Cell Electric Vehicles as a key technology needed for Europe to meet its ambitious target of reducing GHG emissions from the transport sector by 60% by 2050. Hydrogen refuelling technology has progressed significantly since the first demonstration and funding programmes began, but a number of market barriers persist preventing its widespread uptake within European markets.

H2ME combines Europe's four leading initiatives on hydrogen mobility (in Germany, France, The Netherlands and The UK), removing market barriers to create a truly pan-European hydrogen network and a united deployment strategy. The project will provide a unique opportunity for these major initiatives to harmonise their strategies for the first time and significantly expand Europe's hydrogen vehicle and station network.

H2ME is the largest demonstration project to date, testing different strategies and the latest technology from leading car OEMs of the sector (Daimler, Symbio FCell, Honda, Hyundai and Toyota). The project will also test electrolyser technology in refuelling stations and provide valuable insights into the role of hydrogen in providing the solution for an emission free European transport network. H2ME will launch 49 stations and more than 1400 vehicles across 10 countries throughout the course of the project.



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

B1406 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Improved performance of modular HT-PEM based CHP systems considering seasonal effects and degradation effects

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Abstract

In the European joint research project CISTEM, a modular combined heat and power (CHP) system based on high temperature proton exchange membrane (HT-PEM) fuel cells is developed. The system consists of 10 modules, each with one steam reformer and two HT-PEM stacks. The electrical output per module is up to 8 kW. In order to calculate the primary energy savings (PES) of a CHP system, the fuel demand of the CHP system is compared to conventional separated heat and power generation (boiler and electrical grid). The impact of seasonal effects and performance loss on PES in a modular CHP system is presented in this contribution.

In a first step, the demand side and the fuel cell based CHP modules are described. With the data a complete performance map is set up in a second step. The performance map describes the relation of characteristic process parameters (fuel utilization and fuel input) on electrical power output and efficiency. A major benefit of modular fuel cell systems is that the power to heat ratio can be modified in each module. The total amount of generated heat and power can be modified by the number of operating modules. For an optimized operation, following strategy is analyzed in a third step: In winter terms, a lower power to heat ratio is needed than in summer terms. Hence, the operation is performed with high current densities in winter and low current densities in summer. Over time the module suffer losses, represented by a declining polarization curve of the fuel cell stack. In order to remain the power to heat ratio constant, the operating point of the stack is switched towards lower current densities. The stack voltages are held constant for summer and winter mode respectively. Since the total power output per module decreases, more modules are switched on over time. The performance loss is compensated with more operating modules.

The numerical analysis show that PES of above 20% is possible compared to separated heat and power generation. The presented operation strategy considers irreversible performance losses and shows how to achieve a high PES level over a theoretical operating time of about 40,000 hours per module. The operating hours are estimated defining 80% of the initial operating point as end of life. Typical degradation rates of the stacks were determined within this project. As a side effect, the CHP module reaches high operating hours per year which also improves economy.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'

B1407

QualyGridS - Standardized qualifying tests of electrolysers for grid services

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Abstract

The project QualyGridS establishes standardized testing protocols for electrolysers to perform electricity grid services. Low temperature alkaline and proton exchange membrane (PEM) electrolysers are both considered within the QualyGridS project. A variety of different grid services is addressed as well as multiple hydrogen end users. The protocols developed will be applied to both electrolyser systems with powers ranging from 50 up to 300 kW. Additionally, a techno-economic analysis of business cases is realized covering the grid and market situations in the most relevant regions of Europe for large electrolysers (>3MW). The testing protocols and economic analysis also include the review of existing and possibly new key performance indicators (KPI) for electrolysers. An overview is given of multiple electricity grid services for TSOs, DSOs and/or peer-to-peer operators in Europe that could be performed by electrolysers.. The requirements for electricity grid services are simulated through dynamic tests of an electrolyser system.

B1408 (Abstract only)

Innovative Approach for Nano-structured Electrode of Solid Oxide Cells

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Abstract

Solid oxide cells (SOCs) are electrochemical systems capable of operating reversibly and therefore may serve as versatile energy converters. Due to their severe operating conditions, the ideal fuel electrode materials has not been found yet to accomplish of its requirements such as electronic and ionic conductivity, and catalytic activity with strong stability in redox condition. Ni-YSZ cermet has been regarded as the embodiment of this functional trinity. However, even though degradation associated with reversible operation can be mitigated, the cermet electrodes still suffered from agglomeration during redox condition. Recent electrode designs have been developed to microstructures consisting of a porous mixed ionic electronic conductor backbone decorated with metallic nanoparticles by impregnation method. However, these are still hindered by the lack of cost and time-effective methods to produce both robustness and high-performance from their nanostructured electrodes. Here, a simpler alternative, will be introduced, exsolution whereby the catalytically active metal is substituted in the crystal lattice of the backbone in oxidizing conditions and exsolved on the surface as designed metal particles under reduction condition. Here I demonstrated a simple and highly effective in situ method for producing nanostructured electrodes capable of delivering high performances in both fuel cell and electrolysis mode.

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

Chapter 07 - Sessions B05, B10, C12

B05 H2 from Electrolysers: Concepts & costs
B10 Electrolyser cell & stack performance
C12 Photoelectrochemical Water Splitting
Microbial & Direct Formic Acid Fuel Cells

Content **Page B05, B10, C12 - ..**

B0501 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Performance enhancing study for large-scale PEM electrolyser cells based on hydraulic compression

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Abstract

Polymer electrolyte membrane electrolyser (PEMEL) systems with a power consumption in the MW range and a respective hydrogen generation of several hundred $Nm^3 h^{-1}$ have already been demonstrated in recent years. These large-scale systems contain PEMEL stacks with up to 100 cells and cell sizes of more than 1,000 cm^2. However, further research and development is necessary regarding larger cell areas and higher power consumption, in order to get competitive to state of the art alkaline electrolysers.
In this work, we present a novel PEMEL cell design based on hydraulic compression, which offers some relevant advantages in comparison to typical cell designs using mechanical compression. A modular prototype stack has been developed which provides four single cells. Each cell in this stack is completely surrounded by a hydraulic medium. The pressure level of the hydraulic medium can be adjusted depending on the cell design, in order to improve inner cell resistance. During operation, the optimum compression level can be kept constant at any gas output pressure by adjusting the hydraulic pressure accordingly. In addition to that, waste heat transfer and compression forces are homogeneous throughout the entire cell area of each single cell. Hence, homogeneous operation conditions are guaranteed independent of the actual cell size and stack size. As a result, this novel concept allows for upscaling laboratory cells/stacks to industrial scales without performance losses, as the current density can be kept at high levels. Prototype cells with 600 cm^2 cell area have been realised at our institute.
The performance of a laboratory cell was analysed dependent on varying operation conditions using our fully automated PEMEL test bench and a stack able to operate up to four cells at a time (see figure 1). Especially, the influence of the pressure level of the hydraulic medium has been investigated. The results obtained in the laboratory will be used to develop improvements for the industrial scale cells.

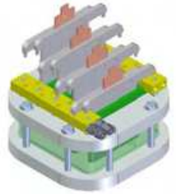

Fig. 1: Schematic drawing of our prototype PEMEL stack.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0502

Hydrogenics' MegaWatt PEM platform, operational monitoring data from prototype and 1.2 MW units

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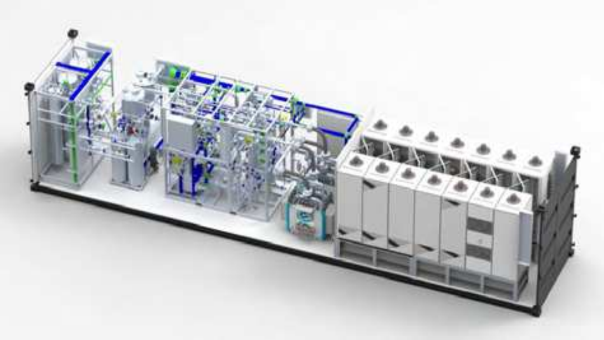
Abstract

This contribution discusses the performance of two PEM hydrogen generation systems based on Hydrogenics 1500 cm² area stack. A 150 kW prototype was installed in august 2015 in the Don Quichote FCH-project. This unit is fully equipped with monitoring devices and test options. Until present the stack has accumulated 460 running hours in a hydrogen fueling application with 850 kg of hydrogen produced. Some of the Balance-Of-Plant (BOP) related downtime called for a small redesign of this prototype. At the same time some control parameters were fine-tuned to increase the overall unit efficiency. The gathered experience served as a basis for a dual stack 1.2 MW installation of the Hybalance project, co-funded by the FCH-JU, the Copenhagen Hydrogen Network (CHN) and Energynet.dk. The unit has been designed for industrial hydrogen production and grid service delivery. The dual stack electrolyzer fully benefits from the lessons learned of the smaller prototype unit on top of various improvements towards higher output, increased operating pressure, prolonged lifetime, higher reliability and improved efficiency. The BOP is optimized to minimize parasitic loads in process and auxiliary equipment. The recorded stack efficiency during FAT was below 50 kWh/kg. This unit has also been optimized for fast reaction times in grid balancing operation, it is able to react to load situations in a few seconds. This experience has led to the design of a 2.5 MW hydrogen generating process skid housed in 40 ft. container together with its utility equipment.



B0503 (Abstract only)

PEM Electrolyser-project Arzberg (Germany) and modular LOHC-Energy storage system

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Abstract

This is a template about practical tests in the field of PEM Electrolysis and LOHC long term Storage in a "green power production" site of a PV field test. The project includes 25 Partners (Public Private Partnership) with the focus to produce green power with different PV Technologies and to store with short term technology like Redox-Flow and long term technology like with the hydrogen chain**:**
Green power production of hydrogen (Solar, wind turbine) -→ H_2/O_2 production via PEM water electrolysis (75 kW) -> Hydrogen as energy storage with LOHC (Liquid Organic Hydrogen Carrier) technology by AREVA

A) PEM Electrolyser will be tested in use to stabilize the grid from variations which may be occur by the use of PV-plants:

Measurements at the Arzberg test site:

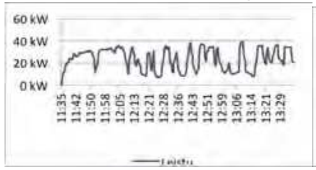

Figure 1

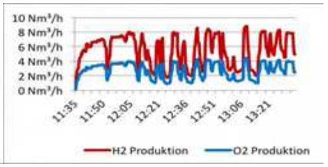

Figure 2

1. Dynamic: Simulation of a PV-profile (Figure 1) Excellent dynamic control of PEM Electrolyser performance – The Hydrogen Production goes on the same level like the PV – profile runs!

2. Hydrogen and Oxygen production from photovoltaics (Figure 2) Dynamic H2 and O2 production
from „green electricity".

3. Efficiency total system vs. hydrogen production
High efficiency on a wide operating range, highest efficiency at design point. The PEM Electrolyser reach a level of 70 % efficiency while running with 30 % of the capacity (5 NM3 of 15 NM3)

B) Storage with LOHC Technology and the field test in Arzberg will help to answer them:

Technical: Cycle stability of LOHC and Catalyst durability, Optimization of sub systems for a better total efficiency and Heat management
Commercial: Design-to-Cost, Serviceability and Usability friendly design

Commercial maturity of PEM Electrolysis & LOHC today & tomorrow
Today: Around 3 times more expensive (incl. development) than prototype targets
Advantages of LOHC -> Safe storage of hydrogen:

- Due to chemically bonded hydrogen on LOHC, no gaseous phase of H_2
  LOHC can be stored under normal conditions (ambient pressure and temperature)
- No loss of hydrogen e.g. due to permeation on gas tanks
- Long term (seasonal) energy storage capability on a small foot print
- LOHC can be transported in existing infrastructure (tanks, trucks, ships etc.)

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

B0504

PEM water electrolysis: impact of cell design and porous components properties on mass transport limitation

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Abstract

With about 50% of the stack cost, it might be beneficial from CAPEX point of view to replace the machined bipolar plate (BP) with a flow-field free BP cell design in PEM water electrolysis systems.
In this study, we investigated the use of “stack” of two titanium grids (expanded metal) and various microporous structures of titanium sinters on PEM water electrolysis (WE) performances. It was found that the grid orientation (overlaid or crossed each other) may modify the mass transport limitation on the polarization curves. In addition, consistently with that was already reported, the sinters properties (mainly the pore size rather than the porosity) may have an impact on the mass transport issue. Interestingly, the study of the water flux through the membrane showed two slopes and an inflection point that corresponds to the current whereby the mass transport limitation appears on the polarization curve. Based on impedance measurements, water flux and polarization curves analysis, we illustrated that sinters properties and cell configuration may impact significantly the mass transport issue in PEM WE system.

B0505

Achieving Cost Reduction in PEM Electrolysis by Material Development

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Abstract

Hydrogen is expected to play an important role as a crosslinking technology between power generation on one hand and transport and industry on the other hand. It can directly replace fossil fuels in transport and industry when produced by water electrolysis renewable energies such as solar or wind, which are converted with low efficiencies. The relevant technologies are either the mature alkaline electrolysis or the newer proton exchange membrane (PEM) water electrolysis. For PEM electrolysis in particular, key components that determine the stack cost are the titanium-based contact elements, such as the bipolar plates (BPP) and the current collectors (CC), and the high iridium loading of electrocatalyst for the OER in state of art membrane electrode assemblies (MEA). However, the cost structure depends on the specific design of the electrolyser. This paper will discuss strategies for cost reduction by synthesizing unsupported and supported IrOx and $IrRuO_x$ electrocatalyst with the aim of lowering the high loading. Our synthesis procedure consists of producing nano-sized iridium particles by reducing iridium chloride ($IrCl_3$) with conventional sodium borohydride at room temperature and in water-free environment. This concept can also be applied to supported and alloy electrocatalysts. The supports need to be highly stable and exhibit sufficient electronic conductivity. The enhancement of activity achieved with improved electrocatalyst reaches a factor of about15 with respect to the best commercially available electrocatalyst. Additionally, the cost reduction achieved by a titanium coating for stainless steel BPPs or CCs for PEM electrolysis will be discussed. We use vacuum plasma spraying (VPS) to coat either dense coatings for corrosion protection of stainless steel components or build up titanium diffusion layers with defined porosity as contact elements for the MEA. The conductivity of the titanium coating can be improved by well-known Pt or Au additions; however, we have also developed promising non-noble conductivity enhancement elements. Furthermore, the VPS coating and production procedure is adaptable to large-scale industrial production.

B0506 (Abstract only)

Cost Break Down and Cost Reduction Strategies for PEM Water Electrolysis Systems

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Abstract

Due to several advantages proton exchange membrane (PEM) electrolysers are an emerging technology with a growing market share and regarded as an important component in a future energy sector based on renewable energies. However, main challenges of the PEM technology are high costs associated with expensive materials and the durability of cells and stacks.

In this work a cost break down model for large scale PEM electrolysis stacks was developed in a first step. It predicts specific stack costs for PEM electrolysers depending on the cell design, size (see Figure 1, left), electrochemical performance and production volume. The model allows a cost analysis and can be used as tool for cost reduction strategies. In a second step the cost analysis was extended to the system level in a similar approach. Main results of the work are cost estimations for PEM electrolysers in different application. Cell performance are key parameters for the cost estimation and results show that specific costs of < 500 €/kW_{el} are feasible for PEM electrolysis systems once the technological progress is met. The results will be compared with literature data for alkaline and PEM electrolysis systems. In a last step the influence of different parameters on hydrogen production costs (see Figure 1, right) will be evaluated and discussed according to the target values of the Multiannual implementation plan (MAWP) from the FCH JU.

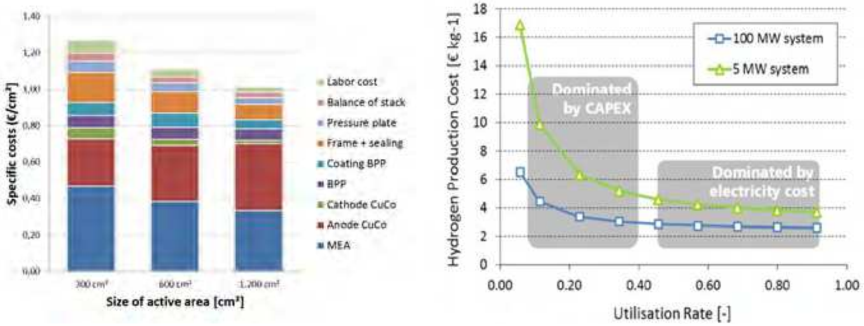

Figure 1: Cost share of different cell sizes for PEM electrolysis stacks(left) and hydrogen production cost depending on the utilization rate (right).

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

B0507 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Vibrational Disassociation

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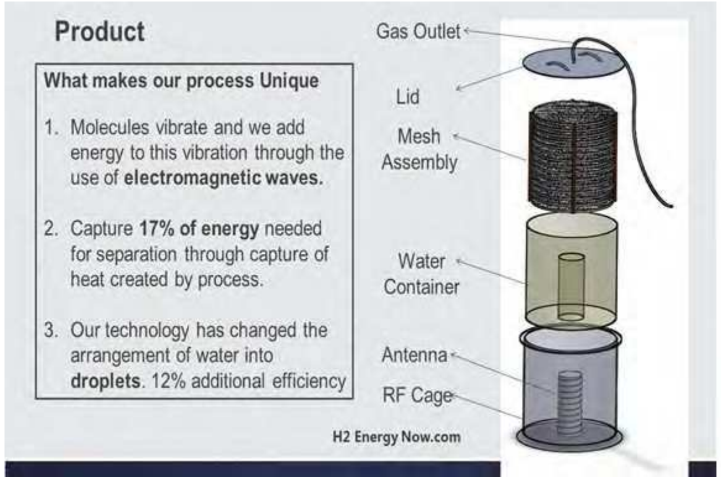
Abstract

We have developed a new technology for the creation of hydrogen from water by the use of electromagnetic waves. This will enable us to store alternative energy enabling its use 24/7. In the state of the art, James C Maxwell stated there is a direct connection between electricity, electromagnetism, light and energy. Our technological breakthrough came from using electromagnetism to disassociate the water molecule. Through thought experiments, testing and research and development we developed a system that is the most efficient method in creating hydrogen from water for large scale production. Our technology breakthrough came from understanding the principles of water and then devising solutions to overcome some of them. For example we realized waters ability to share energy was a disadvantage so we developed a system to spray the water in and a system to hold the water in droplet form. This enabled our system to overcome the ability of water to share energy.



Product

What makes our process Unique

1. Molecules vibrate and we add energy to this vibration through the use of **electromagnetic waves.**
2. Capture **17% of energy** needed for separation through capture of heat created by process.
3. Our technology has changed the arrangement of water into **droplets**. 12% additional efficiency

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B0509 (see B1003)

B0510 (Abstract only)

Hydrogen Production from Zinc Dissolution in Saline Formation Water

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Abstract

One of the promising processes to produce high purity hydrogen using the dissolution of zinc metal in saline formation water at different conditions has been studied using hydrogen evolution and cathodic polarization measurements. This process mainly consumes formation water and zinc which are cheap raw materials. The results show a strong dependence of the hydrogen evolution rate on the temperature and solution pH. An increase of solution temperature from 298 to 338 K causes a rise in the hydrogen production. On the other hand, a decrease in solution pH enhances hydrogen production rates and yields. The activation energy (E_a) of the hydrogen production process is 4.28 kJ mol^{-1}, confirming a control by a mass transfer. Scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) have been utilized to identify and characterize surface corrosion of zinc in formation water.

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

B0511

Densification of gadolinium-doped ceria diffusion barriers for solid oxide electrolysis cells

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Abstract

Gadolinia-doped ceria (GDC) sols were synthesized by the controlled hydrolysis and condensation of cerium(IV) isopropoxide with each gadolinia doping agent to make a dense GDC diffusion barrier for solid oxide electrolyte cells (SOECs) and intermediate-temperature solid oxide fuel cells (IT-SOFCs). The crystallinity of a GDC sol using gadolinium(III) isopropoxide as the doping agent was five to six times stronger than that when using gadolinium(III) nitrate hydrate as the doping agent. The GDC diffusion barrier was fully densified by infiltration of a GDC sol into a porous GDC structure under heat treatment at 1000 °C. The performance of a cell was highly improved from 0.60 W/cm^2 to 0.92 W/cm^2 at 750 °C by densification of the diffusion barrier. EIS results suggest that the improved performance is mainly due to the reduced ohmic resistance through the composite electrolyte (i.e., YSZ/GDC). Finally, the degradation of a single cell with a dense GDC was maintained below 1.72%/1000 h, which was lower than that of a cell with a porous GDC (7.69%/1000 h). Based on these results, it can be concluded that the enhancement of the performance and durability of a single cell with a dense GDC was the result of reduced ohmic resistance through the composite electrolyte.

[Reference]

H.J. Choi, Y.H. Na, D.W. Seo, S.K. Woo, S.D. Kim, Densification of gadolinium-doped ceria diffusion barriers for SOECs and IT-SOFCs by a sol-gel process, Ceram. Int., 42 (2016) 545-550.

B0512 (Abstract only, published elsewhere)

Effect of ozone pretreatment on biohydrogen production from complex biomethanated distillery wastewater

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Abstract

The present study reports the feasibility of ozone oxidation as a pretreatment option for biohydrogen production from complex distillery effluent with complications of low biodegradability index (BOD/COD ratio<0.2),high color and toxicity. Ozone pretreatment of Biomethanated distillery wastewater resulted in biodegradability index (BI) enhancement (0.17-0.6), color , COD and toxicity reduction. Ozone pretreated wastewater with enhanced BI on anaerobic digestion resulted favorable biohydrogen production with hydrogen content up to 63% along with further COD reduction of 52.5%. The HPLC analysis has confirmed the degradation of major coloring compounds during ozone pretreatment. Modified Gompertz equation illustrates the overall rate and hydrogen yield was higher for ozone pretreated effluent compared to control. The ozone pretreated wastewater has shown positive effect on seed germination (up to 100%) indicated toxicity reduction of wastewater post ozone pretreatment.

Remark: Only the abstract is available, because the authors chose to publish elsewhere.
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B1001

Structural Characterization of Porous transport layers for polymer electrolyte water electrolysis cells

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Abstract

In order to develop efficient PEWE systems, the fundamental understanding of the different components and related losses is a main requirement. The least understood loss category are the losses related to mass transport. The porous transport layers (PTL) are key components in the electrochemical cell providing thermal and electrical conductivity, as well as water and gas management between catalyst layer and fluid channels.
The two phase flow induced by water and the produced gases in PTLs is a possible source correlated to mass transport losses. It is reported that the structure of PTLs impact the performance of the cell but the design parameters haven’t been isolated so far. This study focuses on the characterization of PTLs and related transport losses [1].

B1002

Enhanced performance and durability of low catalyst loading PEM water electrolyser based on a short-side chain perfluorosulfonic ionomer

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Abstract

Water electrolysis supplied by renewable energy is the foremost technology for producing “green” hydrogen for fuel cell vehicles. In addition, the ability to rapidly follow an intermittent load makes electrolysis an ideal solution for grid-balancing caused by differences in supply and demand for energy generation and consumption. Membrane-electrode assemblies (MEAs) designed for polymer electrolyte membrane (PEM) water electrolysis, based on a novel short-side chain (SSC) perfluorosulfonic acid (PFSA) membrane, Aquivion®, with various cathode and anode noble metal loadings, were investigated in terms of both performance and durability. Utilizing a nanosized $Ir_{0.7}Ru_{0.3}O_x$ solid solution anode catalyst and a supported Pt/C cathode catalyst, in combination with the Aquivion® membrane, gave excellent electrolysis performances exceeding 3.2 $A\cdot cm^{-2}$ at 1.8 V terminal cell voltage (~80 % efficiency) at 90 °C in the presence of a total catalyst loading of 1.6 $mg\cdot cm^{-2}$. A very small loss of efficiency, corresponding to 30 mV voltage increase, was recorded at 3 $A\cdot cm^{-2}$ using a total noble metal catalyst loading of less than 0.5 $mg\cdot cm^{-2}$ (compared to the industry standard of 2 $mg\cdot cm^{-2}$). Steady-state durability tests, carried out for 1000 h at 1 $A\cdot cm^{-2}$, showed excellent stability for the MEA with total noble metal catalyst loading of 1.6 $mg\cdot cm^{-2}$ (cell voltage increase ~5 µV/h). Moderate degradation rate (cell voltage increase ~15 µV/h) was recorded for the low loading 0.5 $mg\cdot cm^{-2}{}_{MEA}$. Similar stability characteristics were observed in durability tests at 3 $A\cdot cm^{-2}$. These high performance and stability characteristics were attributed to the enhanced proton conductivity and good stability of the novel membrane, the optimized structural properties of the Ir and Ru oxide solid solution and the enrichment of Ir species on the surface for the anodic catalyst [1].

B1003

Developments for alkaline electrolysis: From materials to laboratory electrolysis

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Abstract

Hydrogen production in industry is dominated by the steam reforming of hydrocarbons, resulting in high CO_2 emission. Due to the increasing amount of renewable electricity, water electrolysis attracts increasing interest as an environmental-friendly hydrogen production technology and as a method for energy storage. Besides polymer electrolyte membrane electrolysis, alkaline water electrolysis is of high interest for megawatt systems due to its robust quality and long-life experience.

In order to make the alkaline electrolysis more cost-effective, the energy consumption for water splitting in alkaline electrolyser has to be reduced. The strategies aiming at the efficiency improvement of alkaline electrolysis are elevating the operation temperature and pressure as well as lowering the overpotentials. The latter can be achieved by an optimised cell design, both with respect to materials properties as well as regarding geometrical and process features like electrolyte flow or transport of gas bubbles. Experimental studies on such parameters are, however, scarce, as laboratory equipment for realistic alkaline electrolysis conditions are hardly available.

A prototype lab-scale alkaline electrolyser was built at Empa, which is operated at high pressure (up to 30 bar) and high temperature (up to 80 °C). The system also offers extensive controlling and monitoring capabilities, enables both steady-state and transient electrolysis conditions, and provides a high flexibility to the design of electrodes and diaphragms. A cost-effective barite-polysulfone composite diaphragm was initially invented at Empa. Its properties, such as chemical and mechanical stability, gas tightness and ionic conductivity, are intensively investigated, which feature excellent performance under harsh electrolysis conditions.

B1004 (Abstract only)

Investigation on porous transport layers for PEM electrolysers

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Abstract

Porous transport layer (PTL) plays an essential role in PEM electrolysis cells to transport gas and water and electrical current. The mass transport overpotential is observed at higher current densities in PEM electrolysis cell, which has given comparatively less concern in literature to date. To understand and overcome the mass transport overpotential, we have started to build up a fundamental understanding by comprehensive ex-situ and in-situ characterisation. Different parameters of PTLs are measured using diverse ex-situ experiments. Mercury intrusion porosimetry is used to study pore size distribution and porosity, capillary flow porometry (CFP) is used to investigate through-plane gas permeability and pore size and permeatry is used to determine in-plane absolute water and gas permeability. Besides these standard methods CFP was developed further to investigate capillary pressure versus liquid saturation relation and to get access to contact angle inside PTL structures. In-situ experiments are carried out with a 25 cm² electrolysis test cell. Figure 1 shows the methodology used for the investigation. Results of polarisation curves in Figure 2 are compared against results of standard ex-situ experiments and advanced methods. The influence of in-plane permeability is studied for cell designs without flow field and it is found that in-plane permeability plays a crucial role regarding mass transport limitation. Using CFP, the gas transportability of wetted PTL is established, which explains the ability of PTL to transport gas from catalyst layer to the flow channel at a given current density. The gas transportability is compared with voltage loss from polarization curve measurements. The result indicates a well agreement that an increase in gas transportability of wetted PTL reduces voltage loss due to mass transport limitation. Using the proposed technique, the applicability of any PTL can be quantified for PEM electrolysis cells with flow field.

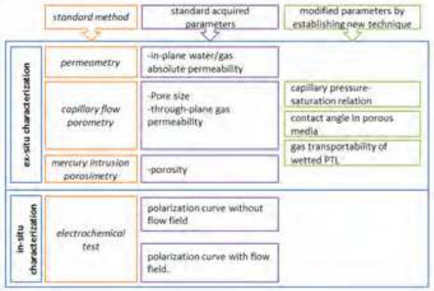

Figure 1: Approached methodology

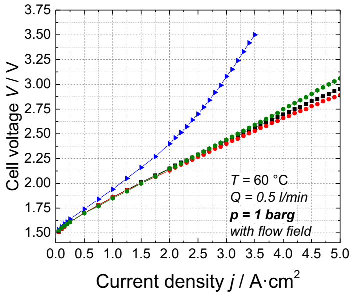

Figure 2: Polarization curves without flow field for different porous transport layers.

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B1005

Towards understanding of component aging in dynamically operated polymer electrolyte water electrolyzers

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Abstract

If polymer electrolyte water electrolysis (PEWE) is to be deployed to serve as an energy storage technology in the grid, the potential challenges related to the component durability need to be understood and addressed. The PEWE industry has demonstrated several systems operating over 30,000 hours with degradation rates in the range of 0-5 μV/h [1,2]. Other systems with a lower content of precious metals in terms of protective coatings and catalysts show degradation rates ranging from 30-600 μV/h [3,4].

We focus on understanding correlations between component aging and cell performance deterioration. Owing to the complexity and coupling of degradation mechanisms, we develop methods to study individual mechanisms in suitable ex-situ experiments.

In this study we investigate the effect of start-stop operation on the performance and gas purity of an in-house developed PEWE test-bench using commercially available Nafion 115 and Nafion 117 based catalyst coated membranes (CCMs). The cell was operated galvanostatically between 0 – 2 A/cm^2 at 60 ^{o}C for 100 hours. After 100 hours of testing, the degradation rates and hydrogen crossover for the two CCMs were evaluated at 1 A/cm^2. Additionally, we investigate whether the performance loss is reversible during the short cycling operation.

B1006 (Abstract in Revision)

Towards selective test protocols for accelerated in situ degradation of PEM electrolysis components (B1006)

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Abstract

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C1201

Photoelectrochemical Water Splitting in Separate Hydrogen and Oxygen Cells

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Abstract

Photoelectrochemical (PEC) water splitting is a promising path to solar hydrogen production. However, separation of the H_2 and O_2 gas products as well as hydrogen collection and transport in large solar fields becomes an overwhelming technical challenge. State of the art water splitting technologies make use single cell units, separated into anode and cathode compartments by membranes. This implies that millions of PEC cell units in the solar field would have to be hermetically sealed and fitted with membranes, gas tubes and tube adaptors in order to separate and collect the hydrogen gas, resulting in a very complicated and expensive construction. The hydrogen would then have to be transported to the end user, either by pipelines or by high-pressure/liquid-H_2 vessels. These obstacles, in addition to efficiency and stability challenges, render PEC hydrogen production economically questionable.

In this work, which was published recentrly in Nature Materials [1], we aim to solve these problems by totally separating the H_2-generation electrochemical cell from the O_2-generation PEC solar cell. This is achieved by introducing an additional set of electrodes, called the auxiliary electrodes. These are $Ni(OH)_2$/NiOOH electrodes, commonly used in rechargeable alkaline batteries, which can be cycled many times with minimal energy loss. By placing a "charged" (NiOOH) auxiliary electrode in the oxygen cell, and electrically connecting it to a "discharged" ($Ni(OH)_2$) auxiliary electrode in the hydrogen cell, electrolysis can be performed in two separate cells. During electrolysis, one auxiliary electrode charges while the other discharges. Thereafter, the process can be repeated by cycling the auxiliary electrodes between the charged/discharged states. Using suitable photoanodes, the PEC cell can generate O_2, which can then be discharged to the atmosphere, alleviating the need for sealing and piping. Since the separate cells are connected to each other by metal wires only, the H_2 can be generated at any location, for example, directly at the end user place.

C1202

Solar Water Splitting: Beating the Efficiency of PV-Electrolysis with Tandem Cell Photoelectrolysis

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Abstract

Solar water splitting is a promising route for hydrogen production from renewable sources: water and sunlight. This can be readily achieved by combining two commercial technologies: photovoltaics (PV) and electrolysis. Such combinations have been demonstrated and tested in self-sufficient solar houses, solar hydrogen refueling stations, and PV solar power plants. Unfortunately, PV-powered electrolysis (PV-electrolysis for short) is too expensive for large-scale solar hydrogen production. This motivates research on photoelectrochemical (PEC) cells that split water by photoelectrolysis, thereby combining the functions of light harvesting and electrolysis together. Such PEC cells can be combined in tandem with PV cells to construct a hybrid system that co-generates electrical power and hydrogen fuel. This work compares the efficiency of PV-PEC tandem cells and PV-electrolysis systems. It shows (see figure below) that in order to beat PV-electrolysis, PEC water splitting cells should produce sufficient photovoltage so that they could be operated at a bias smaller than 1 V (provided by the PV cell).

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C1203 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

The PECSYS Project: Demonstration of a solar driven electrochemical hydrogen generation system with an area > 10 m²

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Abstract

Photovoltaics driven stand-alone water electrolysis for hydrogen production is a promising arrangement to provide both electricity and heating to residential and small commercial consumers. State of the art photovoltaic- electrochemical (PV-EC) systems use a separate PV module array which is connected by wires to the EC electrolyser. However, where restrictions on plant space floor space apply, integrated wireless PV-EC water electrolysis systems are an attractive solution. Up to date, integrated wireless PV-EC water electrolysis has only been demonstrated on a laboratory scale.

The PECSYS project is aimed at demonstrating an operational PV-EC system measuring at least 10 m² with a solar to hydrogen (STH) efficiency of at least 6 % supporting a hydrogen production of at least 16 g/h at a levelised cost of €5/kg. The system is also expected to operate continuously under outdoor conditions with an STH efficiency loss of less than 10% relative after six months. The consortium shall use a stage gate elimination process to select the more promising laboratory scale PV-EC devices based on thin film silicon, silicon heterojunction and $CuInGa(Se,S)_2$ PV absorbers that shall be scaled to prototype size of at least 100 cm². The prototype devices shall be used to refine the modular concept that shall eventually be used in the ultimate 10 m² demonstrator. First results show that solar cells based on $CuInGa(Se,S)_2$ PV absorbers can supply sufficient operating voltage (~1.8V) to drive an electrolyser using catalysts consisting of abundant elements.

The PECSYS project is anticipated to increase awareness of the technical and economic benefits of such a system among the general public and manufacturing companies. Also, results and knowledge acquired from the project would provide an additional alternative for carbon neutral energy generation and improve the competitiveness of European PV and electrolyser manufacturers who would benefit from value added to their products.

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

C1204 (Abstract only)

Enhanced Electron Transfer by a Magnetic Self-assembled Conductive Fe_3O_4/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_3O_4/carbon nanomaterial composites using a magnetic assembling technique. The Fe3O4/CNT composite modified anodes with various Fe3O4 contents were first investigated to find the optimum ratio of the nanocomposite for the best MFC performance. The Fe3O4/CNT modified anodes produced much higher power densities than unmodified carbon anode and the 30wt% Fe3O4/CNT modified anode exhibited a maximum power density of 830mW/m2. In the Fe3O4/CNT composite modified anode, Fe3O4 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_3O_4 and is used to modify the interface between microorganisms *E. coli* and electrode. Among different carbon nanomaterial supports, the MFC with Fe_3O_4/CNT shows the best performance followed by Fe_3O_4/rGO and Fe_3O_4/GNF. The results demonstrate that CNT is the appropriate carbon support to form nanocomposites with Fe_3O_4. 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.

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C1205

Bioelectrochemical systems as tools to steer anaerobic digestion processes

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Abstract

Exoelectrogenic microorganisms have the ability to couple the oxidation of organic or inorganic electron donors to the transfer of electrons onto an anode surface. Hence, the organisms can catalyze the direct conversion of chemical energy into electrical energy. They typically use fermentation end products such as acetate as electron donors. The kinetics of the electron transfer process are dependent on the potential of the electrode. In other words, it is possible to control the respiratory and the substrate conversion rates via the working electrode potential. Here, we show that such a microbial anode can be used to steer anaerobic digestion processes. We constructed a model biogas reactor fed with corn silage in which we implemented microbial anodes based on carbon. Our data show that we can stoichiometrically steer methane production of the reactor by applying a suitable potential to the carbon electrodes. This allows overcoming process imbalances during the biogas process in which volatile fatty acids accumulate in the biogas reactor. Moreover, we can show that it is possible to use a bioelectrochemical system as a tool in a biorefinery process. Here, we fed the microbial anode with a dark fermentation plant percolate containing acetate, butyrate and propionate as organic carbon sources. This way, we were able to remove acetate and butyrate while propionate was not oxidized. It is possible to use the remaining propionate for a subsequent biotechnological process to produce the valuable platform chemical acetoin. Hence, it was possible to establish a biotechnological process for the conversion of biogenic residual and waste streams into valuable platform chemicals.

C1206 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Microbial Fuel Cells: a Platform Technology for Practical Applications

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Abstract

This work reported herewith forms part of a long-term programme of work, which focuses on the development of Microbial fuel cells (MFCs) as a platform technology (across sectors, functions and properties) as a viable renewable energy source that utilises organic “too wet to burn” waste as the fuel for electricity generation. MFCs are energy transducers allowing anaerobic microorganisms to use organic matter as an electron source and an electrode (anode) as the electron acceptor. Such anaerobic electro-active respiration allows for direct transformation of chemical energy into electricity. Regardless of embodiment, this technology requires a plurality of units in order to achieve useful levels of electrical power. Important considerations include the size of individual MFCs and the number of units, which defines the size of the stack. Other intrinsic factors, like use of different materials for construction of electrodes, membranes, current collectors and chambers are also important. However, there are also many extrinsic parameters such as (1) hydraulic retention time; (2) fuel quality (type and concentration); and (3) physicochemical environment of electrodes and biofilms (e.g. temperature, pH, salinity, and redox), that are equally important since all can directly influence the power density of each MFC, and thus the overall efficiency of the system as a whole. MFCs can be “fine-tuned” by adjustment of any of the physicochemical conditions including redox potential, and in this context, an entirely novel method was investigated as a practical way to fine-tune, modulate and monitor the redox within the electrode chambers. The method uses additional electrodes (known as 3rd and 4th-pin for anode and cathode chambers respectively), and they may be used to operate at the level of single MFC units, cascades, arrays, modules or stacks, for both control and monitoring of the system in part or as a whole, and thus optimise the production of a large variety of chemicals, including biomass, water and power.

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C1209

Investigation of temperature and kinetic of irradiation on water splitting reactions in dynamic reactor

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Abstract

Production of hydrogen by water splitting is a significant source that plays a critical role for achieving future fuels. It is important to develop high efficiency methods based on saving energy. Multilayered and nanostructured coatings have been widely used for photocatalytic water splitting into oxygen and hydrogen. The different layers are generally designed according to their applications and substrate. For example, as a barrier layer on metal, two separate ceramic and metallic layers are required. Different gradient of properties among layers can be eliminated by using functionally graded materials. In this work, nanostructured multilayer coatings based on TiO2 semiconductor were employed. The effect of temperature on performance of photocatalytic reactions and kinetics of solar and UV irradiation in a dynamic reactor were also investigated. The kinetic was described using Longmire model by fitting exponential function on curves. The result showed photocatalytic reactions that were conducted in higher temperatures under UV irradiation were more efficient. Furthermore, variations of the decay time in solar irradiation were unstable in comparison to UV.

Keywords: Nanostructured coatings, water splitting, kinetic, photocatalytic

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Chapter 08 - Sessions B07, B11

B07 H_2 Storage: Concepts & systems
B11 Fuel processing, purification & compression

Content **Page B07, B11 - ..**

B0701 (Abstract only, published elsewhere)

Liquid Organic Hydrogen Carriers (LOHCs) - Towards a Hydrogen-free Hydrogen Economy

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Abstract

The need to reduce CO_2 emissions drastically will lead to the transformation of our current, carbon-based energy system to a more sustainable, renewable-based one. In this process hydrogen will gain increasing importance as secondary energy vector. Energy storage requirements on the TWh scale (e.g. to bridge extended times of low wind and sun harvest) and global logistics of renewable energy equivalents will create additional driving forces towards a future hydrogen economy. However, the nature of hydrogen requires dedicated infrastructures. This has prevented so far the introduction of elemental hydrogen into the energy sector to a large extent. Recent scientific and technological progress in handling hydrogen in chemically bound form as Liquid Organic Hydrogen Carrier (LOHC) supports the technological vision that a future hydrogen economy may work without handling large amounts of elemental hydrogen.[1,2] LOHC systems are composed of pairs of hydrogen-lean and hydrogen-rich organic compounds that store hydrogen by repeated, catalytic hydrogenation and dehydrogenation cycles. While hydrogen handling in form of LOHCs allows for using the existing infrastructure for fuels, it also builds on the existing public confidence in dealing with liquid energy carriers.
The contribution will highlight fundamental[3] and applied aspects[4] of LOHC hydrogenation and dehydrogenation catalysis and the related processes. Characteristic differences for the catalytic conversion of pure hydrocarbon and nitrogen-containing LOHC compounds are described. Finally, the operation of these catalytic transformations in LOHC demonstrator applications will be presented. Both, stationary energy storage systems and hydrogen delivery to future hydrogen filling stations will be shortly discussed.

The authors did not wish to publish their full contribution in this proceedings and have published it already (Acc. Chem. Res. 50 (2017) 74-85). Please Contact the Authors directly for further Information.

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B0702 (Abstract only)

Magnesium Oxide an Effective Non-Transition Metal Oxide Catalyst For Hydrogen Storage Improvement of Magnesium Hydrides

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Abstract

Metal hydrides (magnesium and titanium) provide a good alternative for hydrogen storage due to their low cost, small volume and high storage capacity (7.6 wt %). However, to reach the Department of Energy (DOE) requirements, improved reaction kinetics near room temperature, storage capacity, storage efficiency and recycling tolerance are required. Almost all investigators [1,2] agree that magnesium hydride require both mechanical activations and doping with suitable catalyst before it can be used for hydrogen storage. It is found that the composite of MgO/MgH2 after mechanical activation show H-kinetics which is similar to the best transition metal so far reported (e.g. Nb2O5).MgO known as an inhibitor for the H-Kinetics of Mg and MgH2. Here it will be shown that MgO is responsible for removal of impurities such as oxygen interstitials and oxygen gas from the air and facilitate the formation of two phase regions where the H-Kinetics is fast and independent of pressure, (Gibbs phase rule) [3].

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B0703

Hydrogen storage by physisorption in nanostructured graphene-based materials: simulations and experiments

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Abstract

Hydrogen storage capacity of carbon-based materials (carbon foams, nanotube bundles, *etc.*) is usually within ~3.0–6.0 wt.% at 77 K and moderate pressures of 50-70 bar. For comparison, the best metal–organic framework (MOF) adsorbs up to ~9 wt % (excess) of molecular hydrogen at the same conditions. Since MOFs are in general expensive and in most cases humidity-sensitive, we consider graphene-based nanostructures as a reasonable alternative for hydrogen storage applications.

In the last years considerable attention has been focused on the chemistry of graphene-oxide (GO) frameworks (GOFs, alternatively called pillared graphene-oxide). Simulations on model systems gave promising results, with total uptake up to ~10 wt % (77 K). However, the actual structure of GOFs based on covalent cross-linking of GO-layers has to be ruled out because of observed significant swelling of the materials. Furthermore, the structures are usually microporous (pore volume = ~0.5 cm^3/g) with surface areas close to 1000 m^2/g. In line with Chahine's rule, the storage capacity of such materials does not exceed 2 wt % (77 K).

Recently, by KOH-activation of GO-powder and subsequent annealing in hydrogen atmosphere, so-called "3D graphene scaffolds" with high surface area (~3400 m^2/g) and large pore volume (2.2 cm^3/g) have been prepared. This material adsorbs ~7.5 wt % of H_2 at 77 K (~50 bar). The structure of this material is rather irregular. As a model system that could approximate its structure, we suggested polycatenated layers of perforated graphene. The model, however, gave rise to a somewhat lower surface area and smaller uptake (6 wt %).

Finally, we will discuss the influence of defects in graphene sheets on the hydrogen uptake and the effect of doping by metals (Ca, Mg, Ti etc.) to enhance adsorption energies and eventually storage capacities.

B0704 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Hydrogen Blending into the Gas Distribution Grid: The Case Study of a Small Municipality

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Abstract

Hydrogen blending into the gas network may offer an alternative concept for the storage of the exceeding energy from renewable power sources, improving the flexibility of the energy system through the integration of the electricity and gas networks. This scenario foresees the use of electrolyzers to convert power into hydrogen gas. The gas grid could both provide storage and act as the transport facility of the produced gas, taking advantage of the robustness and extensiveness of an already existing energy infrastructure.

In this work, a steady state and multi-species thermal-fluid-dynamic model of the gas network is applied to a portion of the Italian distribution network, located in Emilia-Romagna, covering a surface of 2,900 ha and having a throughput of 8.25 MSm^3/year of natural gas.
The receiving potential capacity of the existing infrastructure is assessed with respect to hydrogen injection. Fluid-dynamic effects of the hydrogen blending are considered and commented.

The maximum allowable percentage of injectable hydrogen is calculated on a nodal basis, referring to the actual gas network configuration. The current Italian regulation on distributed injection (DM 19/02/2007) of gases into the natural gas network only allows injecting gases having nearly the same quality of natural gas (UNI-EN 437), thus excluding any blending practice. However, in the simulated scenario here proposed, it is assumed that gas quality requirements are on the network as a whole (i.e., after blending of hydrogen in the grid) rather than at the single injection point. By exploiting the quality-tracking feature of the model, the constraint of quality assessment at the injection point is thus relaxed.

Once the blending limit is known for each node, the amount of injectable hydrogen is calculated accordingly, taking into account the amount of natural gas already flowing through the node itself.
The node with the major injection capability is the designated one for the injection and used for the simulation of the case study.
Finally, a comparison between the 'base case' and the 'maximum hydrogen injection case' is presented and discussed showing how hydrogen blending into the gas grid may lead to a reduction on the fossil natural gas supply of up to 2,1%.

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B0707 (see B0704)

B0708 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Modelling and Simulation of a Hydrogen Storage Reactor Including Expansion Volume Effects

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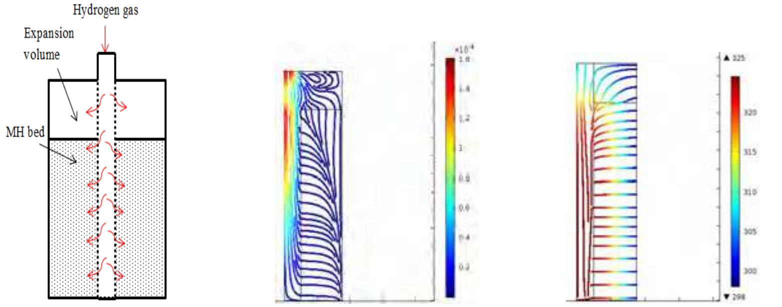
Abstract

In this paper, a novel 2-D numerical model has been presented for annular metal hydride reactors with a porous tube, which can capture the effects of expansion volume domains on their performance. The model was applied to reactors of two different representative sizes- lab scale system (100 W) and large scale system (5 kW), and their behaviour was studied at different operating pressures. The reactor consists of an annular metal alloy bed and an empty space on top of it-the expansion volume. A detailed heat and mass transfer analysis discusses the motion of gas and the evolution of heat flux within the reactor. The continuous presence of hydrogen in the expansion volume domain augmented by thermal buoyancy induced flow affects the reaction rates in the metal bed adversely. The investigation revealed that neglecting the expansion volume underpredicted the time required to reach a particular H/M ratio. The results were strongly dependent upon system scale and pressure. However, they were independent of expansion volume height.



a) MH reactor b) Velocity streamlines (m/s) c) Heat flux streamlines(K)

Remark: Paper runs for publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2017) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

B0709 (Abstract only)

Evaluation of phenomena occurring in a Regenerative Solid Oxide Cell System for energy storage

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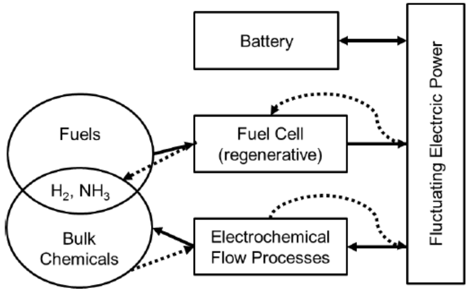
Abstract

It can be expected that the long term future energy supply will be based on renewable sources such as wind, waves or solar, delivered in the form of fluctuating electric power. Therefore, its storage for short and long term will become mandatory to assure a safe grid. Second-life batteries of different designs are being considered, but using H_2 as an intermediate allows more flexibility in terms of volume, durability and destination of the stored energy. The development of regenerative, high-temperature fuel cells, which can operate both in power storage (hydrogen/fuel generation) and power generation (hydrogen/fuel conversion) modes provides a radically improved solution potential in terms of efficiency and system simplicity. High-temperature solid oxide cells/stacks applied for converting power to gas and gas to power therefore need to be developed further to deal with the fluctuating wind energy or solar power profiles and the high-quality power demanded by the grid.



Overview of Electrochemical storage options. [1]

Regenerative Solid Oxide Cells/stacks (Re-SOC) have to be optimized both in terms of detailed physical-chemical phenomena that occur in working conditions and as regards degradation of the stack, subject to frequent cycles in alternating, harsh conditions. The scope of this work is to evaluate by means of polarization curves and Electrochemical Impedance Spectroscopy, both in Open Circuit Voltage conditions and under a constant current load, the performance over time of a Re-SOC stack, connecting degradation phenomena identified through the in-depth analysis with the evolution of the stack response.

Bibliography:

[1] W. G. Winkler, Process Engineering Considerations of Electrochemical Storage, Journal of Energy and Power Engineering 8 (2014) 1763-1776.

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

B1101 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Biorobur ^{Plus}: Advanced direct biogas fuel processor for robust and decentralized hydrogen production

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Abstract

The Biorobur ^{Plus} concept is being developed within the FCH-JU H2020 financing program (Grant: 736272). It aims at realizing a TRL6 Demo-plant delivering at least 100 kg/day of H_2 at 99.9% purity and 1.5 bar, starting from a biogas simply desulphurised having a concentration of 60% CH_4 and 40% CO_2.
The energy efficiency of the process targets the extremely challenging value of up to 81% on a HHV basis. The ways to reach this objective are: i) high thermal integration, ii) PSA (pressure swing adsorption) offgas exploitation for reformer feed preheating, iii) power consumption minimization through CO_2 removal prior to the PSA. Several technological innovations are introduced as key features of the Biorobur ^{Plus} concept, among all the use of structured ceramic supports for both the OSR (oxidative steam reformer) and the offgas porous burner, and the tailoring of the OSR catalytic formulation to withstand the oxidative section in the front of the reactor, and to avoid carbon formation. Finally, the design of a cost effective H_2 purification section, with a recovery exceeding 80%, combines a thermally driven CO_2 absorption (MEA package in the schematic) and a PSA.

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B1102

Demonstration of a Methanol Fuel Processor System for the Production of Pure Hydrogen

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Abstract

The completed FCH JU project “LiquidPower” has been focusing on fuel cell applications for early markets addressing three topics: on-site H_2-production, fuel cell systems for material handling vehicles and fuel cell systems for back-up power. The partners ZBT GmbH and Catator AB have demonstrated a methanol fuel processor system of the 20 - 30 kW class (hydrogen output) tailored for the H_2-supply of a material handling fuel cell vehicle fleet. Utilizing methanol as energy carrier has advantages in transport and infrastructure and promises to be cost-efficient. Furthermore methanol enables an energy-efficient pressurization of the hydrogen generation process.

Catator developed a pressurized reformer based on a coil-concept (Optiformer), where a steam reforming catalyst is inserted into a helix shaped tube. The basic idea is to achieve a close coupling between the exothermic and endothermic reactions for optimal heat-transfer and to minimize the thermal stress on the material. The Optiformer consists of a number of individual components tied together in an integral design. The focus of the ZBT activities has been the development of a pressure swing adsorption plant (PSA) for hydrogen purification and the integration of the Optiformer with the PSA. The concept of choice is a four bed PSA containing activated carbon as well as molecular sieves as adsorbents in each bed. The nominal capacity is about 10 m³/h (30 kW) pure hydrogen and the design pressure is set to 12 bar. The developed PSA contains commercially available balance of plant components and the system design is capable of achieving a following third party CE certification. The application of the Machinery Directive and the Pressure Equipment Directive specify a clearly structured roadmap for a future product launch of the PSA.

Finally the system installation, integration and the coupled operation have been performed by the partners at ZBT facilities. The specified parameters have been confirmed by a successful demonstration thus the given results show the potential of pressurized reforming followed by PSA for the before mentioned fuel cell applications.

B1103 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Electrochemical Hydrogen Separation using HT-PEMFC

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Abstract

In the current work a 100 W_{el} IRMFC (Internal Reforming Methanol Fuel Cell) module was developed. A HT-PEMFC (High Temperature Polymer Electrolyte Membrane Fuel Cell) stack with integrated units for methanol reforming operated at 190-220 °C is termed as IRMFC module. The same HT-PEMFC within the IRMFC module was studied to evaluate its electrochemical hydrogen separation (EHS) ability. EHS technique uses small amounts of electrical energy to separate H_2 from gas streams (e.g. from industrial waste gases or natural gas grid with higher hydrogen concentrations in future). The higher tolerance to impurities such as CO in %-range and H_2S in ppm-range of HT-PEMFCs compared to LT-PEMFCs along with the highly efficient hydrogen reduction reaction (HRR) in the EHS process are the main drivers to focus on HT-PEMFC technology. The said IRMFC module consists of 20 individual fuel cell units and 40 methanol reformer units each of 50 cm² of geometrical area. 200 g/h of H_2O-CH_3OH species premixed at S/C (steam to carbon ratio) of 1,5 were fed through an evaporator into the reformer units at 190 °C to produce 163 liters/hour of reformate gas consisting of 126 l/h (77,2 %) of H_2, 36,9 l/h (22,6 %) of CO_2 and 0,076 l/h (0,047 %) of CO. To evaluate the stack’s performance in the FC mode the reformate gas stream was directed into the anode manifold while supplying 7 l/min of air into the cathode manifold of the HT-PEMFC at 190 °C. The fuel cell generated 131 W_{el} when operated at 262 mA/cm² and 114,7 W_{el} at 219 mA/cm² load current respectively. The same stack was operated in the EHS mode wherein the anode side was fed with the same reformate as in the previous case (FC mode) and the cathode manifold was fed with 150 ml/min of N_2. When supplied with 13,72-17,15 Wh of electrical energy, the H_2 species migrated to the cathode side were 32,5 l/h (97 %) along with 0,785 l/h (1,98 %) of CO_2. No CO species were detected by the gas analyzer employed. The specific electrical energy demand of the stack when operated in the EHS mode with the said methanol reformate was 5,71 kWh per kg of H_2 produced. The HT-PEMFC based EHS technology offers tremendous opportunities in generating high grade H_2 at low energy costs.

Key words: EHS, HT-PEMFC

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B1104 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Hydrogen production by reforming for industrial and transport applications

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Abstract

Hydrogen as a secondary energy carrier is conventionally used in the chemical industry and several metallurgical production processes. The produced hydrogen is consumed mostly directly onsite or has to be transported to the place of consumption in pressurized gas cylinders and tanks. However, the transport is expensive and reduces the energetic efficiency of the entire process chain. Additionally, the role of hydrogen as fuel in the mobility sector is increasing due to its positive effect on the decarbonisation. It can further act as storage particularly for fluctuating renewable energy sources.

To cover the growing need of hydrogen and to establish a suitable hydrogen infrastructure, hydrogen generators in the medium output range from 20 m^3/h to 500 m^3/h at normal conditions are necessary. Besides electrolysis one promising option is the decentralized production of hydrogen via catalytically supported reforming of natural gas or biogas.

In the present work two decentralized reforming plants, producing hydrogen with an output range of 50 to 150 m^3/h at normal conditions, are presented. A novel autothermal biogas reformer has been investigated within the completed European project “BioRobur – Biogas robust processing with combined catalytic reformer and trap”. The pilot plant was located at TU Bergakademie Freiberg in Germany and has been designed to produce 50 m^3/h hydrogen at normal conditions. The setup and selected results of the operational tests of the plant, varying important parameters such as gas hourly space velocity, steam to carbon and oxygen to carbon ratio, are shown and explained in detail. The experimental results indicate a maximum cold gas efficiency of about 98% using a commercial noble metal catalyst. Another type of reforming is used in the actual German research project “HydroGIn – Hydrogen Generator for the Industry”. The scope of the project is the development of a demonstration plant for the generation of pure hydrogen in the output class of 100 m^3/h at normal conditions. TU Bergakademie Freiberg and three enterprises are working together to establish the second hydrogen processor on the basis of steam reforming of natural gas combined with subsequent gas purification at elevated pressure.

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B1105 (Abstract only, published elsewhere)

Reliability of Reformer Gas-Facing Material for Safe Hydrogen Production Service

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Abstract

Hydrogen infrastructures including hydrogen production, storage and transportation have been constructed world-widely along with the development of hydrogen utilization technology (Fuel Cell) in recent years. Reliability of hydrogen infrastructure (materials, parts/components and system) should be seriously considered from a view of public safety for extensive hydrogen usage. In the present research, reliability of gas-facing material of natural gas (NG) fuelled steam reformer (SR) was studied with respect to thermal and gas (hydrogen) exposure degradation of Inconel alloy. The gas-facing material of reformer is exposed to the severe environments of high temperature and hydrogen/steam containing gas, and as a result, the various corrosion issues such as hydrogen embrittlement and carburization influencing on performance and lifetime of reformer will be occurred. The temperature of catalyst zone is around 800 ^{o}C, and the temperature of outlet zone (gas composition: hydrogen, carbon monoxide, carbon dioxide, methane and steam) is the range of 600 ~ 700 ^{o}C. Degradation of gas-facing material under the SR operation condition was studied in terms of corrosion characteristics, corrosive depth profile mapping and surface composition analysis using micro-indentation technique, SEM/EBSD observation and XPS surface analysis.

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

B1106 (Abstract only)

Techno-economic Analysis of State-of-the-Art Electrochemical Hydrogen Compressors (EHCs)

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Abstract

This research analyses the potential for compressing hydrogen (H_2) with electrochemical hydrogen compressors (EHCs). Techno-economic models are developed to analyse EHC systems in terms of their future engineering and economic performance. Currently, most EHCs are at an early technology readiness level (TRL); i.e. individual cells and stacks have been tested in controlled, laboratory environments. This work analyses state-of-the-art, best performing EHC cells, stacks, and systems, tested to-date in the laboratory, and projects their performance into the future for large-scale, commercial EHC systems.

EHCs use electricity to split hydrogen molecules (H_2) into hydrogen ions (H^+) and electrons (e^-). The overall, endothermic reaction is Electricity + H_2 (low pressure) → H_2 (high pressure). A power source delivers direct current (DC) electricity to the EHC electrodes such that, at the anode, H_2 at low pressure split into H^+ and e^-. The e^- flow through an external circuit, and the H^+ flow through an electrolyte selectively conductive to H^+. At the cathode, the H^+ and e^- recombine to form H_2 at high pressure. EHCs can generate high purity, high pressure H_2. The theoretical efficiency of EHCs is higher than that of mechanical piston and/or diaphragm compressors because they compress in a manner that is isothermal, rather than isentropic.

This research deploys a U.S. Department of Energy (DOE) techno-economic modelling tool for H_2 compression, called the HDSAM Model. The HDSAM Model captures a set of standard DOE assumptions and methods. When these standards are adhered to, using the HDSAM Model can facilitate more even-handed techno-economic comparisons of a variety of H_2 compression, storage, and dispensing technologies. This analysis deploys the HDSAM model to evaluate H_2 compression based on EHCs powered by electricity from the grid. Models were developed to describe small-scale, 2,400 kilograms (kg) H_2/day, EHC compression systems envisioned for both the near and far-term futures.

Model results indicate that, for an average electricity cost of about $0.06/kilowatt-hour (kWh), the levelized cost of compressing H_2 with a state-of-the-art EHC systems could be as low as ~$0.50/kg H_2 in the near-term. The levelized cost of compressing the H_2 is most strongly influenced by the electricity price. Electricity costs constitute roughly 65% of the levelized cost. The levelized cost of compressing H_2 is also impacted by the EHC system's capital cost and the EHC's electrical efficiency. Capital costs constitute roughly 35% of the levelized cost. Fixed operations and maintenance costs and other variable costs are negligible.

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

B1107 (Candidate: EFCF Special Issue Series, www.EFCF.com/LIB)

Advancement in Palladium Membrane Hydrogen Purification

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Abstract

Hydrogen has the potential to become a significant vector of clean energy. All of the major car manufacturers are already involved in the development of cars powered by proton exchange membrane (PEM) fuel cells, with thousands of cars being introduced to the market starting in 2015. This technology will be a great step ahead in the introduction of clean cars because the exhaust consists of only water vapor. A necessary requirement for the mass adoption of this new vehicle technology is the development of a suitable infrastructure capable of filling car tanks at high pressure, 700 bar, with high purity hydrogen. The specification limits listed in the ISO Standards, ISO14687-2, for some impurities are very low, less than 200 ppb, for impurities such as carbon monoxide (CO) and sulphur compounds. These strict limits are required because of their ability to deplete the efficiency of the fuel cells. Purification is often required because traditional hydrogen manufacturing techniques contain CO and Sulphur levels above the ISO Standards.

The use of purification provides many advantages such as: consistent gas quality over time, elimination of any impurity coming from the supply chain, elimination of variation in gas cylinder quality, mitigation of impurities introduced during the replacement of gas cylinders, and other random sources of contamination.

Due to the chemical and physical properties of hydrogen, several purification technologies have been developed over the years, some of them specific only to hydrogen, like palladium (Pd) membrane purifiers.

The development of thin film Pd supported membranes compared to self-standing Pd membranes have two main advantages: a drastic reduction in the amount of expensive precious metals and a large increase in H_2 flux. However leak tightness and the elimination of pinholes are the challenges for these type of purifiers. Figure 1 shows an example of a Pd supported membrane.

This paper describes the differences between the self-standing and thin film Pd supported membranes, the latest advancements of each, and the purification results of each.

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B1109 (Abstract only)

High Temperature Electrochemical Hydrogen Pumping

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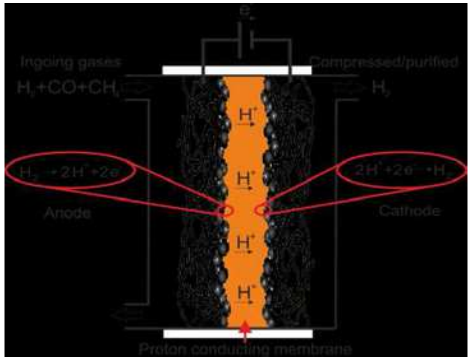
Abstract

With an ongoing shift from fossil fuels to renewable energy sources hydrogen is being considered as s sustainable energy carrier for use in fuel cell vehicles as well as energy storage. Existing natural gas grid infrastructure already provides means for hydrogen distribution, yet efficient hydrogen separation technologies will be required in order to utilize hydrogen contained in the natural gas grid for purposes other than direct burning (e.g. fuel cell vehicles). Established technologies such as pressure swing adsorption and membrane separation are, however, well suited only for extraction of hydrogen from high concentration streams.

Electrochemical hydrogen pumping offers an alternative solution to this challenge. By applying an electrical potential hydrogen present in the feed gas mixture can be oxidized at the anode, transported through a proton conducting membrane and finally reduced to its molecular form at the cathode (product side).

High temperature polymer electrolyte systems may offer advantages over low temperature systems due to low humidification requirements and reduced susceptibility to impurities in the gas stream, such as CO and particularly H_2S, typically present in natural gas distribution network.



In this work, we investigate electrochemical hydrogen separation from low concentration streams using a high temperature polymer electrolyte cell comprising a proton conducting membrane, based on polymers imbibed with phosphoric acid. Influence of operational parameters such as hydrogen concentration, relative humidity and presence of hydrogen sulfide on the performance of electrochemical pumping and purity of the obtained hydrogen is elucidated.

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B1110

Performance and Degradation Study of Pt-Ru Catalysts for Hydrogen Production from Commercial Diesel

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Abstract

Hydrogen is one of the most promising renewable energy due to its eco-friendliness and high energy density. As a typical method to produce hydrogen, hydrocarbon reforming has benefits, comparing with others, technologically and economically. Among the hydrocarbon fuels, diesel has several advantages in terms of high hydrogen content, easy transportation and accessibility from common infrastructure. However, there are several causes to accelerate the degradation of reforming performance such as coke formation and surficial changes at high temperature on the catalysts. Diesel is complex blends of several hundreds of C_{10}-C_{24} hydrocarbon and it contains aromatic benzene rings. Not only long paraffin chains occur coke formation but strong bond of aromatics also accelerate coke formation because of its slow reaction rate at the surface of catalyst. In addition, high temperature condition results on catalyst degradation caused by loss of catalytic surface area, support area and active phase-support reaction.

Objectives of this study are to improve carbon resistance by adding ruthenium promoter in the platinum based reforming catalyst and furthermore, achieve long term reforming performance. To enhance strong metal-support interaction, $Ce_{0.9}Gd_{0.1}O_{2-\delta}$(CGO) has selected as support material. and it makes the surface reaction rate faster. Ruthenium is effective to promote oxidation of coke on the catalyst and increase metal dispersion. Pt-Ru/CGO was synthesized by glycine nitrate process(GNP) and sieved in 250-500µm. Experiment was progressed with changing composition of the catalyst.

As a result, The bimetallic catalyst not only has high activity for reforming reaction but also efficiently removes ethylene which causes coke formation, so that the reforming catalyst stably operated for 200h without causing deterioration. In the case of catalytic investigation by TPO analysis, it was found that the characteristics of the coke deposited on the bimetallic catalyst were superior to those of the catalyst without Ru.

The catalysts with high resistance to coke formation developed through this study can be expected to operate under more severe conditions than existing catalysts by changing operating conditions such as GHSV, OCR and SCR. As a result, the efficiency of the fuel cell system can be improved by reforming the fuel with a large flow rate and a high hydrogen concentration.

B1111

Low Pressure Hydrodesulfurization Processes for Gaseous Fuels

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Abstract

Hydrogen production of gaseous fuels requires feedstocks free of catalyst poisons. As sulphur is one of the main poison, different methods, e.g. hydrodesulfurization (HDS), selective catalytic sulphur oxidation (SCSO) or cold adsorptive desulfurization (ADS) are employed to remove several sulphur species. Cold adsorption is often used in fuel cell applications, because of its simple technical implementation. However, it has the disadvantage that the adsorbers used for this purpose have lower loading capacities and therefore short maintenance intervals for material exchange are required. Furthermore the sulphur species and their concentrations are often not exactly known, e.g. in natural gas or LPG. Therefore the design of a cold adsorption desulfurization must base on a worst case scenario leading to oversizing of these expensive materials. HDS efficiently removes different sulphur species by catalytic conversion to hydrogen sulphide followed by adsorption. Hydrogen sulphide adsorbers provide high sulphur capacity and lead to long maintenance intervals resulting in high yield of the material. HDS needs hydrogen for sulphur remove, which is not only in the context of fuel cell applications recycled from the downstream process.

This paper is focusing on two different HDS developments: The main objective in the EU-project D2Service is to reduce the service costs for two different FC products. In this context the performance of different HDS catalysts and hydrogen sulphide adsorbers as well as the system integration of HDS as life time desulfurization have been investigated. The influence of the odorizing agents, the gas matrix, the temperature and the space velocity on the desulfurization performance have been determined experimentally and will be presented in this paper.

Within another project an innovative HDS process is under development. This process does not require external hydrogen feed to the feedstock. Here the hydrogen required for the hydrogenation of the sulphur species is obtained directly from the hydrocarbon matrix reacting on the surface of the hydrogenation catalyst. The goal of the development of this new process is a considerably simplified process management and a superior process startup with desulfurization performance from the beginning on. The reactivity of catalysts for different sulphur species, gas matrices (NG or LPG) and temperatures will be presented in this paper.

B1112

Study on Start-up Control of Diesel Autothermal Reformer for 1 kW_e Solid Oxide Fuel Cell System

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Abstract

Solid Oxide Fuel Cell (SOFC) system can provide high efficiency during generation of electricity. To utilize the SOFC system for mobile applications, a reliable hydrogen source for the system has to be provided to maintain stable operation. Liquid fuels, such as Diesel, have high hydrogen storage density, so the hydrogen production with the liquid fuel reforming is promising. High quality hydrogen feed have to be continuously provided into SOFC system to ensure its durability and performance, therefore compositions of the reformate gas from the fuel reformer have to be controlled during the system operation.

Autothermal reforming (ATR) enables hydrogen production with self-sustaining reaction temperatures, and ATR also has high resistance on coke formation on catalyst surface with aid of oxygen and steam as oxidants. During initial start-up stages of the ATR reactor, temperatures on the catalytic reaction area have to rise until its operating ranges. In this stage, initial degradations on the reforming catalyst and also the fuel cell can severely occur if the temperatures are not properly controlled. Also, start-up time must be reduced to minimum to provide rapid electricity generation. Therefore, it is needed to control the start-up process for the diesel ATR reformer. The example profiles with control and without control during the start-up of diesel reformer are illustrated in Fig. 1.

In this study, initial start-up control of Diesel ATR reformer for auxiliary power unit application is conducted. Temperature distributions on the reformer were monitored to manipulate inlet flow conditions. As the result, stable start-up profile can be obtained within 60 minutes of start-up time.

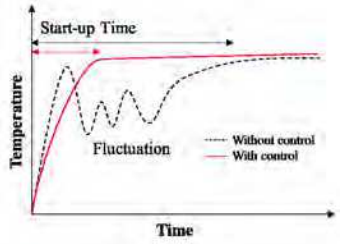

Fig. 1. Example temperature profiles of Diesel ATR with and without control.

Chapter 09 - Sessions C13, C14

Similarities & Differences: FC - Redox Flow Batteries (RFB)

Content **Page C13, C14 - ..**

C1301 (Special Session, no abstract)

PEM Fuel Cells and Redox Flow Batteries Differences, similarities and common problems

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C1303 (Abstract only)

Catalytic Properties of Carbon in the All-Vanadium RFB.

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Abstract

Redox Flow Batteries (RFBs) can be described as a hybrid between fuel cells and batteries. The aqueous RFB concept has many intrinsic advantages, like non-flammable electrolytes, independent scalability of energy and power, high life-time and high efficiencies. Unfortunately, it also inherits the two disadvantages of fuel cells and batteries: Energy density is low, like in a battery, and electrode kinetics are slow, as in fuel cells. Those two short-coming lead to electricity storage costs that are much higher than the current goal of the ARPA-e, which is 100 US$ per kWh.

In this work we describe our efforts at increasing the power density of the All-Vanadium RFB (VRB) by catalyzing the V^{2+}/V^{3+} and the VO^{2+}/VO_2^+ redox reaction [1,2]. By employing a novel characterization method that is based on electrochemical impedance spectroscopy we find that:

- Functional groups increase the electrochemically active surface area of the electrodes;
- Functional groups catalyze the V^{2+}/V^{3+}- but impede the VO^{2+}/VO_2^+-redox reaction;
- Carbon modifications might be short-lived in the reducing or oxidizing environments of the VRB half-cells.

Consequences of these findings for the design of VRBs and future costs of the VRB in comparison to fuel cells will be discussed.

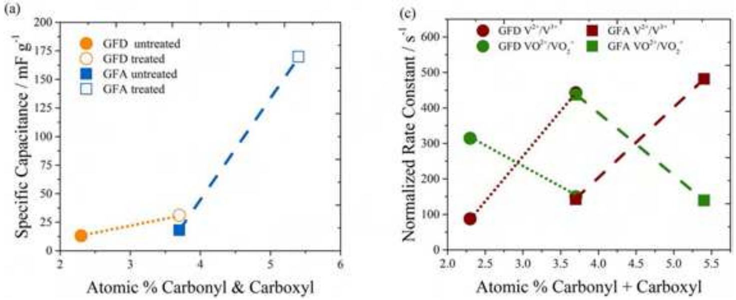

Figure 1: Influence of functional groups (exemplified by atomic% carbonyl and carboxyl) on (a) specific capacitance and (b) activity for the V^{2+}/V^{3+} and VO^{2+}/VO_2^+ redox reaction o commercially available carbon felt electrodes. Graph from [2].

[1] J. Friedl, C.M. Bauer, A. Rinaldi, U. Stimming, Carbon. 63 (2013) 228–239.
[2] H. Fink, J. Friedl, U. Stimming, J. Phys. Chem. C. 120 (2016) 15893–15901.

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

C1401 (Special Session, no abstract)

All-Polymer-Redox-Flow-Batteries (aPRFB)

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C1402 (Special Session, no abstract)

Progress in miniaturized redox flow batteries

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C1403 (Abstract only, published elsewhere)

Electrolytes for bromine/bromide cathode in hydrogen-bromine redox flow battery

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Abstract

For grid and on-board energy storage rechargeable fuel cells like hydrogen-bromine redox flow battery (H_2/Br_2-RFB) will be interesting for future use [1]. The H_2/Br_2-RFB enables power densities up to 500 mA cm^{-2} and theoretical energy densities up to 250 Wh L^{-1}. In the cathode side, bromide is oxidized to toxic and volatile bromine during charge, complexed by bromine complexation agents (BCA) based on quaternary ammonium cations like N-Methyl-N-Ethyl Pyrrolidinium Bromide (MEP) and others. The complexed bromine is stored in a separate heavy but liquid phase, comparable to zinc-bromine batteries [2]: $BCA^+(aq) + Br^-(aq) + xBr_2\ (aq) \leftrightarrow BCABr_{1+2x}\downarrow$. The separate phase is directly formed in the cathode graphite soft felt and influences on ohmic resistances as well as macro kinetics are expected [3] in H_2/Br_2-RFB.

In our work, selected BCAs based on quaternary ammonium cations like N-Methyl-N-Ethyl Pyrrolidinium Bromide (MEP) and others were tested in matters of performance requirements in the cell. Electrochemical kinetics at glassy carbon electrodes for the water based phase and the salty $BCABr_{1+2x}$ phase at different state of charge, as well as conductivity measurements were done and compared to pure $HBr/Br_2/H_2O$ electrolytes. Higher ohmic resistances and weaker kinetics of $BCABr_{1+2x}$ in comparison to pure $HBr/Br_2/H_2O$ electrolytes will be shown and leading to application orientated operation conditions: In charge mode the accumulation of $BCABr_{1+2x}$ in cathode needs to be avoided, while in the discharge mode availability of $BCABr_{1+2x}$ offers better macro kinetics in terms of mass transport limitation. In conclusion a cell test (fig.1) in a developed 40 cm² H_2/Br_2-RFB single cell setup for MEP and pure H_2/Br_2 will be presented.

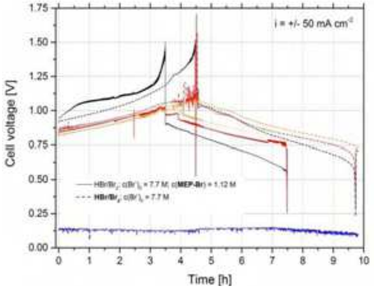

Fig. 1.: Charge and discharge single cycle at +/- 50 mA cm^{-2} for a $HBr/Br_2/H_2O$ and a MEP based electrolyte (black: cell voltage; red: cathode potential vs. NHE, blue: anode potential vs. NHE and orange: cathodic redox potential vs. NHE)

References: *[1] Y. V. Tolmachev, Russian Journal of Electrochemistry, 50 (2014) 301-316.; [2] D.J. Eustace, J. Electrochem. Soc. 127 (1980) 525.; [3] C. Fabjan, G. Hirss, Dechema Monographien, 102 (1986) 149-161.*

*Remark: Only the abstract is available, because the authors chose to publish elsewhere.
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C1404

Local characterization and 3D simulation of mass transport issues in Vanadium Redox Flow Batteries

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Abstract

Development of efficient and cost-effective energy storage systems is nowadays crucial considering the huge amount of electrical energy supplied by the intermittent renewable energy sources and its related issues, such as grid instabilities and volatility in power prices in liberalized electricity markets. Among the energy storage technology, one of the most promising is Vanadium Redox Flow Battery (VRFB), due to its peculiarity of separating power and energy, the high efficiency and the extremely long charge/discharge cycle life. However, the commercialization of VRFB is still hindered by some technological issues, among which mass transport issues within the porous electrode is one of the most important. Recently Mench et al. demonstrated that convective mass transport is critical in VRFB systems and that flow field design, along with electrode morphology, play a key role in determining VRFB performance.

This work proposes a combined experimental and modeling analysis of the mass transport issues in VRFB systems. The experimental tests are firstly performed in half-cell setup with hydrogen at anode and VO_2^+/VO^{2+} at the cathode: in this way it is possible to limit voltage loss of anode and reduce model parametrization. Innovative segmented cell, permitting local measurement of current density and electrochemical impedance spectroscopy, is still in progress. Different flow fields designs, such as serpentine and interdigitated, are tested. The experimental data are supported by a 3D modeling analysis, developed in ANSYS Fluent environment. Figure 1 reports the visualization of the fluxes under the rib in a single serpentine architecture and the corresponding reaction rate in the porous electrode, which highlights an increase where fluxes under the rib occur.

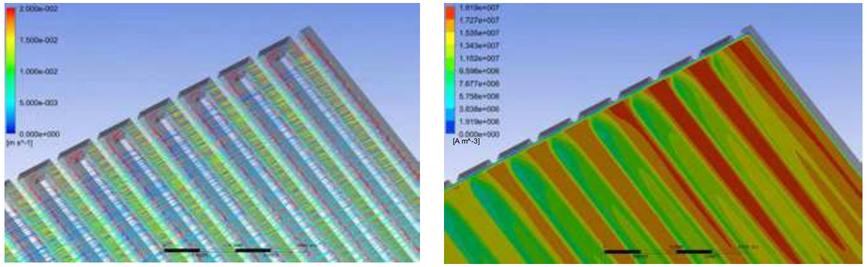

Figure 1 - Velocity (left) and reaction rate (right) in the porous electrode.

C1405 (Special Session, no abstract)

Design and upscaling of a AQDS-bromine based Redox Cell

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C1407

Spatially resolved OCV distribution for studying flow behavior in vanadium redox flow battery

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Abstract

Vanadium redox flow battery (VRFB) offers unique advantages compared to other secondary batteries, such as independent sizing of power density and energy capacity, no detrimental effect of cross mixing of electrolyte, high efficiency, fast response and ambient temperature operation, etc. In a conventional VRFB, the electrolyte is forced through the cross section of a thick (3-6 mm), highly porous (>90 %) electrode, and the bipolar plate does not contain flow fields. A flow frame is used in each half cell, which consists of a cavity to hold the electrode and integrated flow guides for uniformly distributing the electrolyte before entering the porous electrode. A uniform flow distribution of the electrolyte through the electrode is very important in operation of a VRFB, because non-uniform flow can cause effects like local overcharging, gas evolution, degradation of bipolar plate, increased Ohmic and mass transport polarization, etc. An in-situ visualization of flow is therefore necessary.
A segmented cell provides opportunity to measure local voltage and/or current, from which the flow behavior can be reconstructed. Few attempts has been made in segmenting a conventional VRFB in the past, however, lateral flow of current due to the use of thicker bipolar plate and thick porous electrode mislead the information gained.

We present a new and simple method of segmenting a conventional flow battery to study the flow distribution through the porous electrode. To eliminate the effect of lateral flow of current, OCV contours during polarization measurement were monitored to study the flow behavior. Our study shows that OCV contour changes with the flow configurations (Figure 1) and can exactly tell the nature of flow at all flow stoichiometries.

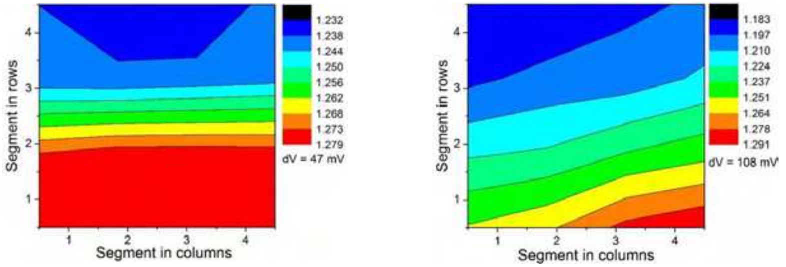

Figure 1: OCV contour for: flow entry from 1st row segments and exit from 4th row (left), and flow entry from bottom of right half and exit from top right half of the cell (right)

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With submitted Abstracts by 24 June 2017

6th EUROPEAN PEFC & Electrolyser Forum 2017

4 - 7 July 2017
Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

List of Participants

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Applied Electrochemistry, School of Chemical Science and Engineering, KTH Royal Institute of Technology
Stockholm/Sweden

Aragon Hydrogen foundation
Huesca/ES

AREVA Energy Storage
Aix-en-Provence/France

AREVA H2Gen GmbH
Köln/Germany

Atomic Energy Commission (CEA)
Grenoble/France

Audi AG
Ingolstadt/Germany

Austrian Power Grid AG
Vienna/Austria

AVL List GmbH
Graz/Austria

AVL-AST d.o.o.
Maribor/Slovenia

B.R.A.I.N AG
Zwingenberg/Germany

Ballard Power Systems
Burnaby/BC/Canada

Beijing Co-Innovation Center for Electric Vehicles, Beijing Institute of Technology
Beijing/China

BMW Group, Powertrain, Hydrogen, Alternative Fuel Tanks
Munich/Germany

Bristol BioEnergy Centre, Bristol Robotics Lab, Faculty of Environment & Technology
Bristol/UK

Canadelectrochim
Calgary Alberta/Canada

Catator AB
Lund/Sweden

CEA, LITEN/DEHT
Grenoble Cedex/France

CEA/Université Grenoble Alpes
Grenoble/France

Centre for Fuel Cell and Hydrogen Research, University of Birmingham
Birmingham/UK

Centre for Solar and Hydrogen Research (ZSW)
Ulm/Germany

Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, CIEMAT
Madrid/Spain

Chalmers University of Technology, Department of Chemistry and Chemical Engineering
Göteborg/Sweden

CNR-ITAE
Messina/Italy

Coatema Coating Machinery GmbH
Dormagen/Germany

Consiglio Nazionale Delle Ricerche CNR-IMM
Catania/Italy

CSIR – National Environmental & Engineering Research Institute,
Maharashtra/India

Daimler AG
Kirchheim unter Teck/Germany

Dalian Institute of Chemical Physics, Chinese Academy of Sciences
Dalian/China

Danish Power Systems
Egeskovvej/Kvistgaard

Danish Power Systems Ltd.
Kvistgård/Denmark

Danmarks Tekniske Universitet (DTU)
Lyngby/DK

Dep. of Energy, CIEMAT
Madrid/Spain

Department of Automotive Engineering, State Key Laboratory of Automotive Safety and Energy, Tsinghua University
Beijing/China

Department of Automotive Engineering, Tsinghua University
Beijing/P.R. China

Department of Chemical Engineering, Technion – Israel Institute of Technology
Haifa/Israel

Department of Chemistry, Simon Fraser University
Burnaby/BC/Canada

Department of Chemistry, Technical University Berlin
Berlin/Germany

Department of Chemistry, Technical University of Denmark
Kgs. Lyngby/Denmark

Department of Eco-Machinery System, Korea Institute of Machinery & Materials
Daejon/Korea

Department of Energetic technology,CR-ENEA
Casaccia(Rome)/Italy

Department of Energy Conversion and Storage, Technical University of Denmark
Kgs. Lyngby/Denmark

Department of Energy Conversion and Storage, Technical University of Denmark, DTU
Roskilde/Denmark

Department of Energy Engineering, National United University
Miaoli/Taiwan

Department of Energy Science & Engineering, Indian Institute of Technology
Maharashtra/India

Department of Energy Science and Engineering, IIT Bombay
Powai Mumbai/India

Department of Energy Technology, University of Duisburg-Essen
Duisburg/Germany

Department of Energy, Politecnico di Milano
Milano/Italia

Department of Materials Science and Engineering, Technion – Israel Institute of Technology
Haifa/Israel

Department of Mechanical and Aerospace Engineering, Seoul National University
Seoul/Korea

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

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

Department of Mechanical Engineering, The University of Tokyo
Tokyo/Japan

Department of Power Mechanical Engineering, National Tsing Hua University
Hsinchu/Taiwan

Department of Social Design Engineering, National Institute of Technology, Kochi College
Nankoku Kochi/Japan

Dept. of Mechanical Engineering, KAIST
Daejeon/South Korea

DTU Chemistry, Technical University of Denmark
Kgs. Lyngby/Denmark

DTU Energy, Technical University of Denmark
Kgs. Lyngby/Denmark

Durban University of technology
Durban/South Africa

ECN
Amsterdam/The Netherlands

Egyptian Petroleum Research Institute (EPRI)
Cairo/Egypt

Elcore GmbH
München/Germany

Electrochemical Innovation Lab, Department of Chemical Engineering
London/UK

Electrochemical Reaction and Technology Laboratory (ERTL), School of Environmental Science and Engineering, Gwangju Institute of Science and Technology (GIST)
Gwangju/South Korea

Electrochemistry Laboratory, Paul Scherrer Institut
Villigen PSI/Switzerland

Element Energy
London/United Kingdom

Energy & Environment Division, Paul Scherrer Institut
Villigen/Switzerland

Energy Department , Politecnico di Torino
Torino/Italy

Energy Research Centre of The Netherlands ECN
Petten/The Netherlands

Energy Research Institute@NTU, ERI@N, Interdisciplinary Graduate School, Nanyang Technological University
Singapore/Singapore

Energy Technology Section, Department of Process and Energy, Delft University of Technology
Delft/The Netherlands

Energy, Mining & Environment, National Research Council Canada
Vancouver/B.C. Canada

Engineering research institute
Tehran/Iran

Ertl Center for Electrochemistry and Catalysis, Gwangju Institute of Science and Technology (GIST)
Gwangju/South Korea

ETH Zürich
Zuerich/Switzerland

ETH Zürich, Laboratory of Physical Chemistry
Zuerich/Switzerland

European Commission Joint Research Centre
Petten/The Netherlands

European Fuel Cell Forum
Lucerne/Switzerland

EWII Fuel Cells A/S
Odense SØ/Denmark

Faculty of Environment and Natural Resources
Freiburg/Germany

Faculty of Mechanical Engineering, University of Ljubljana
Ljubljana/Slovenia

FMF – Freiburg Materials Research Center, University Freiburg,
Freiburg/Germany

Fondazione Bruno Kessler
Trento/Italy

Forschungszentrum Juelich GmBH
Juelich/Germany

Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research, IEK-3: Electrochemical Process Engineering
Jülich/Germany

Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research, IEK-3: Energy Process Engineering
Jülich/Germany

Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science JCNS-1/
Jülich/Germany

Forschungszentrum Jülich, „Helmholtz-Institut Erlangen-Nürnberg“ (IEK-11)
Erlangen/Germany

Fraunhofer IFAM
Dresden/Germany

Fraunhofer IKTS
Dresden/Germany

Fraunhofer Institute for Solar Energy Systems ISE
Freiburg/Germany

Fuel Cell Consultant
Oberrohrdorf/Switzerland

Fuel Cell Nanomaterials Center, University of Yamanashi
Kofu/Japan

Fuel Cell Research Center, Korea Institute of Science and Technology (KIST)
Seoul/Korea

Fuel Cell System and Engineering Laboratory, Dalian Institute of Chemical Physics, Chinese Academy of Sciences
Liaoning/China

Gaia Energy Research Institute
Arlington/VA/USA

German Aerospace Center (DLR)
Stuttgart/Germany

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

Gildemeister energy storage GmbH
Wr. Neudorf/Austria

Giner Inc.
Newton/MA/USA

Graduate School of Engineering, Tohoku University
Miyagi/Japan

Green Energy storage
Trento/Italy

Green Office, Delft University of Technology
Delft/The Netherlands

Greenlight Innovation Corp.
Burnaby/BC/Canada

H2 Energy Now
Beer Sheva/Israel

Hanbat National University
Daejeon/Republic of Korea

Helmholtz Institute Ulm for Electrochemical Energy Storage (HIU)
Ulm/Germany

Helmholtz-Zentrum Berlin GmbH, Institute of Applied Materials
Berlin/Germany

Honda R&D Co., Ltd. Automobile R&D Center
Haga-gun/Tochigi/Japan

Honda R&D Europe (Deutschland) GmbH
Offenabach/Germany

Hydrogen Europe
Brussels/Belgium

Hydrogen Production Materials Group, Center for Green Research on Energy and Environmental Materials, National Institute for Materials Science
Tsukuba, Ibaraki/Japan

Hydrogenics Europe NV
Oevel/Belgium

Hydron Energy
Noordwijkerhout/The Netherlands

HySA Systems, University of the Western Cape
Bellville/South Africa

IBM Research - Zurich
Zuerich/Switzerland

ICGM Aggregates Interfaces and Materials for Energy
Montpellier/France

ICI Caldaie S.p.A.
Frazione Campagnola di Zevio (Verona)/Italy

IHT Industrie Haute Technologie SA (IHT) AG
Monthey/CH

Infinity Fuel Cell and Hydrogen, Inc.
Windsor/USA

inhouse engineering GmbH
Berlin/Germany

Innovation Laboratory, Global Product Innovation, Italcementi s.p.a.
Bergamo/Italy

Institut Charles Gerhardt Montpellier, Université de Montpellier
Montpellier/France

Institute for Applied Biosciences (IAB), Karlsruhe Institute of Technology (KIT)
Karlsruhe/Germany

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

Institute for Energy and Process Engineering, Braunschweig University of Technology
Braunschweig/Germany

Institute of Chemistry of São Carlos, University of São Paulo
São Carlos/SP/Brazil

Institute of Chemistry, University of Rio Grande do Norte
Natal-RN/Brazil

Institute of Energy and Climate Research (IEK-3),
Jülich/Germany

Institute of Energy and Climate Research, IEK-3: Electrochemical Process Engineering, Forschungszentrum Jülich GmbH
Jülich/Germany

Institute of Energy and Climate Research: Electrochemical Process Engineering
Jülich/Germany

Institute of Fluid Science, Tohoku University
Miyagi/Japan

Institute of Innovative Mobility (MOREA), Technische Hochschule Ingolstadt
Ingolstadt/Germany

Institute of Inorganic and Analytical Chemistry, University Freiburg
Freiburg/Germany

Institute of Nuclear and New Energy Technology, Tsinghua University
Beijing/China

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

ITM Power (Research) Ltd
Sheffield/UK

JenaBatteries GmbH
Jena/Germany

Johnson Matthey Fuel Cells
Reading/UK

Johnson Matthey Technology Centre
Reading/UK

K1-MET GmbH
Linz/Austria

Karlsruhe Institute of Technology, Engler-Bunte-Institute
Karlsruhe/Germany

Korea Automotive Technology Institute
Gwangju/Korea

Korea Insitute of Machinery & Materials (KIMM)
Daejeon/Republic of Korea

Korea Institue of Energy Research
Daejeon/Korea

Korea Institute of Energy Research
Daejeon/Republic of Korea

Korea Research Institute of Standards and Science (KRISS)
Daejeon/Republic of Korea

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

Kyushu University, International Research Center for Hydrogen Energy
Fukuoka/Japan

Kyushu University, Department of Hydrogen Energy Systems
Fukuoka/Japan

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

Laboratoire d'Electrochimie Physique et Analytique Ecole Polytechnique Fédérale de Lausanne
Sion/Switzerland

Laboratory for MEMS Applications, IMTEK - Department of Microsystems Engineering, University of Freiburg
Freiburg/Germany

Laboratory of Fuel Cells, Dalian Institute of Chemical Physics, Chinese Academy of Sciences
Dalian/China

Laboratory of Physical Chemistry, ETH Zurich
Zürich/Switzerland

Lehrstuhl für Chemische Reaktionstechnik, Friedrich-Alexander-Universität Erlangen-Nürnberg
Erlangen/Germany

Lucerne School of Engineering and Architecture
Horw/Switzerland

Lucerne University of Applied Sciences
Horw/Switzerland

Lucerne University of Applied Sciences and Arts (HSLU)
Horw/CH

Materials and energy research center (MERC)
Karaj/Iran

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

Max-Planck-Institut für Kohlenforschung
Mülheim an der Ruhr/Germany

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

MS2 Engineering und Anlagenbau GmbH

Kirchheim unter Teck/Germany

MTSA Technopower B.V.
Arnhem/The Netherlands

Nanyang Technological University
Singapore/Singapore

Nedstack fuel cell technology B.V.
ED Arnhem/The Netherlands

NEW NEL HYDROGEN AS
Notodden/Norway

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

Nissan Motor Co., Ltd.
Yokohama/Japan

NuCellSys GmbH
Kirchheim unter Teck/Germany

OWI – Oel-Waerme-Institut GmbH
Herzogenrath/Germany

Ozone Research and Application (I) Pvt Ltd
Maharashtra/India

Paul Scherrer Institut
Villigen/Switzerland

Paul Scherrer Institut

Villigen PSI/Switzerland

Physical Chemistry, Technische Universität Dresden
Dresden/Germany

Politecnico di Milano, Department of Energy
Milan/Italy

Politecnico di Torino
Torino/Italy

Polymer Electrolyte Fuel Cell Group, Global Research Center for Environmental and Energy based on Nanomaterials Science (GREEN), NIMS
Ibaraki/Japan

PVcomB, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH
Berlin/Germany

Queens University, Department of Chemistry
Kingston/ON/Canada

Research and Development Center, Saudi Aramco

Dhahran/Saudi Arabia

Sabanci University, Faculty of Engineering and Natural Sciences
Istanbul/Turkey

Sabanci University, Nanotechnology Research and Application Center
Istanbul/Turkey

SAES Getters SpA
Lainate (Mi)/Italy

Schaeffler Technologies AG & Co. KG, SHARE am KIT
Karlsruhe/Germany

School of Chemical Biological Engineering, Seoul National University
Seoul/Republic of Korea

School of Chemical Engineering and Analytical Science, The University of Manchester
Manchester/United Kingdom

School of Chemical Engineering, Chobnuk National University
Jeonju/Republic of Korea

School of Chemistry, Newcastle University
Newcastle upon Tyne/United Kingdom

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

School of Materials Science and Engineering, Nanyang Technological University
Singapore/Singapore

SGL Carbon GmbH
Meitingen/Germany

Shell (Switzerland) AG
Baar/Switzerland

Siemens AG
Erlangen/Germany

Siemens AG, Corporate Technology, Research in Energy and Electronics
München/Deutschland

Simon Fraser University, Department of Chemistry
Burnaby/BC/Canada

SINTEF - Materials and Chemistry
Trondheim/Norway

Solar Fuels Laboratory, Nanyang Technological University
Singapore/Singapore

Solibro Research AB
Uppsala/Sweden

Solvay Specialty Polymers
Bollate/Italy

Solvay Specialty Polymers Italy SpA
Bollate/Italy

State Institute of Agricultural Engineering and Bioenergy, University of Hohenheim
Stuttgart/Germany

Stichting Nederlands Normalisatie Instituut (NEN)
Delft AX/NL

Swiss Federal Office of Energy
Bern/Switzerland

Swissgrid AG
Laufenburg/Switzerland

Technical Electrochemistry, Department of Chemistry and Catalysis Research Center, Technical University of Munich
Garching/Germany

Technische Universität Dresden, Theoretische Chemie
Dresden/Germany

The Nancy & Stephen Grand Technion Energy Program (GTEP), Technion – Israel Institute of Technology
Haifa Israel

TU Bergakademie Freiberg (TUBAF), Institute of Thermal Engineering
Freiberg/Germany

TU Braunschweig, Institute of Energy and Process Systems Engineering
Braunschweig/Germany

TUM CREATE
Singapore/Singapore

Univ.Grenoble CEA, LITEN
Grenoble/France

University of Cape Town , HySA/Catalysis Centre of Competence
Cape Town/South Africa

University of Genoa, Dept. Civil,Chemical and Enviromental Engineering
Genoa/Italy

University of Johannesburg
Johannesburg/South Africa

University of KwaZulu-Natal
Durban/South Africa

University of Padova, Department of Chemical Sciences
Padova/Italy

University of South Carolina
Columbia/USA

University of Southampton, Engineering Sciences
Southampton/UK

University of Southampton, School of Chemistry
Southampton/UK

University of the Philippines, National Institute of Physics, College of Science
Diliman/Philippines

University of the Philippines, Department of Mining, Metallurgical and Materials Engineering, College of Engineering
Diliman/Philippines

University of the Philippines, Materials Science and Engineering Program, College of Science
Diliman/Philippines

University of the Philippines, Technology Management Center
Diliman/Philippines

University of Tuscia
DAFNE/Italy

Uppsala Universitet
Uppsala/Sweden

VERBUND Solutions GmbH
Vienna/Austria

voestalpine Stahl GmbH
Linz/Austria

Westfälische Hochschule University of Applied Sciences
Gelsenkirchen/Germany

WindEurope asbl/vzw
Brussels/Belgium

Zentrum für Brennstoffzellen Technik (ZBT)
Duisburg/Germany

Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg
Ulm/Germany

Thanks to all the Institutions enabling Know-how
Growth, Transfer and Realisation in Applications.

13th European SOFC and SOE Forum 3 – 6 July 2018
7th European Low/Medium-Temperature Fuel Cells/Electrolysers & H2 Processing Forum 2 – 5 July 2019

www.EFCF.com

List of Exhibitors

Registered by 24 June 2017

6th EUROPEAN PEFC & ELECTROLYSER FORUM 2017

4 - 7 July 2017 KKL Lucerne/Switzerland

	Company	Exhibits
B09	**AVL List GmbH** Hans-List Platz 1 8070 Graz Austria **www.avl.com**	AVL THDA Fuel Cell Diagnoses; AVL PEM System Platform
B07	**balticFuelCells GmbH** Hagenower Str. 73 19061 Schwerin Germany **www.balticFuelCells.de**	quickCONNECTfixture
B01	**Bronkhorst (Schweiz) AG** Nenzlingerweg 5 4153 Reinach Switzerland **www.bronkhorst.ch**	Mass Flow Meters and -Controllers, Pressure Sensors and -Controllers, Evaporator
B08	**Coatema Coating Machinery GmbH** Roseller Strasse 4 41539 Dormagen Germany **www.coatema.de**	Test Solution, Thin Film Coater, Easycoater, Smartcoater
B11	**Danish Power Systems Ltd.** Egeskovvej 6C DK-3490 Kvistgård Denmark **www.daposy.com**	Fuel Cells (MEAs), Test Cells, few other things
B05	**Nova Werke AG** Vogelsangstrasse 24 8307 Effretikon Switzerland **www.novaswiss.com**	Information
B02	**SAES Pure Gas, Inc.** 4175 Santa Fe Road 93401 San Luis Obispo (CA) United States **www.saespuregas.com**	Semiconductors
B04	**Sono-Tek Corporation** 2012 Route 9W 12547 Milton, NY United States **www.sono-tek.com**	Ultrasonic Coating Systems

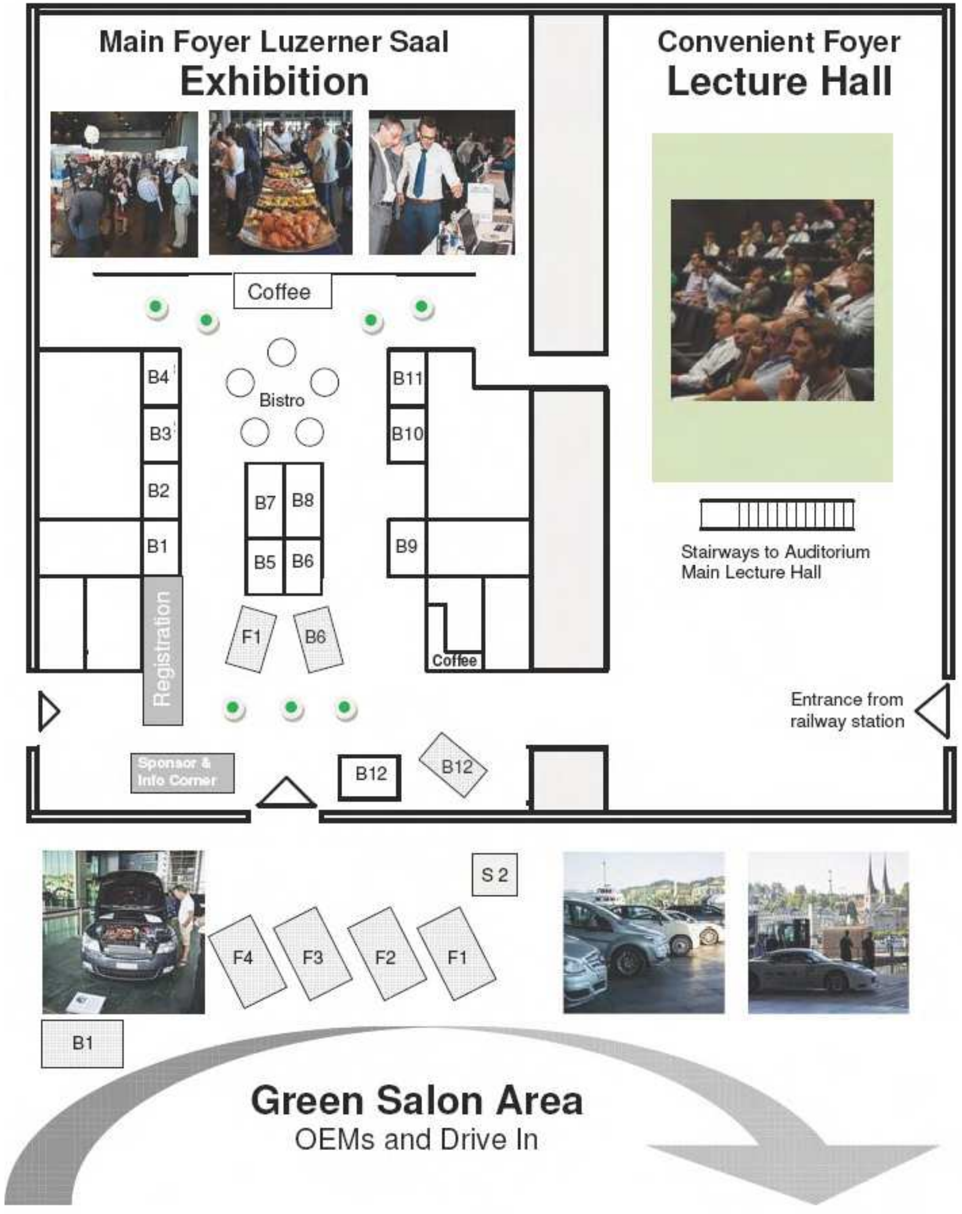
	Company	Exhibits
B06	**Swagelok Switzerland** **c/o ARBOR Fluidtec AG** Loonstrasse 10 5443 Niederrohrdorf Switzerland **www.arbor.swagelok.com**	Fluid & gas system components and services
B12	**SwissHydrogen SA** Passage du Cardinal 1 1700 Fribourg Switzerland **www.swisshydrogen.ch**	100kW PEM FC system and 63kW PEM FC system; FCV Kangoo H2
B03	**Thermo Fisher Scientific (Schweiz) AG** Neuhofstrasse 11 4153 Reinach Switzerland **www.thermofisher.com**	FTIR-Spectrometer
B10	**Westfälische Hochschule** Westfälisches Energieinstitut Neidenburger Str. 43 45897 Gelsenkirchen Germany **www.energie.w-hs.de**	Novel system design for PEM-electrolyzers and -fuel cells based on hydraulic compression
F4	***Daimler AG** Neue Str. 95, 73230 Kirchheim/Teck-Nabern / Germany **www.daimler.com**	Mercedes-Benz GLC F-CELL

	Company	Exhibits
S2	***Empa** Überlandstrasse 129 8600 Dübendorf Switzerland **www.empa.ch**	Wasserstoff-Grill
B1	***HEIG-VD** Route de Cheseaux 1 1401 Yverdon-les-Bains Switzerland **www.heig-vd.ch**	Hydroxy3000
F2	***Honda R&D Europe (Deutschland) GmbH** Carl-Legien-Strasse 30, 63073 Offenbach Germany **http://world.honda.com/FuelCell**	Clarity Fuel Cell
F3	***Hyundai Motor Europe GmbH** Kaiserleipromenade 5 63067 Offenbach **Germany** **www.hyundai.com/worldwide/en**	ix35 Fuel Cell
F1	***TOYOTA Motor Europe** Hoge Wie 33 1930 Zaventem Belgium **http://www.toyota-global.com**	Toyota Mirai

List of Booths 6h EUROPEAN PEFC & ELECTROLYSER FORUM 2017 4 - 7 July 2017 KKL Lucerne/Switzerland

Booth	Exhibitor	Country	Website
B01	**Bronkhorst (Schweiz) AG**	Switzerland	www.bronkhorst.ch
B02	**SAES Pure Gas, Inc**	United States	www.saespuregas.com
B03	**Thermo Fisher Scientific (Schweiz) AG**	Switzerland	www.thermofisher.com
B04	**Sono-Tek Corporation**	United States	www.sono-tek.com
B05	**Nova Werke AG**	Switzerland	www.novaswiss.com
B06	**Swagelok Switzerland c/o ARBOR Fluidtec AG**	Switzerland	arbor.swagelok.com
B07	**balticFuelCells GmbH**	Germany	www.balticFuelCells.de
B08	**Coatema Coating Machinery GmbH**	Germany	www.coatema.de
B09	**AVL List GmbH**	Austria	www.avl.com
B10	**Westfälische Hochschule**	Germany	www.energie.w-hs.de
B11	**Danish Power Systems Ltd.**	Denmark	www.daposy.com
B12	**SwissHydrogen SA**	Switzerland	www.swisshydrogen.ch
F1	***TOYOTA Motor Europe**	Belgium	http://www.toyota-global.com
F2	***Honda R&D Europe (Deutschland) GmbH**	Germany	http://world.honda.com/FuelCell
F3	***Hyundai Motor Europe GmbH**	Germany	www.hyundai.com/worldwide/en
F4	***Daimler AG**	Germany	www.daimler.com
B1	***HEIG-VD**	Switzerland	www.heig-vd.ch
S2	***Empa**	Switzerland	www.empa.ch

Floorplan



Toyota Mirai

exklusiv für Drive-In importiert

Honda Clarity Fuel Cell

in der Schweiz im Handel

Hyundai ix35 Fuel Cell

in der Schweiz im Handel

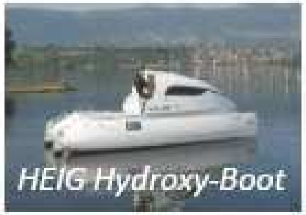
Mercedes-Benz GLC o. B-class (tbc)

Weltneuheit, ab Herbst für Flotten

Swiss Hydrogen Hybird

mit CH-Technologie

EMPA H_2-Grill



HEIG Hydroxy-Boot

SGV MS Diamant

Outlook 2018

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 coming together for the 6th EUROPEAN PEFC & Electrolyser Forum 2017. However, looking beyond these intensive days, we see another important event emerging on the horizon in 2018:

The 13th 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 13th EUROPEAN SOFC&SOE FORUM will once again be THE major event of the 2018 for SOFC scientists, experts, engineers, and also increasingly business developers and managers.

Already many people have expressed a strong interest in participating and contributing 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 is now seeing products entering their first markets, more people are becoming aware of the much larger potential of ceramic membrane reactors. This evolution from pure fuel cells towards generic ceramic membrane reactors has gained 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 are expected from more than 36 countries. 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 into the first commercial products, while both fundamental and incremental research remain a very important part of the activities. To represent this large scope, the EFCF's International Board of Advisors has elected

Prof. Ellen Ivers-Tiffée & Dr. André Weber
KIT Karlsruhe Institute of Technology

who are jointly chairing the upcoming conference. They present both a strong academic background combined with valuable industrial experience. Prof. Ellen Ivers-Tiffée holds the chair of materials for the electrical and electronic engineering at KIT. Dr André Weber is head of both the fuel cell and battery research groups at KIT.

A Scientific Advisory Committee has once again been formed to structure the technical programme in an independent and neutral manner, and will exercise full scientific independence in all technical matters.

For everybody interested in SOFC and SOE, please make a note in your agenda of the next opportunity to enjoy Lucerne as a scientific and technical exchange platform. The 13th EUROPEAN SOFC&SOE FORUM will take place from 3 to 6 July 2018, in Lucerne.

We look forward to welcoming you to Switzerland in 2018.

The organisers Olivier Bucheli & Michael Spirig

Outlook 2019

The **7th European**
Low/Medium-Temperature
Fuel Cells/Electrolysers & H2 Processing Forum
will take place **2 – 5 July 2019** in Lucerne, Switzerland.

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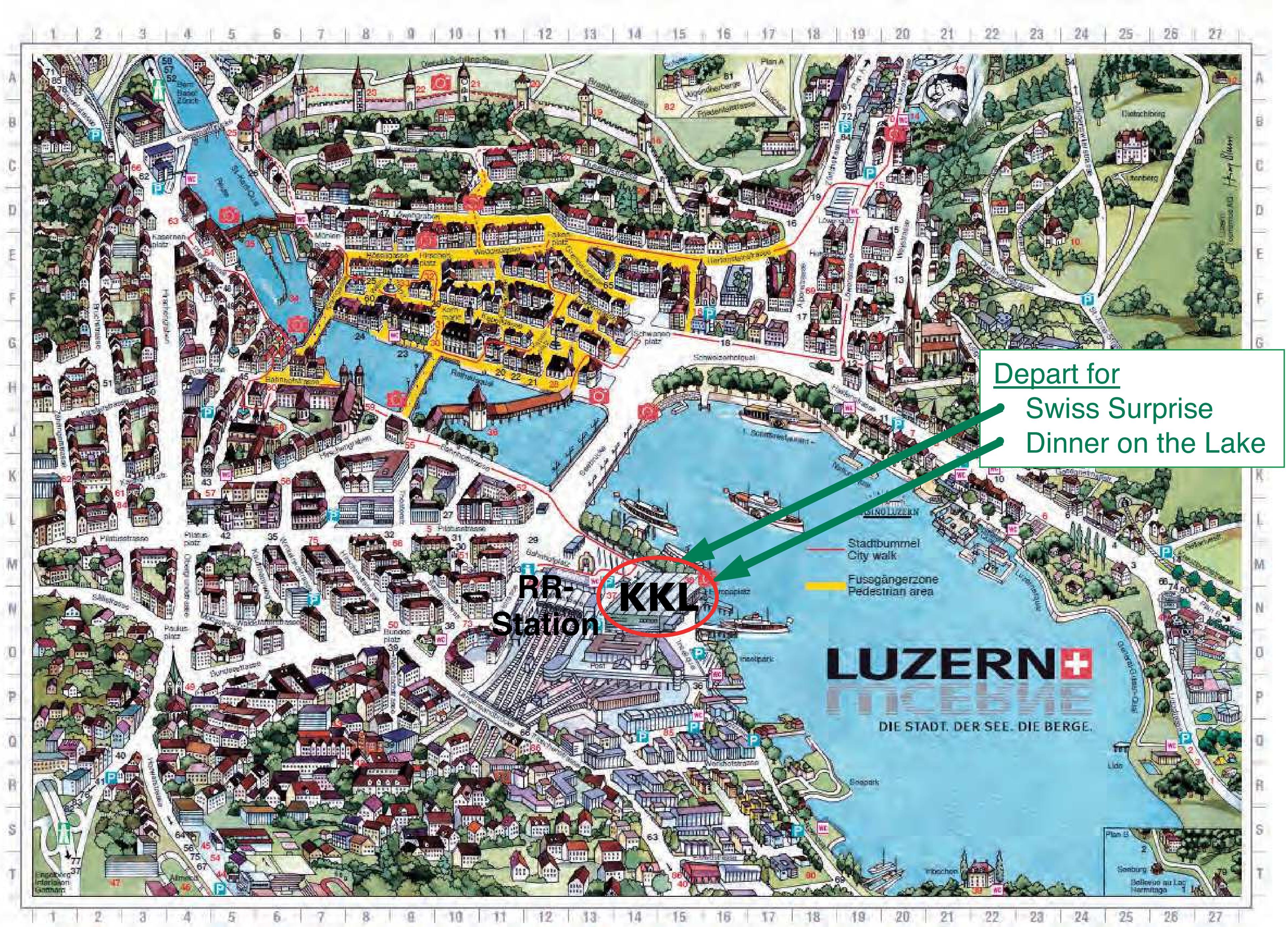
Depart for
Swiss Surprise
Dinner on the Lake
RR-Station
KKL
Stadtbummel City walk
Fussgängerzone Pedestrian area
LUZERN
LUCERNE
DIE STADT. DER SEE. DIE BERGE.

www.EFCF.com

International FUEL CELL, ELECTROLYSER & HYDROGEN Conference with Exhibition and Green Salon,
covering: All Hydrogen, Direct Alcohol, Microbial FCs; Redox Flow Battery comparison; Alkaline + PEM Electrolysis;
PEC; H_2 storage, processing, purification, compression; CO_2 Reduction; Green Salon, Grid Service Markets symposium

6th European PEFC & Electrolyser Forum

4 – 7 July 2017 Kultur- und Kongresszentrum Luzern (KKL) Lucerne/Switzerland

Schedule of Events

Tuesday – 4 July 2017	09:30 – 16:00	**Tutorial** by Dr. Günther G. Scherer & Dr. Jan Van herle (09:30 – 10:00 Registration, KKL, Clubroom, 2nd Floor above Auditorium)
	09:00 – 17:00	**Workshop on Monitoring, Diagnostics & Control for FC** (by FCH-JU projects DIAMOND + HEALTH-CODE, KKL, Clubroom, 2nd Floor)
	11:00 – 16:00	**Exhibition set-up**
	16:00 – 18:00	**Poster pin-up** (continued on following morning) / **Opening** of the exhibition, On-site **Registration** (continued on following days)
	18:00 – 19:00	**Welcome gathering** in the exhibition in the splendid KKL (ground floor)
Wednesday – 5 July 2017	08:00 – 16:00	On-site **Registration** (continued on following days); 08:00 – 09:00 **Speakers' Breakfast** (info at the registration desk)
	09:00 – 18:00	**Conference sessions 1 – 5** with keynotes on Hydrogen Economy; Automotive OEM Status; Bridge to Products: Material to Cells Performance; Electrolysers & H_2: Concepts, production & costs; Poster presentation, networking & exhibition
	09:00 – 18:00	**Poster** area & **exhibition** open, 13:15 – 14.30 Poster Session I; Drive-In & AUTOMOBIL-SHOW at the **"Green Salon"**-H_2-Grill
	12:30	Press Conference by invitation only
	18:30 – 23:00	**Swiss Surprise Evening** – separate registration for 80 places to be booked on a first-come-first-served basis
Thursday – 6 July 2017	08:00 – 09:00	**Registration** continuation, Speakers' Breakfast
	09:00 – 18:00	**Conference sessions 6 – 11** with keynotes on Green Power for Green Hydrogen; Technical FC, Electrolysers & H_2 sessions; Poster presentation, networking & exhibition
	09:00 – 18:00	In parallel: **European Grid Service Markets Symposium**: Business with New Technologies like Electrolysers
	09:00 – 18:00	**Poster** area & **exhibition** open, 13:15 – 14:30 Poster Session II; Drive-In & AUTOMOBIL-SHOW at the **"Green Salon"**-H_2-Grill
	19:30 – 23:00	Great **Dinner on the Lake**
Friday – 7 July 2017	08:00 – 09:00	**Registration** continuation, Speakers' Breakfast
	09:00 – 16:15	**Conference sessions 12 – 15**: Science, Bridge to Products & Industrial Achievements, Inventions, Implementation & Expectations; **SPECIAL Sessions:** Electrochemical CO_2-Reduction (B12), PEC Water Splitting – Microbial & Direct Formic Acid Fuel Cells (C12), Similarities & Differences: FC-Redox Flow Batteries (C13+14); networking and exhibition
	09:00 – 12:30	**Poster** area & **exhibition** open; 12:30 – 14:00 Poster and exhibition removal
	15:00 – 16:15	**Closing &** Christian Friedrich Schoenbein **Award Ceremony**: Best poster, best scientific contribution & outstanding lifetime work; **Keynote** by **Prof. Hubert Gasteiger**, TU Munich: «New materials, methods & concepts for Hydrogen Fuel Cells»
	16:15 – 17:00	**Goodbye** coffee and travel refreshment in front of the Luzerner Saal

Motto 2017: Fuel Cells & Reversible Technologies: From Materials & Components to Applications – Practical Inventions & Competitive Solutions