Book of Abstracts

Topical Meeting on

Potential for cost reduction and performance improvement of the IEA AFC TCP for PEMFC at component and system level

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Graz University of Technology, 10./11. November 2021

Wednesday, 10. November 2021 – Afternoon session

USA -7 (Chicago)	Asia +8 (Seoul)		
09:00	00:00	16:00	**Welcome** Detlef Stolten (FZ Jülich), Di-Jia Liu (ANL), Viktor Hacker (TU Graz)
09:40	00:40	16:40	**Recent advances of PEMFC technologies and challenges for applications beyond personal owned vehicles** Hongfei Jia (Toyota North America)
10:10	01:10	17:10	**Engineering Solutions for Economical and Durable Fuel Cell Vehicles** Erik Kjeang (Simon Fraser University, Canada)
10:40	01:40	17:40	**Cost-efficient and environmentally friendly recycling of materials in PEM fuel cells and electrolysis cells** Mikkel Juul Larsen (IRD, Denmark)
11:10	02:10	18:10	**PEMFC Development for Road and Maritime Applications** Richard Schauperl (AVL, Austria)
11:40	02:40	18:40	**Closing**

Thursday, 11. November 2021 – Morning session

02:00	17:00	09:00	**Welcome**
02:10	17:10	09:10	**High Pressure Nitrogen-infused ultrastable Core-Shell Catalyst for the Oxygen Reduction Reaction of Fuel Cells** Gu-Gon Park (KIER, Korea)
02:40	17:40	09:40	**Hybrid PEM fuel cell systems** Sönke Gößling (ZBT, Germany)
03:10	18:10	10:10	**Fuel Cell research in Spain with a focus on potential for cost reduction and performance improvement for PEMFC at component and system level** Alfredo Iranzo (University of Sevilla, Spain)
03:40	18:40	10:40	**Membrane Electrolyte Assembly for Polymer electrolyte fuel cell** Hongmei Yu (Dalian Institute of Chemical Physics, China)
04:10	19:10	11:10	**Closing**

Thursday, 11. November 2021 – Afternoon session

09:00	00:00	16:00	**Welcome**
09:10	00:10	16:10	**PBI-based High Temperature PEMFC – from materials to systems** Hans Aage Hjuler (Blue World, Denmark)
09:40	00:40	16:40	**Aquivion®-based MEA for enhanced PEFC performance** Alessandra Carbone (ITAE CNR, Italy)
10:10	01:10	17:10	**Application of stationary fuel cells for the local energy transition** Philipp Rechberger (Fronius, Austria)
10:40	01:40	17:40	**Discussion**
11:10	02:10	18:10	**Closing**

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Aquivion®-based MEA for enhanced PEFC performance

A. Carbone*

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Renewable energies are considered the most promising solution for the decarbonization challenge. Among the wide variety of alternative energy production sources, polymer electrolyte membrane fuel cells (PEMFCs) are ready for market penetration, particularly in the automotive sector. In fact, different car manufacturers are engaging in the marketing of hydrogen cars. The research in this area still needs a reduction of the costs and improved performance and stability.

The required operative conditions of high temperature and low relative humidity maintaining a good performance level and low degradation require the development of the components such as catalysts, ionomers, and membranes with proper stability.

In this work, Pt and Pt alloys based-electrocatalysts were investigated to verify the performance and stability. MEAs manufacturing using an innovative reinforced Aquivion® membrane and optimized electrode configurations were carried out, according to the different ionomer characteristics used in the catalytic layer. The stability was verified considering the variations of the performance and electrochemical parameters, such as electrochemical surface area (ECSA) and mass activity (jm), at the beginning and end of the accelerated stress test procedure.

Hybrid PEM fuel cell systems

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Nowadays, PEM fuel cell systems for passenger cars are always realized as hybrid systems. If the architecture of a hybrid system is given, then the dimensioning of the fuel cell and battery subsystems is crucial in terms of costs, dynamics, and driving behavior in general.

In order to analyze these dependencies correctly, the ZBT fuel cell model was integrated into a fuel cell system and a full vehicle simulation. The subject of the investigation is the interaction of different drive cycles, which in part are very different, with differently dimensioned sub models for the fuel cell system and the battery. The ZBT fuel cell model is integrated into the simulation environment AVL CRUISE™ M for the fuel cell system and the vehicle.

An analysis is presented that compares the different drive cycles and system dimensions and provides specific recommendations for different use cases.

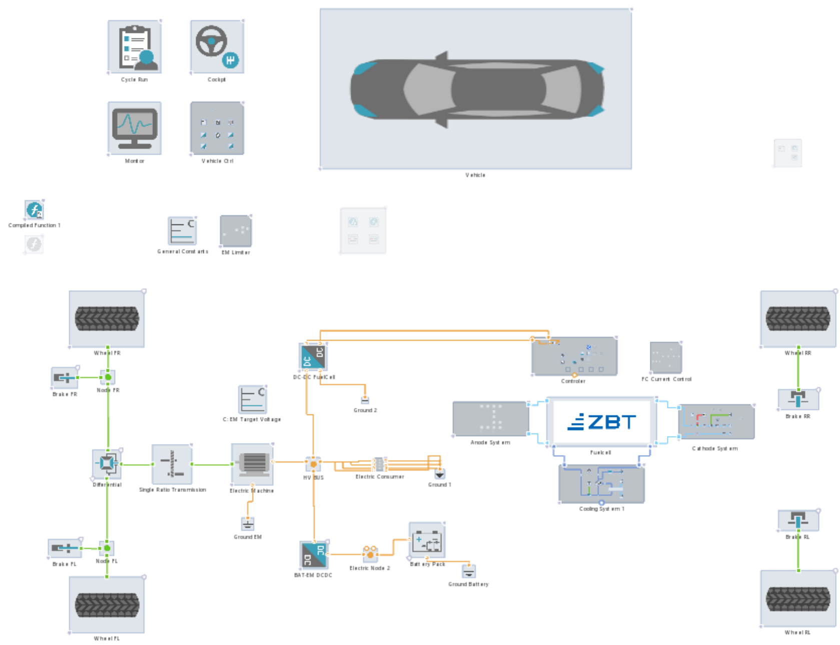

Figure 1: Screenshot of the PEM fuel cell hybrid vehicle simulation

PBI-based High Temperature PEMFC – from materials to systems

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Proton exchange membrane fuel cells have received attention as promising energy conversion sources for residential, automotive, and portable applications. However, issues such as performance and lifetime still need to be improved.

This study focuses on the durability of high temperature PEM fuel cells (HTPEM) using polybenzimidazole membranes (PBI) by measuring cell voltage degradation.

The high operating temperature (160 ^{o}C) makes it possible to operate commercial fuel cell systems using methanol (or methanol-water mixtures) as fuel. The HTPEM cells can tolerate fuel impurities e.g., up to 3 vol-% CO and 20 ppm H_2S without significant performance losses, which could lead to better operating economy.

The fuel cell voltages were carefully monitored over thousands of hours and hundreds of cycles. Our studies have shown remarkable durability of a HTPEM equipped with a thermally cross-linked m-PBI membrane. A decay rate of only 0.5 µV /h at 0.2 A/cm^2 over an extended period of time (9,200 h) was observed. Further, we have illustrated that an increase in the pressure of the in-going gases to 1.5 bar (abs) at 170 ^{o}C – as expected – increases the performance. The preliminary results showed a power density of 0.5 W/cm^2 at 0.9 A/cm^2 using humidified reformate.

Continuous operation and with more than 260 start stop cycles have been performed in order to study the degradation effects of both continuous operation and of repeated start stops. Start stop cycles led to a degradation of 0.31 mV/cycle at a current density of 0.31 A/cm^2 and 0.45 mV/cycle at 0.55 A/cm^2.

The durability of HTPEM can now be considered similar to low temperature PEM fuel cells. We have shown more than 15,000 hours in single cells at 0.3 A/cm^2. The degradation rate is around 4 µV/h for approx. 13,000 hours. Single cell performance during operation have shown very stable behavior for over 10,000 with an overall degradation of 9 µV/h at a current density of 0.4 A/cm^2. Several demonstration projects have been made, especially for cars and we continue improving our products looking for innovative solutions to customer needs. Full scale production has been established. Fuel cell stacks and systems will be shown.

Fuel Cell research in Spain with a focus on potential for cost reduction and performance improvement for PEMFC at component and system level

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An overview of PEM Fuel Cell research in Spain is provided, focusing on activities involving cost reduction and performance improvement for PEMFC at component and system level. In order to provide a general overview, the major research activities ongoing at Universities, Research&Technology Centres, and also at industrial level are introduced and discussed. Additional details are provided for the University of Sevilla, involving modelling and experimental techniques for PEMFC research. Computational Fluid Dynamics (CFD) for PEMFC modelling is discussed, as well as experimental testing of PEMFCs prototypes (including EIS and current density distribution measurements). Studies on cell water management both by CFD and by means of advanced experimental techniques such as Neutron Radiography are presented. Activities at system level in PEMFC/hydrogen-based microgrids are also introduced.

Recent advances of PEMFC technologies and challenges for applications beyond personal owned vehicles (POVs)

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Earlier development of PEMFCs had been mostly motivated for passenger vehicle applications, of which substantial technology advances were demonstrated with the successful commercialization of several models of FCEVs in the last several years. As the global H2 and fuel cell community lately expands quickly beyond POVs, new opportunities emerge for further developing the technology to fulfill the requirements for applications in commercial trucks, buses, trains, aviation, marine time, etc.. In this presentation, recent progresses and current state of art of PEMFC technology will be reviewed with the 2nd gen Toyota Mirai fuel cell system as an example, followed by in depth discussion of gaps and R&D needs towards these new mobility needs.

Engineering Solutions for Economical and Durable Fuel Cell Vehicles

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Fuel cell electric vehicles powered by hydrogen offer zero emissions while maintaining the driving performance and range of conventional vehicles. However, most fuel cell vehicles are not yet competitive in terms of capital cost and engine durability. The research conducted at Simon Fraser University's Fuel Cell Research Laboratory (fcrel.ca) addresses these challenges in close collaboration with the fuel cell industry cluster in the Metro Vancouver region and international partners. In the present talk, I will provide two examples of proposed engineering solutions for economical and durable fuel cell vehicles. Firstly, I will present a novel strategy for the use of low-cost hydrogen in fuel cell systems by active mitigation of CO contamination. Secondly, I will demonstrate visualization guided fuel cell membrane durability improvements accomplished by tuning the design and fabrication of the membrane electrode assembly.

Cost-efficient and environmentally friendly recycling of materials in PEM fuel cells and electrolysis cells

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The Danish companies IRD Fuel Cells A/S and CriMaRec ApS together with the University of Southern Denmark are developing and scaling up efficient and sustainable processes to recycle platinum-group metals (PGMs), mainly platinum and iridium, with the aim of establishing production alternatives to the costly, energy-intensive and pollutive conventional processes. The approach is based on patented electrochemical methods involving potential cycling [1,2]. The efforts also comprise recycling or reuse of perfluorosulphonic acid (PFSA) polymer as an alternative to incineration. The expected outcome is a highly competitive production of membrane–electrode assemblies (MEAs) containing PFSA material recovered from spent MEAs and PGMs recycled from MEAs [3] as well as from existing scrap resources such as autocatalysts. This will allow IRD to offer the end users of its MEAs the cost-reducing possibility of returning the spent products for recycling. Moreover, it can ensure adequate reuse and/or recycling of production process waste, thus reducing the amount of scrap material.

This presentation will give an introduction to the recycling concepts and show some preliminary low-temperature polymer electrolyte membrane fuel cell (LT-PEMFC) results serving as proof of concept.

Acknowledgement:
The work is supported by the Energy Technology Development and Demonstration Programme (EUDP) of the Danish Energy Agency through the project 64019-0551 3R – Recycle, Reuse, Reduce.

References:

[1] E. Skou, C. Noergaard, S. N. Stamatin: Method for recovering platinum group metals from catalytic structures; United States Patent no. US 9,580,826 B2

[2] S. M. Andersen, R. Sharma: Method for dissolving precious metals; EPO/WIPO patent application no. EP 3 788 177 A1, WO 2019/211318 A1

[3] R. Sharma, S. M. Andersen: Circular use of Pt/C through Pt dissolution from spent PEMFC cathode and direct reproduction of new catalyst with microwave synthesis; Materials Chemistry and Physics 265 (2021) 124472 pp. 1–9

High Pressure Nitrogen-infused ultrastable Core-Shell Catalyst for the Oxygen Reduction Reaction of Fuel Cells

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Core-shell electrocatalysts have shown remarkable results in terms of activity as well as durability. The mass activity of Pt-based catalysts can be sustained throughout the fuel cell vehicle life by optimizing their stability under the conditions of an oxygen reduction reaction (ORR) that drive the cells. Here, we demonstrate improvement in the stability of the readily available PtCo core-shell nanoparticle catalyst over a million cycles by maintaining its electrochemical surface area by regulating the amount of nitrogen doped into the nanoparticles. The high pressure nitrogen-infused PtCo/C catalyst exhibited a two-fold increase in mass activity and a five-fold increase in durability compared with commercial Pt/C, exhibiting retention of 80% of the initial mass activity after 180k and maintaining the core-shell structure even after 1000k cycles of accelerated stress tests. Synchrotron studies coupled with pair distribution function analysis reveal that inducing higher amount of nitrogen in core-shell nanoparticles increases the catalyst durability.

Application of stationary fuel cells for the local energy transition

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The increased use of renewable energy plays a major role in the change of the energy system. Due to high fluctuation of renewable energy production, storage is needed to fulfil the need. Batteries are one option but especially for long time storage, hydrogen can play a major role. Next to large-scale systems especially decentralized energy production, local energy communities and prosumers are key players for an energy transition. Research and demonstration of hydrogen systems based on electrolysis, fuel cells and related storage components for such energy communities are needed for a broader use of green hydrogen.

Currently long-term storage systems based on hydrogen are not economically competitive. Optimizing system efficiency, lifetime and cost reduction by material research and economies of scale are key components. Next to electrolysis this mainly affects stationary fuel cells too. If the necessary hard- and software is developed the share of renewables in the local energy grids can be raised significantly.

This talk will give an insight in application scenarios of small-scale stationary hydrogen systems with a focus on the key parameters which are necessary to generate competitive solutions. Next to an overview of relevant components usage of renewable energy as photovoltaic electricity for the operation of electrolysis and the interaction and dependency of batteries and fuel cells will be in focus. This example in particular is a good way of highlighting the tension between system- and device-optimisation.

Fronius is a producer of electrolysis systems, supplier for renewable energy solutions and system integrator. An overview of our solutions and current research and development projects will be given, as a currently undergoing project of the development of a fuel cell system based on an already commercially available stack. As a system and solution provider the economic motivation of the customers and future cost and performance developments are of key interest – relevant studies will be discussed.

AVL PEM-FC Development for Road and Maritime Applications

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Due to the global hydrogen hype driven by the movement to a renewable energy system, PEM fuel cell technology is on the path to become a mainstream energy conversion technology in various applications like on-road, marine, rail, power-gen and aviation.

AVL is investigating fuel cell technology for the last 20 years and has today a global footprint to test and develop PEM stacks and systems till production maturity for various applications.

Over the last 2 years, AVL has developed in its dedicated tech-center in Vancouver a PEM stack platform balancing the power density and durability requirements of commercial applications. This stack platform is incorporated in various fuel cell systems for different applications. In this presentation the design choices to balance durability & reliability will be explained. Additionally, 2 fuel cell system development programs will be introduced - on the one hand side a 310kW heavy duty truck fuel cell system and on the other hand side a 1.2MW power module for maritime application. Due to the challenging lifetime requirements of these applications, innovative durability extension measures will be introduced. Also, the market drivers and business parameters for in particular fuel cell trucks will be addressed.

Membrane Electrodes Assembly for Polymer Electrolyte Fuel Cell

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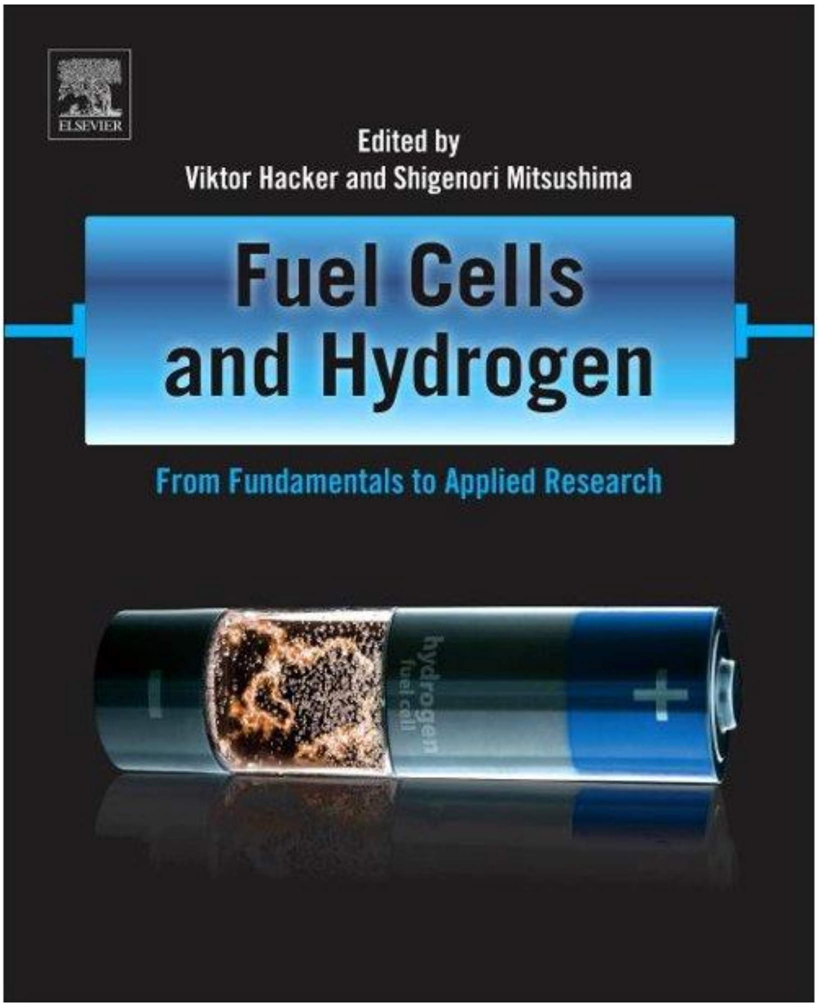
Polymer Electrolyte Membrane Fuel Cells (PEMFCs) haven been pursued as an alternative power supplier for clean energy. However, as the precious metal loading in membrane electrode assembly (MEA) results in high cost of PEMFC, cutting down the precious metal in MEA becomes one of the main targets for PEMFC wide application. Beyond the applicable catalyst coated membrane (CCM) manufacturing technology, Dalian Institute of Chemical Physics investigated on the microstructure of catalyst layer in PEMFC. Nano-structure catalyst layer, i.e. Pt/Nb2O5 nanobelt, PtCo nanotube array and Pt-Ni nanobelt were prepared and tested in PEMFC single cell. With low platinum loading at low humidity and ambient air conditions, the fuel cell performance with the nano structure catalyst layer is comparable with that of the conventional CCM.



Fuel Cells and Hydrogen: From Fundamentals to Applied Research
Viktor HACKER, Shigenori MITSUSHIMA (eds.)
[ISBN: 9780128114599](), Elsevier 296 pages, 19th July 2018.

Fuel Cells and Hydrogen: From Fundamentals to Applied Research provides an overview of the basic principles of fuel cell and hydrogen technology, which subsequently allows the reader to delve more deeply into applied research. In addition to covering the **basic principles of fuel cells** and hydrogen technologies, the book examines the principles and methods to **develop and test fuel cells**, the evaluation of the **performance** and **lifetime** of fuel cells and the concepts of **hydrogen production**. *Fuel Cells and Hydrogen: From Fundamentals to Applied Research* acts as an invaluable reference book for **fuel cell developers** and **students**, researchers in **industry** entering the area of fuel cells and lecturers teaching fuel cells and hydrogen technology.

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