European Commission

Directorate-General for Research

FP7, Cooperation /NMP, Cooperation/Energy

FUEL CELLS AND HYDROGEN

JOINT UNDERTAKING

Workshop

Materials Issues for Fuel Cells and Hydrogen Technologies: from innovation to industry

European FCH Projects Meeting

26th March – 27th March 2012

MINATEC

Grenoble — France

European Commission

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MINATEC

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SMAllin One

liten

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Monday 26th March 2012

1:30 pm:Welcom to CEA

1:40 pm: Objectives of the workshop

Chair: Bertrand Fillon, LITEN CTO

PEMFC (materials development)

2:00 pm: SMAllinOne – Smart Membrane for hydrogen energy conversion: All fuel cell functionality in One material

2:20 pm: IRAFC - Development of an Internal Alcohol Reforming High Temperature PEM Fuel Cell Stac

2:40 pm: Pemican - PEM with Innovative low cost Core for Automotive applicatioN

3:00 pm: questions and discussion

3:30 pm: coffee break

4:00 pm: Zeocell - Nanostructured electrolyte Membranes based on polymer-ionic liquids-zeolite composites for high temperature PEM fuel cell

4:20 pm: MAESTRO - MembrAnEs for STationary application with RObust mechanical properties

4:40 pm: Quasidry - Quasi-anhydrous and dry membranes for next generation fuel cells

5:00 pm: questions and discussion

5:30 pm: End of day 1

Hydrogen Storage

2:00 pm: NANOHy - Novel Nanocomposites For Hydrogen Storage Applications

2:20 pm: FLYHY - Fluorine substituted High Capacity Hydrides for Hydrogen Storage at Low Working Temperatures

2:40 pm: HYPOMAP - New materials for hydrogen powered mobile applications

3:00 pm: questions and discussion

3:30 pm: coffee break

4:00 pm: SSH2S - Fuel cell coupled solid state hydrogen storage tank

4:20 pm: ISH2SUP - In situ H2 supply technology for micro fuel cells powering mobile electronics appliances

4:40 pm: questions and discussion

5:30 pm: End of Day 1

7:30 pm: Dinner at Chateau de la Baume

Tuesday 27th March 2012

PEMFC (Degradation studies)

9:00 am: Keepemalive - Knowledge to Enhance the Endurance of PM fuel cells by Accelerated Lifetime Verification Experiments

9:20 am: Demmea - Understanding the Degradation Mechanisms of Membrane-Electrode-Assembly for High Temperature PEMFCs and Optimization of the Individual Components

9:40 am: FCGEN - Fuel Cell Based On-board Power Generation

10:00 am: questions and discussion

10:30 am: Coffee break

11:00 am: Decode - Understanding of degradation mechanisms to improve components and design

11:20 am: Premium Act - PREdictive Modelling for Innovative Unit Management and ACcelerated Testing procedures of PEFC

11:40 am: questions and discussion

12:00: Lunch

SOFC anionic

9:00 am: SOFC Life - Solid Oxide Fuel Cells – Integrating Degradation Effects into Lifetime Prediction Models

9:20 am: Robanode - Anode degradation for H2 and natural gas fuelled SOFCs

9:40 am: Sulphur, Carbon, and re-Oxidation Tolerant Anodes and Anode Supports for Solid Oxide Fuel Cells

10:00 am: questions and discussion

10:30 am: Coffee break

11:00 am: METSOFC - Development of next generation metal supported SOFC cells

11:20 am: RAMSES - Robust Advanced Materials for Metal Supported SOFC

11:40 am: questions and discussion

12:00: Lunch

PEMWE

1:00 pm: Weltemp - Water Electrolysis at Elevated Temperatures

1:20 pm: Nexpel - Next Generation PEM Electrolyser for Sustainable Hydrogen Production

1:40 pm: Primolyser - Pressurised PEM Electrolyser stack

2:00 pm: nanoPEC - Nanostructured Photoelectrodes for Energy Conversion

2:40 pm: questions and discussion

3:00 pm: Coffee break

PCFC & SOFC

1:00 pm: EFFIPRO - Efficient and robust fuel cell with novel ceramic proton conducting electrolyte

1:20 pm: IDEAL Cell - Innovative Dual mEmbrAne fueL-Cell

1:40 pm: RelHy - Innovative Solid Oxide Electrolyser Stacks for Efficient and Reliable Hydrogen production

2:00 pm: ADEL - ADvanced ELectrolyser for Hydrogen Production with Renewable Energy Sources

2:20 pm: questions and discussion

3:00 pm: Coffee break

Round table on material development at european level

3:15 pm: Funding opportunities for FCH projects under Horizon 2020, Lenaic Georgelin, European Commission

3:30 pm: FCH JU AIP 2012 - materials topics, Jean-Luc Delplancke, FCH JU

3:45 pm: SET Plan materials – outcome presentation from Erno Vandeweert, European Commission "materials roadmap enabling low carbon energy technologies"

4:00 pm: The EMIRI association, Peter Rigby

4:15 pm: Summary of main materials bottlenecks for FC&H

4:30 pm: Panel discussion and workshop closure

5:00 pm:End of meeting

PEMFC (materials development)

SMAllinOne – Smart Membrane for hydrogen energy conversion: All fuel cell functionality in One material,
Coord: CEA/LITEN, France Dr. Jessica Thery..... p.7

IRAFC - Development of an Internal Alcohol Reforming High Temperature PEM Fuel Cell Stac
Coord: Advanced Energy Technologies S.A, Greece, Prof. J. Kallitsis p.8

LoLiPem - material, cell and stack developement and integration CHP and degradation study
Coord: National Research Council - Institute on Membrane Technology, Italy, Dr. Giuseppe BARBIERI..... p.9

Pemican - PEM with Innovative low cost Core for Automotive applicatioN
Coord: CEA – LITEN, France, Joël PAUCHET p.10

Zeocell - Nanostructured electrolyte Membranes based on polymer-ionic liquids-zeolite composites for high temperature PEM fuel cell.
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MAESTRO - MembrAnEs for STationary application with RObust mechanical properties
Coord: Deborah Jones, France, CNRS Université Montpellier..... p.13

Quasidry - Quasi-anhydrous and dry membranes for next generation fuel cells
Coord: Deborah Jones, France, CNRS Université Montpellier..... p.14

Smart Membrane for hydrogen energy conversion: All fuel cell functionality in One material

(Project **SmallinOne**, CEA – Liten, France)

Grant agreement n°: 227177-2
Start and end dates: 01/04/2009 to 31/03/2012
Coordinator: CEA LITEN DTNM, FRANCE, J. Thery Jessica.thery@cea.fr (tel 0033 438 78 19 40)

Consortium:

Partner	Beneficiary Name	Country	Role
1	CEA	france	Coordination and material developments
2	UNIBA	Italy	Material development via vacuum technique and precursor syntesis
3	BIU	israel	Nanoprecursor synthesis
4	SIL	UK	Material developments via ASPD
5	IRD	danemark	Material and Fuel cell benchmark / test
6	FMSP	france	Up scalability
7	ALMA	france	Administrative

Title: Smart Membrane for hydrogen energy conversion: All fuel cell functionality in One material **SmallinOne**

Objectives: In the most common ways, PEM fuel cells are built using deposition of catalyst on GDLs supports, both hot pressed around a ion-conductive membrane. The SmallinOne project addresses an architecture that strongly differs from this approach. The catalysts and the membrane are deposited step by step on a porous substrate using vacuum techniques. This architecture can be compared to the "top down integration" approach that is common in microelectronic. With respect to classical PEM fuel cells, this modifies drastically the morphology of the fuel cell materials.

Description of the work : In a first part of the project, the objectives were to develop the catalysts and the ionic membrane via vacuum technologies. This was done in two steps: development of precursors and use of these precursors to build the ionic membrane and the catalysts. Various techniques have been use to develop carboxylic and sulfonic membranes, such as PECVD, iCVD and ASPD with ionic conductivities as high as 200mS/cm. In addition, an innovative method UV photo-deposition method using covalently attached benzophenone (BPh) moieties onto the surface of inorganic conductive (WO_3, WC, & ATO NPs) was used for the synthesis of composite catalyst systems. Promising electrochemical outputs (ATO support most promising results) and specific alectrochemical activities superior to commercial HISPEC C/Pt 60% were measured.
These materials have been assembled together for the fabrication of fuel cells via the incorporation of the catalysts in a proton conductive matrix. Maximal power output of 120mW/cm2 were measured when the catalyst are associated with Nafion membranes. When associated to a sulfonic membrane deposited via vacuum technique, open circuit voltage of 900-1000mV were measured. All of these processes still need to be improved for adjusting the ratio ionic material versus catalyst or improve the decomposition of the precursors. Taking into account the specific architecture proposed in SmallinOne, one very important issue was to find or develop substrates compatible with the SmallinOne objectives. In this frame, various plastic sheets were evaluated such as PEN, PET and polyimide and were showed compatible with the drilling process. Polyimide substrates were chosen for the realization of fuel cell via vacuum techniques. The drilling process was optimized to have hydrogen flow sufficient at very low hydrogen pressure. To evaluate this support, fuel cell were stacked via printing techniques and power outputs as high as 100mW/cm^2 were reached.

Further research needs: In the light of the results, we think that the initial commercial targets of the project should be refocused on small scale, portable application rather than the more demanding automotive or stationary applications, with a particular emphasis on planar micro-power fuel cells for portable electronic devices. Indeed, the materials itself as well as the solution proposed for their integration might bring very interesting opportunities to miniaturize the systems. Regarding automotive or stationary application, we can point out various drawbacks for using vacuum deposited membranes, related to the low growth rate, cost and lack of mechanical stability. However, part of the material developed within the project might be of interest of stationary and automotive applications: even if the results we had with the composite catalyst materials do not reach the required, we still have a margin to progress, and the developed processes might be competitive, especially regarding the catalyst composites.

Development of an Internal Alcohol Reforming High Temperature PEM Fuel Cell Stack"

(Project **IRAFC**, Advanced Energy Technologies S.A, Greece)

Grant agreement n°: 245202
Start and end dates:01/01/2010 to 31/12/2012
Co-ordinator: Advanced Energy Technologies S.A, Greece, Prof. J. Kallitsis, email at kallitsi@upatras.gr, (tel: 0030 2610 962 952)

Consortium:

Partner	Beneficiary Name	Country	Role
1	Advent Technologies S.A.	Greece	Coordinator
2	University of Maria Curie-Sklodowska	Poland	Participant
3	Nedstack Fuel Cell Technology BV	The Netherlands	Participant
4	Centre National de la Recherche Scientifique	France	Participant
5	Foundation for Research and Technology HELLAS, Institute of Chemical Engineering and High Temperature Processes	Greece	Participant
6	Institut für Mikrotechnik Mainz GmbH	Germany	Participant

Title: Development of an Internal Alcohol Reforming High Temperature PEM Fuel Cell Stack **IRAFC**

Objectives: The main goal of this project is the efficient combination of a low temperature methanol reformer operating at 200-220°C, with a high temperature polymer electrolyte fuel cell, also operating at 200-220°C, in a single compact structure.

Description of work: In order to realize this goal, certain improvements of the existing materials are required.
Polymer electrolytes/membranes
New type cross-linked membranes based on aromatic polyethers bearing main and/or side chain pyridine groups and side chain cross-linkable functionalities were developed. Among the different methodologies used for cross-linking the one based on the introduction of side double bonds and the consequent thermal or chemical reaction, was proven more efficient. The doped cross-linked membranes were used for MEA preparation and single cell testing at temperatures up to 230°C. The results are promising since high ionic conductivities, well above 10^{-1} S/cm in some cases, and performances as high as 0,7 V at 0,2 A/cm^2 for hydrogen-air feed gases were obtained. The operating stability of these materials at temperatures above 200°C was examined and a stable performance for about 550 h at 210^{o}C was demonstrated.
Catalysts
Among the different catalyst used for methanol reforming, the ones based on Copper manganese and on Palladium were chosen for optimization in respect to their use as low temperature methanol reforming catalysts.
Copper manganese catalysts:Doped copper manganese (CuMnOx) catalysts were prepared via the urea-nitrates combustion method by adding the corresponding metal nitrate salt as dopants. Addition of small amounts of third metal leads to a significant enhancement of specific surface area and reducibility.
Palladium-zinc oxide-supported catalysts: The activity and selectivity of palladium-zinc oxide-supported catalysts are fairly stable. That kind of catalysts are resistant to shuts down and exposes to air. They enable to achieve very high H_2 and CO_2 as well as low CO (lower than 2 %) selectivity at 200^{o}C.

Expected results: The proposed compact system allows for efficient heat management, since the "waste" heat produced by the fuel cell is in-situ utilized to drive the endothermic reforming reaction. The targeted power density of the system is 0.15 W/cm^2 at a cell voltage of 0.7V.
Indeed the successful completion of the project will provide new aspects on the possibility to combine reformer with fuels cells open thus the way for new applications.

Advances in FCH Energy RTD

(Project **LOLIPEM**, National Research Council - Institute on Membrane Technology, Italy)

Grant agreement n°: 245339
Start and end dates: 01/01/2010 – 31/12/2012 (www.LoLiPEM.eu)
Co-ordinator: National Research Council - Institute on Membrane Technology, Dr. Giuseppe BARBIERI Via Pietro BUCCI cubo 17C c/o University of Calabria, Rende CS, Phone +39 0984 492029 Fax +39 0984 402103 g.barbieri@itm.cnr.it

Consortium:

Partner	Beneficiary Name	Country
1	National Research Council - Institute on Membrane Technology, www.itm.cnr.it	Italy
2	University of Rome "Tor Vergata", www.uniroma2.it	Italy
3	University of Provence, www.univ-provence.fr	France
4	University of Saarlander, www.uni-saarland.de	Germany
5	Edison SpA, www.edison.it	Italy
6	Fumatech GmbH, www.fumatech.de	Germany
7	MATGAS 2000 A.I.E., www.matgas.com	Spain
8	Politechnika Krakowska, www.transfer.edu.pl	Poland

Title: **LOLIPEM**

Objectives: The key objective of the LoLiPEM project is to give a clear demonstration that long-life SPG&CHP systems based on PEMFCHs operating at temperatures higher than 100°C can now be developed on the basis of recent knowledge on the degradation mechanisms of membranes disclosed by some LoLiPEM partners.

Description of the work: Stable perfluoro sulfonic acid (PFSA) and new stable non-perfluorinated ionomers, such as sulfonated aromatic polymers (SAPs), are the materials mostly used in this project for the membranes development for the MEAs preparation. These innovative MEAs will be developed for operating above 100°C. A PEMFCH operating in the temperature range of 100-130°C is highly desirable and could be decisive for the development of SPG&CHP systems based on PEMFCHs. LoLiPEM aims to operate in this temperature range exceeding the state-of-the-art (70-80°C). The lower temperature is the main drawback for PEMFCH development. Several advantages including easier warm water distribution in buildings, reduced anode poisoning due to carbon monoxide impurities in the fuel, improved fuel oxidation kinetics, etc. would be gained by operating above 100°C.

Results New protocols for the evaluation of mass transport properties of membranes and MEA as well as for the testing of MEA in fuel cell have been elaborated and successfully applied.
Novel PFSA and SAP membranes able to withstand temperatures higher than 100°C have been prepared and successfully tested. Innovative electrodes have been prepared with a new electrodeposition process which allows all the electrocatalyst nanoparticles to be in contact with both the ionically conducting ionomer and the electronically conducting electrode materials. MEAs have been prepared and tested at operating temperatures above 100°C.

Expected results
The expected results are:

- The preparation of PFSA and SAPs membranes stable at a temperature higher than 100°C
- Development of new long-life catalytic electrodes and MEAs operating in the above temperature range
- Accelerated ageing tests and long-term single cell tests
- Development of a prototype of a modular SPG&CHP system based on multi-PEMFCHs also utilizing the new long-life MEAs.
- Benchmarking the single-cell and the modular prototype performance at temperatures above 100°C against the best literature results

PEM with Innovative low cost Core for Automotive applicatioN

(Project **PEMICAN**, CEA – Liten, France)

Grant agreement n°: FCH JU 256798
Start and end dates: 01/04/2011 – 31/03/2014
Co-ordinator: French Alternative Energies and Atomic Energy Commission. Joël Pauchet, CEA/LITEN, 17 rue des Martyrs, 38054 Grenoble Cedex 9, France; tel: 33 (0)4 38 78 52 96 - Fax: 33 (0)4 38 78 94 63, joel.pauchet@cea.fr; www.liten.fr

Consortium:

Partner	Beneficiary Name	Country	Role
1	French Alternative Energies and Atomic - Energy Commission	France	Coordination, MEA developments, modelling, characterization, tests
2	Adam Opel AG	Germany	Specifications, modelling
3	Solvay Specialty Polymers	Italy	Development of Aquivion ionomer, tests
4	Tecnalia	Spain	Active layers by PVD, tests
5	Timcal	Switzerland	Development of Carbon Blacks
6	Imperial College	United Kingdom	Fundamental electrochemistry, characterization

Title: PEM with Innovative low cost Core for Automotive application **PEMICAN**

Objectives:
Up to now, a lot of work has been performed on the catalyst of the active layers (AL) of PEMFC but much less on the structure of the AL and on the two other major components (carbon and electrolyte) whereas they do have a major impact on the performance of PEMFC and on Pt utilization.
Based on this analysis, PEMICAN proposes to reduce the Pt cost for automotive application down to 0.15 gram of Pt per kW, by a twofold approach: i) to increase Pt utilization and power density by improving effective transport properties of AL by tuning some properties of the electrolyte and by adding special carbon blacks in order to improve catalyst, electrolyte distribution and water management; ii) to reduce Pt loading by controlling its distribution: very thin layer on the anode side and gradients of Pt on the cathode side. These structured layers will be defined in order to optimise the utilization of the Pt. The combination of these two approaches will allow reducing the total mass of Pt for a given power density.
Whereas the main objective of PEMICAN is to develop and manufacture MEA (membrane Electrode Assembly) with reduced Pt cost, it is supported by scientific approach: i) numerical modelling will help defining the best Pt distribution; ii) special structural and electrochemical characterizations will be done to improve the existing models and to analyse the performance of MEA as a function of manufacturing processes and properties of components. Performance and durability tests under automotive conditions will be performed and analysed.

Expected results:
- Improved raw materials to increase performance (kW/cm²)
  - Ionomer: increase proton conductivity, water handling and gas diffusion
  - Carbon black: improve water management (add Carbon in the ink for cathode) and reduce Pt size (MPL for anode)
- New active layers with reduced Pt quantity and good performance
  - Thin anodes (Direct Electro Deposition, Particle Vapor deposition…)
  - Structured cathodes with gradients of catalyst, C and ionomer (ink jet, screen printing…)
- Improved knowledge of active layers transport properties: H+ conductivity, gas diffusion, structure, electrochemical behaviour
- Improved modeling to better link local properties to performance ; H+ and gas transfers, electrochemistry, experimental validation

Further research needs

- PEMICAN shall demonstrate gains in terms of Pt cost (g Pt/kW) obtained by improving the design and properties of the AL. Its results will be useful also in the future when non pure Pt is available.
- The link between water management, durability (reversible, non-reversible), and design of AL is expected to be slightly more important in the case of low loaded MEA. This shall be analyzed in detail in the future.
- Optimization of MEA shall take into account the coupling between all the layers (AL, MPL and GDL). This shall also be investigated in the future.

Nanostructured electrolyte Membranes based on polymer-ionic liquids-zeolite composites for high temperature PEM fuel cell

(Project **ZEOCELL,** Institute of Nanoscience of Aragon – Spain)

Grant agreement n°: 209481
Start and end dates: 01/01/2008 to 31/12/2010
Co-ordinator: Institute of Nanoscience of Aragon, University of Zaragoza Dr. Jesús Santamaría (jesus.santamaria@unizar.es); Dr. María Pilar Pina (mapina@unizar.es),. Mariano Esquillor s/n. 50018. Zaragoza (SPAIN).

Consortium:

Partner	Beneficiary Name	Country	Role
1	Institute of Nanoscience of Aragon (University of Zaragoza) http://www.unizar.es/ina	Spain	Zeolite Membranes and Nanostructured Materials
2	Centro de Tecnologías Electroquímicas http://www.cidetec.es	Spain	Electrochemical Technologies and Materials for Electrochemical Applications
3	University of Twente; http://www.utwente.nl	The Netherlands	Polymeric Membranes
4	Foundation for Research and Technology Hellas / Institute of Chemical Engineering and High Temperature Process; http://www.iceht.forth.gr	Greece	Nanocomposite Materials and Modelling
5	Centro Ricerche FIAT; http://www.crf.it	Italy	Industry (Microfabrication of Ordered Polymeric Membranes)
6	Solvionic, S. A. http://en.solvionic.com/	France	Industry (Ionic Liquids Development)
7	Celaya Emperanza y Galdós, S. A; http://www.cegasa.com	Spain	Industry (Scaling and Mass Manufacturing)

Title: Nanostructured electrolyte Membranes based on polymer-ionic liquids-zeolite composites for high temperature PEM fuel cell **ZEOCELL**

Objectives: ZEOCELL puts forward an innovative concept to overcome the current limitations of commercial available PEMFCs based on the use of multifunctional nanostructured materials, capable to withstand temperatures in the range 130º-200º C with the following properties:
High ionic conductivity: higher or equal than 100 mS/cm at 150ºC.
Suitability for operating at temperatures between 130-200ºC (the membrane materials are expected to be thermally stable up to 200ºC. Membrane performance will be validated on single cells at temperatures of at least 150ºC).
Good chemical, mechanical and thermal stability up to 200ºC.
Durable (<1% of performance degradation during the first 1000 working hours).
Low fuel cross-over (<five times lower than Nafion methanol permeability lower or equal than $3x10^{-7}$ cm^2 s^{-1}).
Reduced manufacturing costs (< 400 EUR/m^2).

Description of the work: ZEOCELL puts forward an innovative concept to overcome the current limitations of commercial available PEMFCs based on the use of multifunctional nanostructured materials, capable to withstand temperatures in the range 130º-200º C. Starting from the well-known PBI polymer, Zeocell pushes the "state of the art" with the development of nanostructured electrolyte membranes based on the synergic combination of porous PBI, protic ionic liquids and microporous inorganic nanocrystals. The final aim is to use the advantages of each primary building block by choosing a proper electrolyte membrane configuration. Seven electrolyte membrane compositions have been studied. As the polymer membrane architecture plays the key role to ensure proton transport through heterogeneous media, dense and porous (random or straight pores) PBI films

have been deployed as proton conductor supports. Phosphoric acid doping and/or protic ionic liquid embedding have been mainly studied in the project. The incorporation of microporous materials either as inorganic fillers to the membrane casting solution or as thin film coatings onto pre-existing porous PBI membranes has been considered. To gain insight the synergic effects provided by materials combination, different membrane categories, ranging from 1 component (i.e. Pure Polymeric Ionic Liquid Films), through binary (supported ionic liquid membranes in track-etched porous PBI substrates, supported ionic liquid membranes in randomly porous PBI substrates, reinforced polymeric ionic liquid membranes on porous PBI supports, acid doped track-etched porous PBI substrates), ternary composites (hybrid acid doped dense or porous PBI and hybrid dense or porous PBI embedding ionic liquid) to the final nanostructured electrolyte membranes based on four components (i.e. PBI, phosphoric acid, ionic liquid and microporous materials) have been deeply studied.

Achieved results: The best conduction performance of 1 component-membranes is exhibited by polymeric ionic liquid films prepared from ImSF0108b (350 mS/cm at 200ºC after 1000 h working). For 2 components-membranes, it is clearly outstanding the conduction behaviour of poly[ImSF0108b] on randomly porous PBI supports (275 mS/cm at 200ºC after 1,000 h working).Thus, both membrane categories effectively accomplish with the durability and conductivity targets. Concerning 3 components-membranes, Hybrid Randomly Porous Doped PBI 75% in porosity including a 3% wt. of NaY-Im008b as inorganic filler shows 223 mS/cm at 150ºC as in-plane conductivity. The 4-components nanostructured electrolyte membrane based on phosphoric acid doped porous PBI embedding Im008b as proton conductor with ETS-10 titanosilicate type coatings as top layers allows to attain 100 mS/cm at 150ºC. In addition to conduction requirements which have been successfully addressed, the hybrid doped PBI membranes and the nanostructured electrolyte membranes stand up as the most adequate in terms of methanol and hydrogen cross-over respectively. Overall, the most promising electrolyte membranes are those based on polymeric ionic liquids although further efforts to reduce fuel cross-over at temperatures above 120ºC are required. The cost assessment results clearly indicate that the aforementioned membranes would be competitive in the high temperature PEMFC stationary applications market.

Further research needs: The main ST outcome from ZEOCELL is the development of three novel electrolyte membranes fulfilling all the ST requirements originally claimed for high temperature PEM fuel cells in stationary applications with the exception of durability issues which are briefly described below:

1) Hybrid randomly porous PBI membranes doped with phosphoric acid (PCT/EP2010/064857; priority date 05/10/2010). The endurance properties of this family are under investigation.
2) Nanostructured Electrolyte Membranes based on randomly porous acid doped PBI membranes with tortuous pores filled up with protic ionic liquid and two microporous ETS10 coatings on top surfaces. The endurance properties a 150º and 200ºC reveals severe performance decay after 150 h operation in presence of 5% H_2O
3) Reinfonced Polymeric Ionic Liquid Membranes on Porous PBI supports (also being considered for intellectual protection). A continuous stepwise loss in performance is observed during the first 500 h at 200ºC, but thereafter conductivity values remain constant at around 275 mS/cm.

In addition further research efforts are required on:

1) Porous PBI membranes as protic ionic liquid containers. The exhibited conduction performance of Supported Protic Ionic Liquid Membranes is far below the Zeocell requirements, whatever the protic ionic liquid uptake values. Thus, the conduction performance has been somewhat limited due to the availability of adequate PBI porous supports. This fact is in agreement with: i) the prevailing role of free protic ionic liquid molecules on proton transport, ii) the existence of a specific percolation threshold limit that has to be overcome, and, iii) the limited number of percolation pathways available in the porous architectures prepared either by chemical or track etching routes.
2) MEAs preparation based on porous PBI membranes embedding Protic Ionic Liquids or Reinforced Polymeric Ionic Liquids onto porous PBI Membranes.
3) 3-layer integrated MEAs by CCM relying on the catalytic properties of zeolite coatings of the nanostructured electrolyte membranes and FC assembly.

MembrAnEs for STationary application with RObust mechanical properties

(Project **MAESTRO,** CNRS – Montpellier, France)

Grant agreement n°: 256647
Start and end dates: 01/01/2011 to 01/12/2013
Co-ordinator: Deborah Jones, CNRS Montpellier – ICGM-AIME, France - Phone: +33 467 143330; Fax: +33 467 143304

Consortium:

Partner	Beneficiary Name	Country	Role
1	CNRS Montpellier	France	Coordinator, membrane development
2	Solvay-Solexis	Italy	Polymer and membrane development, MEA fabrication
3	Johnson-Matthey Fuel Cells	UK	MEA development, testing
4	Università di Perugia	Italy	Membrane modification
5	Pretexo	France	Project management support

Title: MembrAnEs for STationary application with RObust mechanical properties **MAESTRO**

Objectives: MAESTRO aims to establish methods to increase the mechanical stability of state of the art low equivalent weight perfluorosulfonic acid membranes for stationary application of proton exchange membrane fuel cells (PEMFC) to increase their durability and cell lifetime.

Description of the work: Various materials methods are being explored to improve the mechanical stability of low equivalent weight short side chain type membranes. These include both chemical routes, by modification of the properties inherent to the polymer itself, and physical approaches, whereby the polymer is associated with another component or where the membrane architecture is adjusted. The properties of the membranes are characterised according to agreed protocols, in particular for their proton conductivity under relevant conditions, and for their tensile strength, as well as for their water uptake properties and dimensional stability. The membranes are then incorporated into MEAs and characterised under agreed sets of conditions of temperature and anode/cathode relative humidity, and by application of stress tests specifically targeting evaluation of their chemical and mechanical stability.

Expected results: The final project target for the membrane is to have increased the tensile strength (compared with the benchmark material at the project beginning) by 50%, with a milestone at the mid-term stage of improvement by 20-25%. In terms of the MEA integrating the mechanically stabilised membranes, the target is for 4000 hours of operation under conditions relevant to stationary application, with performance degradation less than 10% compared to beginning of life.
Key technical items delivered in year 1 of the project include: Protocols for characterisation of membranes and MEAs including accelerated stress testing and long-term operation; Elaboration of benchmark MEAs and their characterisation according to these protocols; Development of membranes having elastic modulus increased by 78% compared with that of the project benchmark, while retaining conductivity of ca. 0.01 S cm^{-1} at 25 % relative humidity and 0.2 S cm^{-1} at 90 % relative humidity; co-authored review article on the state of the art on approaches to membrane mechanical stabilisation.

Further research needs: The use of thinner membranes significantly reduces area resistance as well as material cost and improves water management in the cell through facilitated back-diffusion. Low equivalent weight membrane materials are required for the high proton conductivity they provide. Together these requirements present a significant challenge that fully justifies the further development of research to improve the mechanical stability membranes of low equivalent weight state of the art polymers.

Quasi-anhydrous and dry membranes for next generation fuel cells

(Project **QUASIDRY,** CNRS – Montpellier, France)

Grant agreement n°: 256821
Start and end dates: 01/12/2010 to 01/01/2013
Co-ordinator: Deborah Jones, CNRS Montpellier – ICGM-AIME, France - Phone: +33 467 143330 ; Fax: +33 467 143304

Consortium:

Partner	Beneficiary Name	Country	Role
1	CNRS Montpellier	France	Coordinator, membrane development, support materials
2	University of Lund	Sweden	Polymer synthesis, membrane preparation and characterisation
3	Max-Planck Institut für Polymerforschung	Germany	Synthesis and characterisation of high temperature proton conductors
4	Consiglio Nazionale delle Ricerche – Institute for Advanced Energy Technologies	Italy	Support materials, non-Pt catalysts, MEA preparation and characterisation
5	Johnson-Matthey Fuel Cells Ltd	UK	Electrode and MEA development, testing
6	Funktionelle Membranen und Anlagentechnologie GmbH	Germany	Polymer and membrane preparation and scale-up
7	Pretexo	France	Project management; dissemination

Title: Quasi-anhydrous and dry membranes for next generation fuel cells **QuasiDry**

Objectives: The objective of QuasiDry is to develop the fuel cell electrolyte membranes of the next generation of fuel cells. The increase of proton conductivity with temperature, including at low RH, will allow continuous increase in fuel cell performance with temperature, rather than the drop in performance for all sulfonic acid functionalised membranes above ca. 80-90 °C.

Description of the work: New concepts have evolved in the partner laboratories over the last decade engaging alternative proton carriers that mark a move towards reducing the need for high levels of hydration of the fuel cell membrane. Recent work indicates that phosphonic acid functionalised and phosphoric acid complexed polymers are viable alternatives to sulfonic acids for high temperature operation. The potential of phosphonic acid functionalised polymers as membrane materials having high proton conductivity that demonstrates little variation with temperature and relative humidity is being shown in the QuasiDry project, and validated by integrating them into membrane electrode assemblies.

Expected results: Key technical items delivered in year 1 of the project include: Protocols for characterisation of membranes, novel catalyst supports, electrocatalysts and MEAs including accelerated stress testing; First generations of double functionality (sulfonic and phosphonic acid) membranes, of composite membranes incorporating highly phosphonic acid functionalised organic crystals, of partially fluorinated block copolymers selectively grafted with poly(vinylphosphonic acid), of membranes with high acid doping levels; Inorganic conductive supports showing corrosion currents 2-3 orders of magnitude lower than carbon black; Novel PtXY ternary catalyst formulation that matches baseline stability with 20% activity improvement; Development of electrode structures appropriate for high temperature operation with non-PFSA electrolytes; First MEA data with benchmark and novel membranes.

Further research needs: Integration of the new materials components into an optimised MEA

Hydrogen Storage

NANOHy - Novel Nanocomposites For Hydrogen Storage Applications

Coord: Karlsruhe Institute of Technology, Germany, Dr. Maximilian Fichtner p19

FLYHY - Fluorine substituted High Capacity Hydrides for Hydrogen Storage at Low Working Temperatures
Coord: Helmholtz-Zentrum Geesthacht, Germany, Dr. Klaus Taube p20

HYPOMAP - New materials for hydrogen powered mobile applications
Coord: Jacobs University Bremen, Germany, Prof. Dr. Thomas Heine...p.22

SSH2S - Fuel cell coupled solid state hydrogen storage tank
Coord: *Università di Torino*, Italy, Prof. Marcello BARICCO p.24

ISH2SUP - In situ H2 supply technology for micro fuel cells powering mobile electronics appliances
Coord: Aalto University, Finland, Professor Aarne Halme p.26

Novel Nanocomposites For Hydrogen Storage Applications

(Project **NANOHy,** Karlsruhe Institute of Technology, Germany)

Grant agreement n°: 210092
Start and end dates: 1.1.2008 – 31.12.2011
Co-ordinator: Karlsruhe Institute of Technology (KIT), Dr. Maximilian Fichtner, P.O. Box 3640, D-76021 Karlsruhe, Phone +49 721 608 25340, Fax +49 721 608 26368, m.fichtner@kit.edu

Consortium:

Partner	Beneficiary Name	Country	Role
1	Karlsruhe Institute of Technology, www.kit.edu	Germany	Research materials
2	CNR-ISC Firenze, www.isc.cnr.it/	Italy	Characterisation
3	CNRS Grenoble, www.grenoble.cnrs.fr/	France	Research materials
4	FutureCarbon GmbH, www.future-carbon.de/	Germany	Industry (SME)
5	Institutt for Energiteknikk, www.ife.no	Norway	Characterisation
6	Max-Planck-Institut, www.mpikg.mpg.de	Germany	Research materials
7	NCSR Demokritos, www.demokritos.gr/	Greece	Research materials
8	University of Oslo, www.mn.uio.no/smn/english/	Norway	Theoretical Modelling
9	Korean Institute of Science and Technology, www.kist.re.kr	Korea	Research materials

Title: Novel Nanocomposites For Hydrogen Storage Applications **NANOHy**

Objectives: It was the goal of the project to produce nanocompositic materials for hydrogen storage which have altered properties with respect to working temperature and pressure, an enhanced reversibility, and controlled interaction between the hydride and the environment, leading to improved safety properties.

Description of the work: The composites developed in NANOHy were synthesized out of novel complex hydrides with very high hydrogen content and of nanocarbon templates. Alternatively, hydride colloids were coated in a Layer-by-Layer self-assembling process of dedicated polymers. Computational methods are used to model the systems and predict optimal materials/size combinations for improved working parameters of the systems. Sophisticated instrumental analysis methods were applied to elucidate the structure and the properties of the nano-confined hydrides. In addition, technical aspects were investigated such as the feasibility of an upscale of selected nanocomposite materials and their integration into a laboratory test tank.

Expected results: NANOHy has achieved several scientific breakthroughs and has been an international leading activity in the field. It was shown for the first time that it is possible to infiltrate microporous scaffolds by complex hydrides and to change their properties: Considerable improvement of *kinetics* was noticed but also *thermodynamic* effects were observed for the first time for complex hydrides and for MgH_2.
Property changes were successfully predicted by modeling. It was demonstrated that the reactivity in air can be lowered by nanocoatings.
An upscale production of 500 g nanocomposite was performed for the first time and a laboratory tank filled with hydride/nanocarbon composite was built and tested for the first time.
The work also showed that it was not possible to change the reaction pathway in the hydrogenation/ dehydrogenation so that irreversible bulk hydrides would become reversible.

Further research needs:

- Optimisation of scaffold properties such as the pore volume and the surface reactivity in order to increase the fraction of active material and the reversible amount of hydrogen.
- Transfer of the concept to other systems such as battery materials in order to benefit from enhanced kinetics and stability of nanoconfined systems. First work shows that this is possible and beneficial.

Fluorine substituted High Capacity Hydrides for Hydrogen Storage at Low Working Temperatures

(Project **FLYHY**, Helmholtz-Zentrum Geesthacht, Germany)

Grant agreement n°: 226943
Start and end dates: 01/01/2009 – 31/12/2011
Co-ordinator: Helmholtz-Zentrum Geesthacht, Germany, Dr. Klaus Taube, Max-Planck-Strasse 1, D-21502 Geesthacht, Phone +49 4152 87 25 41, Fax +49 4152 87 2636, klaus.taube@hzg.de

Consortium:

Partner	Beneficiary Name	Country	Role
1	Helmholtz-Zentrum Geesthacht, http://hydrogen.hzg.de	Germany	Research materials
2	Institutt for Energiteknikk, Kjeller, http://www.ife.no	Norway	Research materials
3	Aarhus Universitet, http://www.chem.au.dk/~webuorg/	Denmark	Research materials
4	Università degli Studi di Torino, http://www.nis.unito.it	Italy	Research modelling
5	CONICET Instituto de Investigaciones Fisicoquímicas Teóricas y Aplicadas, La Plata, http://www.inifta.unlp.edu.ar/	Argentina	X-ray based characterisation
6	Tropical S.A., Athens, http://www.tropical.gr	Greece	Industry (SME)

Title: Fluorine substituted High Capacity Hydrides for Hydrogen Storage at Low Working Temperatures **FLYHY**

Objectives: FLYHY focused on tailoring of materials thermodynamics and kinetics by anion substitution in high capacity hydrogen storage materials (alane, borohydrides and Reactive Hydride Composites RHC, >6 wt.%), on employing novel paths of materials synthesis, on obtaining in depth scientific understanding by extended structural and thermodynamic characterisation and modelling, and on scaling-up materials synthesis for testing a prototype solid state hydrogen storage tank. The ambitious targets of materials development were to lower the temperature of reversible operation of high capacity hydrogen storage materials to below 200°C and to tune the thermodynamics of the hydrogenation reaction to values of the envisaged range of 30 – 40 kJ/(mol H_2).

Description of the work: H substitution by more electronegative halogens F, Cl, Br, and I in a functional group or a complex is expected to change the bond strength of the remaining elements and thereby may facilitate release and uptake of hydrogen. FLYHY investigated, whether too stable or too unstable materials could be modified such, that their stability reached the desired state, while retaining high storage capacity.

Expected results: For alane no indications of fluorine substitution were observed, agreeing with our theoretical calculations. Due to a positive mixing enthalpy of AlH_3 and AlF_3, fluorine substitution is rather unlikely. Work on alane was terminated after the first year of the project.
For pure, stable borohydrides like $LiBH_4$, $Mg(BH_4)_2$ and $Ca(BH_4)_2$ new routes of wet chemical synthesis with high yield were developed. They show a high cost advantage compared to the same, commercially available materials. Substitution with the heavier halogens mostly leads to the stabilisation of the hexagonal high temperature polymorph down to lower temperatures. By addition of fluorine their stability could be lowered significantly and hydrogen, but in some cases also other compounds like boranes, were released already below 150°. The hydrogenation was not completely reversible, but significantly enhanced compared to the pure compounds.
In Ca-based RHCs, fluorine addition resulted in a lowered dehydrogenation temperature and significantly increased reaction rates. Cycling of that compound lowered the onset of hydrogen desorption from ca. 300°C down to less than 250°C, but also the storage capacity of ca. 7 wt% decreased to ca. 4wt.% in the first cycle, remaining constant in the following cycles. A value of reactin enthalpy of 49 kJ/(mol H_2) was estimated from DSC measurements. The behaviour could be completely explained by the reaction pathway leading to unwanted side and end products.
Comparison of life cycle and fuelling cost of present hydrogen storage methods showed that solid state hydrogen storage already today is competitive with compressed and liquid storage, provided that raw materials are purchased from large scale industrial suppliers in tonnage quantity and not from fine chemical suppliers in gram amounts. The developed materials synthesis routes and employed storage tank technology are especially suitable for manufacturing by SME's.
No results on tank prototype testing could be obtained during the runtime of FLYHY

Further research needs

- Optimisation of reaction pathways by studying effects of additives and catalysts, pressures and temperatures for avoiding unwanted side- and end products and achieving complete reversibility.
- Effects of less purity of raw materials on hydrogenation properties to decrease materials cost.
- Demonstrating overall energy efficiency of solid state hydrogen storage in selected applications, taking advantage of low operation pressures, high inherent safety, and low tank cost.

New materials for hydrogen powered mobile applications

(Project **HYPOMAP,** Jacobs University Bremen, India)

Grant **agreement n°:** 233482
Start and end dates: 01/06/2009 to 31/05/2012
Co-ordinator: Jacobs University Bremen, Prof. Dr. Thomas Heine, Campus Ring 1, 28759 Bremen, Phone +49 421 200 3223, Fax +49 421 200 49 3223, t.heine@jacobs-university.de, Indian side: Sourav Pal, National Chemical Laboratory Pune, India.

Consortium:

Partner	Beneficiary Name	Country	Role
1	Jacobs University, Bremen	Germany	Research, Coordination
2	Centre National de la Recherche Scientifique (CNRS)	France	Research
3	Universita della Calabria, Rende	Italy	Research
4	Stockholms Universitet	Sweden	Research
5	National Chemistry Laboratory, Pune	India	Research, Coordination
6	Central Leather Research Institute, Chennai	India	Research
7	Indian Institute of Technology, Kharagpur	India	Research
8	Bhabha Atomic Research Centre, Mumbai	India	Research

Title: New materials for hydrogen powered mobile applications **HYPOMAP**

Objectives: HYPOMAP is focused on the hydrogen storage in various materials, such as Metal-Organic Frameworks (MOFs), metal hydrides, carbon-based nanostructures, etc., and on the proton transport for fuel cell technology. Using various computational approaches we are modelling different classes of hydrogen storage materials and the interactions of hydrogen gas molecules with these solid surfaces. Transport of protons is another important subject for development of effective fuel cells. We are investigating new proton-conducting materials for high- and low-temperature fuel cells, based on perovskites and new inorganic nanomaterials, like imogolite derivatives and organic substances. Imidazole and its derivatives are investigated as one-dimensional polymers that can be incorporated into MOFs or inorganic nanotubes for efficient proton transport.

Description of the work: HYPOMAP includes work packages that provide the answers to the principal questions of this project, the suitability of new materials to store hydrogen, including their kinetic loading and unloading properties, and to serve as membranes for fuel cells. These work packages form a logical line, from long-term storage over short-term storage up to the technical usage of hydrogen as fuel. Long-term storage is based on chemisorption of H_2 in metal hydrides, aminoboranes, clathrates and on doped carbon nanotubes. Not only storage capacity is of interest but also the thermodynamic stability and possible mechanisms to improve hydrogen adsorption and desorption. Short-term storage is based on physisorption in nanostructured materials, such as carbon foams or MOFs. This part is important because H_2 is temporarily stored before it can be electrochemically oxidised in fuel cells. Simultaneous physisorption and chemisorption might be achieved in materials, such as MOFs, with large secondary building units, which may result in large storage capacities. Determination of proton conductivity through membranes is the essential step to design new efficient fuel cells operating at low and high temperature.

Expected results: HYPOMAP is close to completion and has already delivered most of the results anticipated in the Description of Work. We have developed and published a series of modelling techniques, including a quantum mechanical method to assess hydrogen adsorption, a DFT functional to describe proton hopping, and a tool to efficiently embed clusters into arrays of polar molecules. From the simulation viewpoint, we can disregard pure carbon-based systems for efficient hydrogen storage. Strong progress has been achieved in creating metal-organic frameworks with linkers exposing charged species (i.e. metals) into the voids. In the proton conduction part, we have understood the mechanism of proton hopping in imidazole and triazole, and proposed polymers with optimized hopping sites.

Further research needs

- New MOFs with polar linker molecules and with metal sites
- Covalent-Organic Frameworks and related materials for H_2 uptake
- MOF-based membranes in 3 strategies: (a) using the MOF as template to generate 1D polymers, (b) using MOF channels to host polymers, and (c) using channels in MOFs to generate 1D liquids to conduct protons
- New catalysts for water splitting and recombination in order to reduce electrode overvoltages

Fuel cell coupled solid state hydrogen storage stank

(Project **SSH2S**, NIS Centre of Excellence, Dipartimento di Chimica, Università di Torino, Italy)

Grant agreement n°: 256653
Start date: 01/02/2011 to 01/08/2014
Co-ordinator: Prof. Marcello BARICCO, NIS Centre of Excellence, Dipartimento di Chimica, Università di Torino, Via P.Giuria, 9, I-10125 TORINO (Italy), Tel. + 39 011 670 7569, Fax. + 39 011 670 7855, marcello.baricco@unito.it

Consortium:

Partner	Beneficiary Name	Country	Role
1	UNITO - Università di Torino	Italy	Coordination. Materials characterisation. Theoretical modelling.
2	IFE - Institute for Energy Technology	Norway	Materials synthesis and characterisation.
3	KIT - Karlsruhe Institute of Technology	Germany	Materials synthesis and characterisation.
4	DLR - Deutsches Zentrum für Luft- und Raumfahrt e.V.	Germany	Tank simulation and validation.
5	TD - Tecnodelta s.r.l.	Italy	Tank design and building.
6	SER - Serenergy A/S	Denmark	Tank-Fuel Cell integration.
7	CRF - Centro Ricerche Fiat	Italy	End user.
8	JRC - Joint Research Centre of European Commission	Belgium	Materials characterisation. Safety.

Title: **Fuel cell coupled solid state hydrogen storage tank SSH2S**

Objectives: The main objective of SSH2S is to develop a solid state hydrogen storage tank fully integrated with a fuel cell and to demonstrate its application on a real system. A well assessed hydrogen storage material (i.e. mixed LiNH2-MgH2 system) will be considered as active material for the tank. A new class of material for hydrogen storage (i.e. mixed borohydrides) will be also explored. The application of the hydrogen tank on real system will be experimentally investigated with a 1 kW prototype on High Temperature Polymer Electrolyte Membrane Fuel Cells (HTPEMFC). If suitable performances will be obtained, a scale-up of the tank will be applied to a 5 kW Auxiliary Power Unit (APU) to be installed in a Light Transport Vehicle (LTV).

Description of the work: The design and the synthesis, as well as the physico-chemical characterization, of existing and novel materials for solid state hydrogen storage will be carried out. Ab-initio and thermodynamic calculations will drive the selection of materials. Synthesis of material will be performed by ball milling. The characterisation will be performed by a combination of structural and spectroscopic experimental techniques. The fluido-dynamic modelling of different tank concepts, as well as the experimental validation of the models in a lab-scale tank, will be carried out. A prototype tank, optimized for selected materials, will be used for the integration with a 1 kW HTPEMFC. The final step will be the application of the integrated system as 5 kW APU to be installed in a LTV.

Expected results, industrial applications and potential commercialisation: The development of a material for solid state hydrogen tank with capacities up to 4.5 H2 wt%, fully reversible at 180 °C and with high stability on cycling is expected. In addition, new concepts on design and the coupling of solid state hydrogen tank with HT-PEM fuel cells will represent a significant achievement of the project. Finally, the development of a prototype 1 kW integrated system, and the possible application to a 5 kW APU, are a real novelty in the field. The results of the project can be of significant economical impact for large industries, as well as for SMEs industrial partners. The possibility to couple the HTPEM with a compact and safe hydrogen storage system will greatly enlarge the business opportunities of industrial partners. The availability of safe hydrogen tanks at low pressures is expected to contribute to the social acceptance of hydrogen technologies.

Further research needs
System specifications of the integrated system will be updated.
Experimental and theoretical characterization of selected materials will continue.
New concepts and simulation of a laboratory scale tank will be developed.
Design of prototype tank will be defined.

In situ H2 supply technology for micro fuel cells powering mobile electronics appliances

(Project **ISH2SUP,** Aalto University, Finland)

Grant agreement n°: 245294
Start and end dates: 01/01/2010 to 31/12/2012
Co-ordinator: Aarne Halme, professor, Aalto University, Tel: +358 50 5553390, aarne.halme@aalto.fi
Project website: http://autsys.tkk.fi/en/ISH2

Consortium:

Partner	Beneficiary Name	Country	Role
1	Aalto University	Finland	Co-ordinator
2	CEA	France	Participant
3	myFC	Sweden	Participant
4	Hydrocell	Finland	Participant

Title: In situ H2 supply technology for micro fuel cells powering mobile electronics appliances **ISH2SUP** http://autsys.tkk.fi/en/ISH2

Objectives: The key objective of the project is to develop a fuelling system for micro-fuel cells. The concept is based on in-situ production of hydrogen. Two novel solutions are proposed: one is based on using NaBH4 as the fuel and the other one on utilizing catalyzed electrolysis of methanol. The primary application area is fuel cell based power sources of mobile and portable electronic appliances . The ISH2 project concentrates on research and development of the hydrogen cartridge technology and the electrical system. Development of micro-fuel cells is excluded, validation of the fuelling system will be performed with commercially available small fuel cells. The main practical targets are to prove the feasibility of each fuelling technology and to fulfill the RCS requirements of mobile/portable electronic appliances in consumer markets**,** and to scheme a logistics system for disposable or recyclable cartridges used for fuelling the proposed system.

Description of the work: The targeted power range is 5 – 20 W. Within this range there are many electronic appliances for mobile use, like phones, laptops, cameras, etc, which suffer short operation time caused by easily draining batteries. We like to develop fuel cartridges for the chargers or use-extenders of those devices. Challenges are related in addition to safety issues, to technical design making the cartridges usable for common people and finally to environmental issues making them recyclable or disposable. Borohydrid (NaBH4)-technology to make hydrogen producing cartridges is already well known, but needs still studying and development to make it functioning well in small scale and for a long use period. Catalyst based electrolysis of methanol is a new method, which needs more basic studies. In the project we have studied use of two catalysts, platinum and an enzyme. At present state of the project the platinum catalyst has been chosen for further development because of problems to obtain a high enough energy efficiency in hydrogen production when the enzyme catalyst is used.

Expected results: The technical approach adopted by the project is to develop the two cartridge technologies in parallel and test them in two application devices during the last project year. The test devices chosen are a smart mobile phone and a laptop computer. Both these devices are standard commercial appliances for which the project will build a specific hydrogen driven non-grid charger or use-extender. The key targets in the development phase are:

- Prototype of 20 Wh $NaBH_4$-cartridge for a mobile phone charger.
- Prototype of 120 Wh $NaBH_4$ container for a fuel cells power pack.
- Electrolyser cartridge-fuel cell system prototype for a non-grid long term power source for 10 W devices.
- Electrolyser-PEM fuel cell system prototype with a better methanol/electricity conversion (Wh/ml) than commercial DMFCs.
- Control electronics for the both fuelling concepts

The prototypes are expected to open up possibilities for further product development.

Further research needs: Both of the concepts of in-situ production of hydrogen are not limited to the small power range. Preliminary investigation to enlarge the area to 100 W – 1kW will be done during the project. This will open applications e.g. to portable tools, small backboard motors etc.
As a future perspective, electrolysis by the aid of enzyme opens up interesting possibility to produce hydrogen from different kind of bio-decomposable wastes including alcohols or sugars. The energy level around 3 W/l H_2 can be reached, which is considerably lower than that of water electrolysis.

PEMFC (Degradation studies)

Keepemalive - Knowledge to Enhance the Endurance of PM fuel cells by Accelerated Lifetime Verification Experiments
Coord: SINTEF, Norway, Dr. Steffen Møller-Holst p.31

Demmea - Understanding the Degradation Mechanisms of Membrane-Electrode-Assembly for High Temperature PEMFCs and Optimization of the Individual Components
Coord: Advanced Energy Technologies, Greece,
Dr. Stylianos Neophytides p.32

FCGEN: Fuel Cell Based On-board Power Generation
Coord: Jazaer Dawody, Volvo Technology AB, Sweden p.34

Decode - Understanding of degradation mechanisms to improve components and design
Coord: Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany,
Prof. K. Andreas Friedrich p.36

Premium Act - PREdictive Modelling for Innovative Unit Management and ACcelerated Testing procedures of PEFC
Coord: CEA/LITEN, France, Sylvie ESCRIBANO p.37

Knowledge to Enhance the Endurance of PM fuel cells by Accelerated Lifetime Verification Experiments

(Project **KEEPEMALIVE,** SINTEF, Norway)

Grant agreement n°: 245113
Start date: 01/01/2010 to 30/06/2013
Co-ordinator: SINTEF, Norway, Dr. Steffen Møller-Holst, tel: +4792604534, Steffen.Moller-Holst@sintef.no

Consortium:

Partner	Beneficiary name	Country	Role
1	Stiftelsen SINTEF	Norway	Coordination. Single cell testing, *ex-situ* materials characterization, modelling and statistical analysis.
2	IRD Fuel Cells A/S	Denmark	Fabrication of single cells and stacks, testing of single cells and stacks. Real-life operation data. Link to µCHP demonstration project.
3	Stichting Energieonderzoek Centrum Nederland	Nederlands	Testing of single cells and stacks, *ex-situ* materials characterization. Initial coordination until their withdrawal.
4	Centre National de la Recherche Scientifique, Institut Charles Gerhardt	France	*Ex-situ* materials characterization, single cell testing, materials development.
5	FuMA-Tech GmbH	Germany	Materials development and characterization, single cell testing
6	EIfER – European Institute for Energy Research	Germany	Testing of single cells and stacks. Link to µCHP demonstration project.
7	Technische Universität Graz	Austria	Testing of single cells.
8	SEAS-NVE	Denmark	System integration requirements. Link to µCHP demonstration project.
9	European Commission Joint Research Centre, Institute for Energy	Belgium	Testing of single cells and stacks, modelling.

Title: Knowledge to Enhance the Endurance of PM fuel cells by Accelerated Lifetime Verification Experiments **KEEPEMALIVE**

Objectives: KeePEMalive aims at establishing improved understanding of degradation and failure mechanisms, by developing and approving accelerated stress test protocols, a sensitivity matrix and a lifetime prediction model for Low Temperature Proton Exchange Membrane Fuel Cells (LT PEMFC), targeting a lifetime of 40 000 h at realistic operating conditions for stationary systems.

Description of the work: The working methodology of the KeePEMalive project is to integrate materials development and characterization, testing of PEM FC single cells and stacks, as well as modelling in an iterative manner. Improving the quality of membranes is part of the project, whereas other components are purchased from commercial suppliers. Experimental design and statistical analysis are used to optimize the information from experiments, and allows for quantification of the effects of the various operating parameters.

Expected results: For the KeePEMalive project, laboratory tests of single PEM fuel cells and stacks, results from *ex-situ* materials characterization, as well as real-life operation data from demonstration projects forms, together the basis for improving materials and development of accelerated stress test protocols as well as a lifetime prediction model. The increased understanding of degradation mechanisms achieved in the KeePEMalive-project will eventually contribute to development of mitigation strategies.

Further research needs: The KeePEMalive project will provide a first generation set of accelerated stress test protocols for stationary PEMFC, as well as a life-time prediction model. It is anticipated that further revisions of these are required, as materials are improved and mitigation strategies are implemented.

Understanding the Degradation Mechanisms of Membrane-Electrode-Assembly for High Temperature PEMFCs and Optimization of the Individual Components

(Project **DEMMEA,** Advanced Energy Technologies, Greece)

Grant agreement n°: 245156
Start and end dates: 01 January 2010 to 31 December 2012
Co-ordinator: Advanced Energy Technologies, Stadiou Str., Platani, GR-26504, Greece, Contact: Dr. Stylianos Neophytides, tel: +302610965265, e-mail: neoph@iceht.forth.gr

Consortium:

Partner	Beneficiary Name	Country	Role
1	Advanced Energy Technologies	Greece	
2	Foundation for Research and Technology Hellas-Institute of Chemical Engineering & High Temperature Chemical Processes	Greece	
3	Paul Scherrer Institute	Switzerland	
4	Centre National de la Recherche Scientifique	France	
5	FUMATECH GmbH	Germany	
6	Institute of Chemical Technology Prague	Czech Republic	
7	Next Energy - EWE-Forschungszentrum fur Energietechnologie e.V.	Germany	
8	Technical University of Darmstadt	Germany	

Title: Understanding the Degradation Mechanisms of Membrane-Electrode-Assembly for High Temperature PEMFCs and Optimization of the Individual Components **DEMMEA**

Objectives: The objective of the present proposal is to understand the functional operation and degradation phenomena of a high temperature H_3PO_4 imbibed PEM and its electrochemical interface. The fundamental understanding of the failure mechanisms can be used to guide the development of system approaches to mitigate these failures and will permit the tailormade optimization of the MEA through the proposal of new materials (PEMs and catalysts).

Description of the work: For the achievements of the project's goals, ex-situ and in-situ testing methodologies are applied for the examination of the polymer electrolytes, the catalytic layers and the MEAs. Innovative characterization methods have been developed and employed like in-situ spectroscopy and locally resolved electrochemical measurements. The most challenging areas towards the optimization of the HT PEMFC technology are: (i) the development of stable long lasting polymer structures with high ionic conductivity and minimal cost and (ii) the design and development of Pt based catalytic layers with novel structures and architectures aiming to very high metal electrocatalyst utilization leading to reduced Pt loadings and more active and stable electrochemical interfaces with minimal Pt corrosion. In this respect a series of polybenzimidazole derivatives and pyridine based aromatic polyether structures have been prepared and studied as H_3PO_4 imbibed polymer electrolytes. Moreover, Pt based electrocatalysts have been prepared using new modified carbon supports and characterized as to their physicochemical properties and electrochemical performance.

Expected results: Certain failure mechanisms of the current technology HT MEAs have been identified. Novel polymer electrolytes have been prepared providing stable membranes able to operate at elevated temperature. The novel electrocatalytic systems with new architectures prepared so far seem to overcome certain limitations of current state of the art formulations towards the improvement of performance and stability of the HT MEAs. A mathematical model on Pt degradation has been developed. The expected outcome at the end of the project is a commercially reliable product for stack manufacturers.

Further research needs: Targeted on-going in-situ spectroscopic and electrochemical measurements, which will give a deeper insight into the degradation phenomena (mainly focusing on the degradation of the anode side of the MEA) and will lead the development of prediction tools for the MEA performance. The innovative materials produced within the framework of this project need to be further characterized in order to extract clear evidence of the improvements on performance and durability which need to be quantified. Experimental validation of the mathematical model on catalyst degradation.

Fuel Cell Based On-board Power Generation

(Project **FCGEN**, Group Truck Technology, Advanced Technology & Research, Germany)

Grant agreement n°:
Start and end dates: 01/11/2011 to 31/10/2014
Co-ordinator: Group Truck Technology, Advanced Technology & Research, Jazaer Dawody, Sven Hultins Gata 9D - SE 412 88 Gothenburg Jazaer.dawody@volvo.com

Consortium:

Partner	Beneficiary Name	Country	Role
1	Volvo Technology AB	Volvo	Sweden
2	Powercell Sweden AB	Powercell	Sweden
3	Forschungszentrum Juelich GMBH	Juelich	Germany
4	Institut Jozef Stefan	JSI	Slovenia
5	Centro Ricerche Fiat SCPA	CRF	Italy
6	Institut fuer Mikrotechnik Mainz GMBH	IMM	Germany
7	Johnson Matthey PLC.	JM	UK
8	Modelon AB	Modelon	Sweden

Title: Fuel Cell Based On-board Power Generation **FCGEN**
https://teamplace.volvo.com/sites/vtec-FCGEN/default.aspx

Objectives: The overall objectives of FCGEN are to develop and demonstrate a proof-of-concept complete fuel cell auxiliary unit in a real application, on-board a truck. The project will further develop the key components and subsystem technologies that have been advanced by the project partners in previous collaborations and move them closer towards commercially viable solutions, see Table 1 for specific and concrete targets. Particular issues, such as catalyst cost, fuel vaporisation and desulphurisation, packaging of components, robustness etc. will be addressed through targeted R&D.
Table 1: Concrete targets for the Auxiliary Power Unit.

Issues	3-5 kW Diesel APU
Durability (hours)	20000[1]
Cost (Euro/kW)	≤ 1000
Efficiency	≈ 30%
Weight (kg)	125
Volume (L)	300

The targets for FCGEN also include significant reductions in fuel consumption:

- 80% reduction compared to conventional idling (>4 litres/hour)
- 40% reduction compared to diesel based APU

The main identified challenges that are addressed in the FCGEN project are: Cost, size and weight, operational conditions, reforming of logistical fuels, component and system durability and efficiency.
Fuel processor components needs cost, durability, weight, volume, efficiency optimization.
For the Balance of Plant (BoP) components major development work is needed as many of these components are more or less on-shelf products that are not compatible with the chemical environment in the system and likely not able to withstand the truck environment regarding temperature; vibrations chock etc.. For the complete APU system efficiency and compactness are two challenging targets. The system shall be placed in real truck vehicle and deliver the required power for the hotel cabinet as specified by the OEM, and according to the usage cycle, with minimum interface to the main truck. This demands a compact, robust, manufacturable and cost effective APU system to meet the market targets.

The work within the project contains different phases with predefined milestones and deliverable in order to reach the system targets for high efficiency, very low emissions of harmful gases, long durability and reduced system cost and size. A major part of the work is devoted to the development of the fuel processor system parts. As the fuel processor contains several precious metal based catalyst, the project will issue system cost reduction by reducing the precious metal loading without scarifying the catalyst performance. System size reduction is achieved by replacing several conventional reactors and heat exchangers with two coated micro channel heat

exchanger as well as by system packaging optimization. Another important milestone and deliverable is to work together with supplier to develop or optimize on shelf balance of plant components that are adapted to FC-based APU systems. Most system components need to be controlled and for that purpose, the project will demonstrate the functionality of all control hardware modules, develop software modules and demonstrate the functionality of the complete control system under real conditions. As the system is going to be integrated and tested on –board a vehicle, the work will include safety and vehicle interface specifications deliverables. At the end of the work period, the project will report on cost reduction analysis and manufacturing approach of fuel processor and report on energetic, environmental, economical benefit achievable through FCGEN APU introduction on Mass market.

Expected results: The project started on November 1st 2011. The target of this project is to develop a high efficiency and very low emissions fuel cell based electric power generator and integrate it on-board a truck and demonstrate power generation and utilization from this system. The need of electric power when the vehicle stands still has led to an increasing need for an on-board electric power generator. A fuel cell based APU, with a diesel fuel processor is regarded as one of the most interesting options since it combine high efficiency low emission and the use of the same fuel as the main engine. The on-board generator or Auxiliary Power Unit, APU, should be able to run when the main engine is shut off. The emission from long haulage trucks in the USA has been estimated to about 180 000 tons NO_x, 5000 tons PM and 11 million ton CO_2 per year. By developing a fuel cell based APU for truck application in Europe, we can compete with the strong on-going initiatives in US supported by Department of Energy, and contribute to:

- Decarbonisation of transport
- Ensuring mobility: reliable, safe and secure transport
- Global competitiveness - growth & jobs

Understanding of degradation mechanisms to improve components and design

(Project **DECODE**, Deutsches Zentrum für Luft- und Raumfahrt e.V. Germany)

Grant agreement n°: 213295
Start and end dates: 01/01/ 2008 to 31/03/2011
Co-ordinator: Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany, Prof. K. Andreas Friedrich, DLR-TT, Pfaffenwaldring 38-40, D-70569 **Stuttgart, Germany, email:** andreas.friedrich@dlr.de

Consortium:

Partner	Beneficiary Name	Country	Role
1	Deutsches Zentrum für Luft- und Raumfahrt e.V.	Germany	Coordinator
2	Chalmers University of Technology	Sweden	Partner
3	Friedrich-Alexander-Universität Erlangen	Germany	Partner
4	Commissariat á l Energie Atomique (CEA)	France	Partner
5	DANA Sealing Products – Victor Reinz, Reinz-Dichtungs GmbH	Germany	Partner
6	Adam Opel GmbH	Gemany	Partner
7	European Commission, DG Joint Research Centre, Institute for Energy, (JRC-IE)	Belgium	Partner
8	SGL Technologies GmbH	Germany	Partner
9	Solvay Solexis S.p.A.	Italy	Partner
10	Volvo Technology AB	Sweden	Partner
11	Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)	Germany	Partner

Title: Understanding of degradation mechanisms to improve components and designradation Mechanisms to Improve Components and Design **DECODE**

Objectives: The main objective of the planned project DECODE was to increase the life-time of fuel cells for automotive applications. The DECODE project was aimed at identifying characteristic behaviour regarding degradation and malfunctions with special emphasis on liquid water interactions. The work will quantitatively elucidate fundamental degradation mechanisms with PEFC under steady-state and cycling conditions. The elucidated mechanisms will be used to improve PEFC durability.

Description of the work: The first task of the project was the definition of the state-of-art fuel cell components, test cells and operating conditions for the investigation of the degradation processes. In the next phase the degradation processes of the PEFC and the fuel cells were investigated by in-situ and ex-situ experiments and characterizations. In addition, the degradation processes were modelled with different methodologies. After identification of the most relevant degradation processes and their ranking, the individual components were modified (improved material properties, novel coatings, new MEA design) in order to increase cell durability. The improved components were tested and characterized by the same methods used for the identification of the degradation processes. A 1000 h test in short stack with metallic bipolar plates demonstrated a significant durability improvement.

Expected results: Achievements are scientific and economic. The industrial partners had the possibility to improve their materials and components with the help of extensive testing, sophisticated analysis tools and sophisticated modelling of research partners. Thinking tools and predictive models were developed which resulted in various publications. The improvement of durability was demonstrated with a new MEA design, modified GDL hydrophobic properties and novel coatings for the metallic bipolar plate. An advancement of the components as well as stacks operation was demonstrated benefitting the DECODE industrial partners. This may result in economic benefits in the future due to better products.

PREdictive Modelling for Innovative Unit Management and ACcelerated Testing procedures of PEFC

(Project **PREMIUM ACT,** CEA-Liten, France)

Grant agreement: FCH JU 256776
Start date: 0/03/2011 to 28/02/2014
Coordinator: Sylvie ESCRIBANO, CEA/LITEN, 17 rue des Martyrs, 38054 Grenoble Cedex 9, France ; tel : 33 (0)4 38 78 94 06 - Fax : 33 (0)4 38 78 94 63 - sylvie.escribano@cea.fr

Consortium:

Partner	Beneficiary Name	Country	Role
1	CEA/LITEN	France	Research, Coordination
2	IRD FUEL CELLS A/S	Denmark	Research
3	POLITECNICO DI MILANO	Italy	Research
4	DLR	Germany	Research
5	ICI CALDAIE	Italy	Research, Coordination
6	JRC IE	European Commission	Research
7	SOPRANO	France	Research

Title: PREdictive Modelling for Innovative Unit Management and ACcelerated Testing procedures of PEFC **PREMIUM ACT**

Objectives: A general objective is to contribute to the improvement of stationary PEFC systems durability, one of the main hurdles to overcome before successful market development, knowing that the target required is 40000h. Premium Act specific objectives are to propose a reliable method to predict lifetime, to benchmark components and to improve operating strategies of two types of real systems, in order to reach the following achievements: satisfactory relative or absolute prediction of durability and innovative unit management strategies allowing a measurable durability increase in the stacks and systems of the industrial partners without negative impact on the customer needs' fulfilment.
These objectives are followed in favour of two strategic fuel cell technologies for stationary markets: DMFC (Direct Methanol Fuel cell) power generators and CHP systems fed by reformate hydrogen.

Description of the work:
The technical approach is to combine specific experimental and modelling tools to study the degradation at different scales from fuel cell performance down to the microstructure. First step is to identify and understand the causes of degradation, particularly of Membrane Electrode Assemblies, in real conditions (with a focus on the accelerating features). These conditions are thus reproduced on small devices to estimate MEAs' lifetime. Then, analyses are conducted on the components, to elucidate how their microstructure or their properties are degraded during fuel cell operation.
In parallel, multi-physics models are developed to enable the description of the phenomena appearing during the ageing at the different scales of the cell and for different conditions, considering as well the decrease of the electrochemical performance as the alteration of the MEA materials features (catalysts, electrodes and membranes); models validation being conducted through specific single cell tests.
The core technical part of the project will be to combine all the information coming from the experimental tests or analyses and from the modelling to propose and validate **relevant accelerated tests able to couple various degradation factors** and to assess different MEAs' lifetime more rapidly than with normal tests. Final expected outcomes are **operating strategies able to improve the lifetime** of the systems considered and a **methodology to predict the life time of their MEAs**.
The impact of materials will be principally considered thanks to the comparison of different MEAs, which will be tested in both normal and accelerated aging tests.

Further research needs

- Optimisation of the systems considered (incl. the components) to fully adapt the recommendations about lifetime improvement coming from PREMIUM ACT
- Application of the approach and tools to develop accelerated aging tests or lifetime prediction or operating strategies, to improve other fuel cell systems durability
- Development of fine-tuned improved materials, MEA components or complete MEAs based on the experimental or modelling results of the degradation mechanisms analyses.

SOFC anionic

SOFC Life - Solid Oxide Fuel Cells – Integrating Degradation Effects into Lifetime Prediction Models
Coord: Fz Juelich, Germany, Dr. Bert de Haart p.41

Robanode - Anode degradation for H2 and natural gas fuelled SOFCs
Coord: Foundation for Research and Technology Hellas, Institute of Chemical Engineering and High Temperature Chemical Processes (FORTH/ICE-HT) Dr. Symeon Bebelis p.42

SCOTAS SOFC - Sulphur, Carbon, and re-Oxidation Tolerant Anodes and Anode Supports for Solid Oxide Fuel Cells
Coord: Danmarks Tekniske Universitet, Denmark, Dr Peter Holtappels p.43

METSOFC – Development of next generation metal supported SOFC cells
Coord: Top0soe Fuel Cell A/S, Denmark, Niels Christiansen.....p.44

RAMSES - Robust Advanced Materials for Metal Supported SOFC
Coord: CEA – LITEN, France, Julie MOUGIN.....p.46

Solid Oxide Fuel Cells – Integrating Degradation Effects into Lifetime Prediction Models

(Project **SOFC-Life,** Forschungszentrum Jülich GmbH, Germany)

Grant agreement n°: 526885
Start and end dates: 01/01/2011 to 31/12/2013
Co-ordinator: Fz Jueliche, Prof. Dr. L. G. J. de Haart, Institute of Energy and Climate Research (IEK-9) D-52425 Jülich, Germany, Phone +49 2461 61-6699, l.g.j.de.haart@fz-juelich.de

Consortium:

Partner	Beneficiary Name	Country	Role
1	Forschungszentrum Jülich GmbH	Germany	Research
2	Hexis AG,	Switzerland	Industry (SME)
3	HTceramix,	Switzerland	Industry (SME)
4	Topsøe Fuel Cell A/S	Denmark	Industry (SME)
5	Commissariat à l´Energie Atomique	France	Research
6	DTU-EC	Denmark	Research / University
7	Eidgenössische Materialprüfungs- und Forschungsanstalt	Switzerland	Research
8	Institute of High Temperature Electrochemistry	Russia	Research
9	Valtion Teknologian tutkimuskeskus VTT,	Finland	Research
10	Ecole Polytechnique Fédérale Lausanne	Switzerland	University
11	Imperial College	United Kingdom	University
12	Electricité de France	France	Research
13	Zürcher Hochschule für Angewandte Wissenschaften	Switzerland	University

Title : Solid Oxide Fuel Cells – Integrating Degradation Effects into Lifetime Prediction Models **SOFC-Life**

Objectives : The project addresses the quantification and understanding of the details of major Solid Oxide Fuel Cells (SOFC) continuous degradation effects. The goal is to isolate effects occurring on the anode and cathode side of SOFC and developing descriptions of the degradation mechanisms as functions of distinctive operating parameters (mainly temperature, atmosphere and current density). These functional descriptions are to represent the physical and chemical changes of basic materials and layer properties over time. This information will be integrated into higher level models that are then capable of predicting single degradation phenomena and their combined effect on SOFC cells and single repeating units.

Long-term stable operation of Solid Oxide Fuel Cells (SOFC) is a basic requirement for introducing this technology to the stationary power market. Electricity generating equipment usually is designed for lifetimes of 10 years and well above, corresponding to 40,000 to over 100,000 hours of operation. The continuous degradation of fuel cell voltage commonly observed has to be reduced such that the loss of power remains within acceptable limits during the lifetime. The project aims at a better understanding of the degradation phenomena as a tool for mitigating these effects and as a first step towards developing accelerated testing methods.

The project follows a systematic approach to analysis of some of the most important degradation mechanisms. It concentrates on the 'continuous' (baseline) degradation phenomena determining stack behaviour in the long term. By deconstructing the SOFC stack into isolated elements and interfaces, these are exposed to the physical conditions found in typical SOFC system operation (and beyond). At regular intervals specimen are taken form the experiments and thus a time series of the gradual development of degradation effects is recorded. This time-lapse photography type approach is designed specifically to allow the modelling of physical change over time.

Expected results :

- Anode sub-model
- Cathode sub-model
- Integrated model(s) for predicting cell and SRU level degradation
- Identification, Assessment and Simulation of Major Degradation Parameters - Concluding report (M36)

The project aims at improving the longevity of SOFC and such contributes towards market introduction and economic development of the stationary fuel cell sector.

Understanding and minimizing anode degradation in hydrogen and natural gas fuelled SOFCs

(Project **ROBANODE**, Helmholtz-Zentrum Geesthacht, Germany)

Grant agreement n°: 245355
Start and end dates: 01/01/2010 to 31/12/2012
Co-ordinator: Foundation for Research and Technology Hellas, Institute of Chemical Engineering and High Temperature Chemical Processes (FORTH/ICE-HT) Dr. Symeon Bebelis, Associate Professor, Greece, simeon@chemeng.upatras.gr

Consortium:

Partner	Beneficiary Name	Country	Role
1	FORTH/ICE-HT (Coordinator)	Greece	RG
2	Technische Universität Clausthal (TUC)	Germany	RG
3	National Technical University of Athens (NTUA)	Greece	
4	Ecole Polytechnique Federale de Lausanne (EPFL)	Switzerland	RG
5	Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC)	Spain	RG
6	Centre National de la Recherche Scientifique (CNRS)	France	RG
7	Ceramics and Refractories Technological Development Company (CERECO S.A.)	Greece	SME
8	Saint-Gobain Centre de Recherches et d` Etudes Europeénes (Saint Gobain)	France	IG

Title: Understanding and minimizing anode degradation in hydrogen and natural gas fuelled SOFCs **ROBANODE**
http://robanode.iceht.forth.gr/

Objectives: One of the main obstacles for commercialization of Solid Oxide Fuel Cells (SOFCs) is insufficient durability, which is largely due to degradation of the anode electrode. Anode degradation in hydrogen fuelled SOFCs corresponds mainly to micro-structural changes due to thermal and/or electrochemical sintering and oxidation/reduction of the anode, due to interruption of the fuel supply. Anode degradation in SOFCs using natural gas or other hydrocarbon fuels is additionally due to carbon deposition and sulphur poisoning, which result in severe decrease of both the electrocatalytic activity of the anode and its catalytic activity for internal reforming or direct oxidation of the fuel. The key objective of ROBANODE is the development of an integrated strategy for understanding the mechanism of anode degradation in SOFCs. This is realised through combination of theoretical modelling with experiments over an extended range of operating conditions, using a large number of modified state-of-the-art (SoA) Ni-based cermet anodes. In brief, the main objectives of the project are:

- Development of a mathematical model to describe the operational performance and degradation of Ni-based cermet anodes.
- Experimental investigation of the processes which are responsible for Ni-based anodes degradation, focusing on carbon deposition, sulphur poisoning and re-oxidation processes, and improvement of anodes robustness via proper modification of Ni.

Description of the work: The project does not aim to development of new materials, but to a detailed study of the mechanism of the anode degradation processes, through identification of similarities/differences in the degradation behaviour of unmodified and modified (via different methods and modifiers) state of the art Ni-based (Ni/GDC and Ni/YSZ) cermet anodes, assisted by detailed characterization of the anode materials (as-prepared and used). An important point of the proposed strategy is the development of a theoretical model for description of the performance and degradation of the anode, with no adjustable parameters, which will accept as input a number of parameters that will be experimentally determined.

Expected results: ROBANODE deals with the improvement of the durability of Ni-based state of the art SOFC anodes and addresses relevant scientific and technological issues. These are expected to offer significant impact concerning the:

- Reduction in the degradation rate of state of the art SOFCs that operate with H_2 or natural gas.
- Long-term durability and reduction of the commercial cost of hydrocarbon fuelled SOFCs.

Sulphur, Carbon, and re-Oxidation Tolerant Anodes and Anode Supports for Solid Oxide Fuel Cells

(Project **SCOTAS-SOFC**, Danmarks Tekniske Universitet, Denmark)

Grant agreement n°: FCH JU 256730
Start and end dates: 01/10/2010 to 30/09/2013
Co-ordinator: Danmarks Tekniske Universitet, Denmark, Dr Peter Holtappels. Department of Energy Conversion and Storage, Frederiksborgvej 399, DK-4000 Roskilde, peho@dtu.dk

Consortium:

Partner	Beneficiary Name	Country	Role
1	DANMARKS TEKNISKE UNIVERSITET	Denmark	Materials R&D
2	FORSCHUNGSZENTRUM JUELICH GMBH	Germany	Materials R&D
3	HEXIS AG	Switzerland	Fuel Cell Assessment
4	TOPSOE FUEL CELL A/S	Denmark	Fuel Cell Assessment
5	THE UNIVERSITY COURT OF THE UNIVERSITY OF ST ANDREWS	Great Britain	Materials R&D

Title: Sulphur, Carbon, and re-Oxidation Tolerant Anodes and Anode Supports for Solid Oxide Fuel Cells **SCOTAS-SOFC**

Objectives: Solid oxide fuel cells (SOFCs) have a great advantage in their fuel flexibility compared to other fuel cells (such as PEMFC), and thus are particularly suited for stationary cogeneration of heat and power based on natural gas or other hydrocarbon fuels. The aim of the project is to demonstrate a new more robust type of solid oxide fuel cell for application in small scale, combined heat and power systems (micro CHP). Thus, the project is a materials' based approach to increase micro CHP robustness, simplify operation strategies and thus reduce system costs. It addresses in particular critical issues in the StartUp/Shut Down phase and during grid outage/system failures.

Description of the work: The project will demonstrate a new full ceramic SOFC cell with superior robustness as regards to sulphur tolerance, carbon deposition (coking) and re-oxidation (redox resistance).
Oxide ceramics based on strontium titanates have been investigated in previous EU projects (Real-SOFC and SOFC600) and developed up to button cell sizes. The approach in this project is to focus on three of the most promising compositions and develop them into full cells for performance evaluation under application relevant conditions.

Expected results: It is expected that the outcome of the project will be improved anode and anode support materials, which improves the performance in regards to the identified failure mechanisms for fuel tolerance (sulphur and carbon) and re-oxidation resistance in SOFCs. Having a more robust cell will thus enable the system to be simplified, something of particular importance for small systems, e.g. for combined heat and power (CHP). Thus, the project can contribute significantly to fulfilling the electrical efficiency, lifetime and target costs requirement for SOFCs used with the relevant types of fuels and applications.

Further research needs

- Control of powder morphology and electrical properties during synthesis and pre-treatment of strontium titanate materials
- Understanding thermo-mechanical properties of the new cells
- Life time and degradation studies on the newly developed cells

Development of next generation metal based SOFC technology

(Project **METSOFC,** Top0soe Fuel Cell A/S, Denmark)

Grant agreement n°: 211940
Start and end dates: 01/04/2008 to 31/12/2011
Co-ordinator: Top0soe Fuel Cell A/S, Denmark, Niels Christiansen, nc@topsoe.dk

Consortium:

Partner	Beneficiary Name	Country	Role
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3	Sandvik Osprey Ltd	United Kingdom	Partner
4	DTU Risø	Denmark	WP manager
5	AVL List GnbH	Austria	WP manager
6	Chalmers University	Sweden	Partner
7	KIT Karlsruhe	Germany	WP manger

Title: Development of next generation metal based SOFC technology **METSOFC**

Objectives: The objective of the METSOFC project has been to develop next generation stack technology based on metal-supported cells to improve robustness, cost effectiveness and functionality including the objective to reach a robustness of SOFC stacks which fulfils the requirements defined by the transportation sector. The development of the METSOFC cells and stacks has encompassed the introduction of a novel cell architecture including new metallic alloys, radical innovative anodes and new processing methods. One primary objective has been to select and verify effective manufacturing methods suitable for up-scaling. The target was to test the developed stacks up to the 1 kWe level aiming at functionalities and operation parameters defined by heavy duty APU mobile applications. The metal-supported concept is attractive because such a new platform is expected to yield improvements in cell cost, component handling, operational constraints, mechanical robustness, and operational temperature, which would also make way for cheaper system and stack components. Initially the following targets and benchmark values had to be taken into account regarding heavy duty truck applications in quasi-steady operation mode:

- Sulphur tolerance up to 10 ppm
- 5.000 operating hours with outlook on 10.000 operating hours
- 500 thermal and full redox-cycles (i.e. warm-up and cool down in air)
- System costs <800 Euro/kW (with < 45% stack costs)

Testing procedures considering the boundary conditions and system requirements had to be developed in accordance with the product definitions on the one hand and FCTESTNET / FCTESQA on the other hand. A special emphasis was put on dynamic and cycling tests (load-, redox-, thermal cycles).

Description of the work: To ensure cost effectiveness and up-scalability of the novel cell concept, it has been a prerequisite to rely upon a metal support layer based on powder metallurgy and co-sintering. The choice of powder composition and particle size distribution has been evaluated in order to fulfill the following criteria: adequate high temperature corrosion resistance, chromium evaporation, mechanical durability and process ability. Metal-supported cells were manufactured using powder based on the state-of-the-art ferritic chromium steel developed by Sandvik/Osprey using gas atomization. The cells were then tested to provide benchmark performance data. 5 types of different powder alloys were manufactured and evaluated in an iterative development sequence. The design process utilised an effective LEAN spiral concept upon which the METSOFC project has been structured successfully. In overall terms it was concluded that the alloy compositions and particle size requirements evaluated within the METSOFC project could be manufactured effectively in pilot scale manufacturing equipment.

The different powder alloys developed were used to fabricate metal supports with focus on processing compatibility with other cell components, porosity, microstructure, and corrosion resistance. All metal supports were fabricated based on tape casting. Quantitative targeted performance values were established for different

components, including the metal support. In order to have improved corrosion resistance of the metal support the available surface area for corrosion of the metal support should be < 0.02 m^2/g with porosity around 25%. Corrosion testing on metal supports and half cells was carried out to give feedback during the iterative optimization of metal powder compositions. The results obtained also provided important feedback on how to optimize the microstructure of the metal support to have as low corrosion as possible of the metal component. Furthermore, the effect of some selected protective coatings on the corrosion behavior has been evaluated. Establishment of an effective integrated manufacturing concept focusing of co-processing of ceramics and metals has represented a major challenge including many unknowns.

Because the typical mechanical failure mechanism of metallic supports are different from failures of ceramic supports (electrolyte or anode supported cells), a radical different treatment of mechanical properties and behaviours was needed in this project. To truly understand the possibility of a viable metal supported cell, the difficult relationship between the elastic and plastic response of the metal supports had to be investigated at both room temperature and high temperature, as this relationship becomes more complex at elevated temperatures as creep and corrosion also enters as significant mechanisms. An increased understanding of the complexity of the mechanical characterization of the novel metal supported cell has been obtained and some modifications of the plans regarding mechanical testing had to be implemented.

Expected results: Metal supported cells have been up-scaled from 4 cm^2 to 144 cm^2, and even a few cells with 300 cm^2 foot prints have been produced to demonstrate the potential in the fabrication process. The ASR performance of the button cells tested have been improved from about 0.8 Ωcm^2 to <0.5 Ωcm^2 measured at 650 ^oC which is better than the project target. The degradation rate has been improved from 4.5 to 0.9 % per 1000 hours. These numbers are in good accordance with the key milestones. The novel metal-supported cells have proved to exhibit significantly better red-ox cycle resistance than current SoA anode supported cells. Stack up to 25 cells have been assembled and tested. To ensure lifetime and cost effectiveness a new continuous strip steel coating concept for metallic interconnects has been developed. The Cr evaporation rate from the coated steel is well below the targeted value of 0.1 mg/cm^2 per 1000 hours after the first 1000 hours of operation.

Further research needs: The METSOFC cell and stack concept builds upon cheaper materials and minimization of use of Nickel in comparison with current anode-supported cells based on Ni/YSZ support layers. Generally the lower operation temperature in combination with metallic alloys promises improved robustness, reliability and further reductions of cost. As a spin off from METSOFC a new EU FCH JU project METSAPP has been launched by the end of 2011 aiming at further improvement of durability and lifetime for residential applications. Further research includes improvements of high temperature corrosion resistance of the metallic support and introduction of stable anode compositions analogous to some of the candidate materials developed in the EU SCOTAS SOFC project. The cell and stacks developed in the METSOFC and METSAPP projects will be evaluated for potential implementation in the APU development project EU FCH JU DESTA.

Robust Advanced Materials for Metal Supported SOFC

(Project **RAMSES**, CEA - Grenoble, France)

Grant agreement n°: FCH JU 256768
Start and end dates: 01/01/11 to 31/12/13
Co-ordinator: Julie MOUGIN, Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA) DRT/LITEN/DTBH/LTH, 17 rue des Martyrs, F-38054 GRENOBLE Cedex 9, France. Tel: +33.(0)4.38.78.10.07, julie.mougin@cea.fr

Consortium:

Partner	Beneficiary Name	Country	Role
1	Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA)	France	R&D
2	SOFCpower S.r.l.	Italy	SME
3	Centre National de la Recherche Scientifique - Bordeaux	France	R&D
4	Höganäs AB	Sweden	Industry
5	Baikowski	France	Industry
6	AEA S.r.l	Italy	Industry
7	Stiftelsen SINTEF	Norway	R&D
8	Ikerlan S. Coop.	Spain	R&D
9	Copreci S. Coop.	Spain	Industry
10	National Research Council Canada	Canada	R&D

Title: Robust Advanced Materials for Metal Supported SOFC **RAMSES**

Objectives: The RAMSES project aims at developing an innovative high performance, robust, durable and cost-effective Solid Oxide Fuel Cell based on the Metal Supported Cell concept i.e. the deposition of thin ceramic electrodes and electrolyte on a porous metallic substrate.
Both planar and tubular cells will be developed. By considering advanced materials tailored for this application, such cells will be able to operate at 600°C not only in hydrogen but also in methane steam reforming, targeting in this latter case an ASR of 0.8 Ohm.cm² for planar cells and 1.0 Ohm.cm² for tubular cells and a degradation rate of 30 mOhm.cm²/khr. Degradation upon thermal and redox cycling is also considered.

Description of the work, including (if applicable) benefits and barriers of the materials-based approach: The achievement of such performance needs several key-developments linked to materials and related manufacturing processing to be addressed:

- manufacturing of a durable metallic substrate
- deposition of the ceramic layers without affecting the substrate microstructure, with a special emphasis on the dense electrolyte deposition
- proof-of-concept via the integration of the cells into a short stack, supported by inspection techniques to evaluate the good quality of components at each step of the process
- testing activities to determine the performance and durability of cells and stacks, and to investigate specific identified failure mechanisms

The technical objective of this project is the development of a SOFC cell with an **improved lifetime** due to the low operating temperature (600°C) while achieving **high performances** by applying advanced low-temperature electrodes and electrolyte materials. The Metal Supported Cell concept (MSC) will in addition **reduce statistically based mechanical failures**, since this type of cell is intrinsically more mechanically robust, and **decreasing manufacturing cost** by decreasing the amount of expensive ceramic materials to minimum. Cost reduction of Balance-of-Plant components will also be achieved because of the lower operating temperature (e.g. insulation, heat exchangers and recycle blowers).

Two technological objectives are targeted in this project:

Objective 1 – Development of a performing, durable and cost-effective Metal-Supported Cell

Metal-supported Cells development will **include both the metal-substrate development and the cell development**. The materials selection within the present project will benefit from the extensive investigations on materials that have been carried out mainly within the integrated project SOFC600, and to a lesser extent Real SOFC. The best performing cell materials resulting from these projects will be optimized and customized to the specific MSC manufacturing and functional requirements in this project. The major innovative activities will be focused on the design of the cell and the development of manufacturing processes, with a major focus on the deposition of the electrolyte, which is a key issue of this project.

The main goal for cell development is to develop processes for manufacturing the electrodes and electrolyte ceramic layers in order to achieve the microstructure necessary for high electrochemical performance at low operating temperature without detrimentally affecting the metal substrate microstructure and chemical properties. The main challenge of the project is the achievement of **dense and gastight electrolyte layers** without using high temperature sintering steps that would melt, sinter or heavily corrode the porous metal substrate.

Objective 2 – Manufacturing and integration of the new MSC technology into a short stack for a final proof-of-concept: For the proof-of-concept, the target is to produce full-scale cells, with the best architecture, materials and processes and to integrate them into a planar short stack (approx 100 W) and a tubular stack (approx 75 W). Performance will be evaluated at 600°C with hydrogen as well as with internal steam methane reforming (ISR).

The achievement of these technical objectives will be evaluated through the performance and durability testing of the MSC cells produced in this project, followed by extensive post test analysis.

Expected results, industrial applications and potential commercialization: Fuel cell applications can contribute significantly to European public policy objectives for energy security, air quality, reduction of greenhouse gas emissions and industrial competitiveness. Cost and durability/reliability are the two major impediments to SOFC widespread development and commercialization. The 3 year RAMSES project will produce a robust, highly performing and durable cell for stack manufacturers addressing the Combined Heat and Power (CHP) application. The expected impact of the project will be the availability of a stable competitive SOFC cell, with significantly improved mechanical reliability, as well as combined redox-thermal cycling, and lower manufacturing costs, particularly regarding materials. As a result it will contribute to make SOFCs more attractive and affordable, for a market entry in CHP applications at the horizon 2015 – 2020.

Further research needs: Further developments of improved materials and/or associated microstructures would be valuable, as well as development in the field of processing. Upscaling of such cells and stacks to build and test larger cells and stacks would also be necessary.

PEMWE

Weltemp - Water Electrolysis at Elevated Temperatures
Coord: Technical University of Denmark, Department of Energy Conversion and Storage (previously Department of Chemistry), Denmark, Prof. Niels J. Bjerrum, ...p.51

Nexpel - Next Generation PEM Electrolyser for Sustainable Hydrogen Production
Coord: SINTEF Materials and Chemistry, New Energy Solutions, Magnus Thomassen, Norway.....p.52

Primolyser - Pressurised PEM Electrolyser stack
Coord: IRD A/S, Denmark, Laila Grahl-Madsen.....p.53

nanoPEC - Nanostructured Photoelectrodes for Energy Conversion
Coord : Ecole Polytechnique Fédérale de Lausanne, Prof. Michael Grätzel, Switzerland p.54

Water Electrolysis Elevated Temperatures

(Project **WELTEMP**, Technical University of Denmark)

Grant agreement n°: 212903
Start and end dates: 01/01/2008 to 30/03/2011
Co-ordinator: Technical University of Denmark, Department of Energy Conversion and Storage (previously Department of Chemistry), Denmark, Prof. Niels J. Bjerrum, Kemitorvet build. 207, DK-2800 Kgs. Lyngby, Phone +45 45 25 23 07 nibj@dtu.dk. Contact: Senior researcher Erik Christensen, erchr@dtu.dk

Consortium:

Partner	Beneficiary Name	Country	Role
1	Technical University of Denmark, www.dtu.dk	Denmark	Membranes, Electroche. testing
2	Institute of Chemical Technology Prague,www.vscht.cz	Czech Republic	Electrochemical testing, Corrosion
3	The Norwegian University of Science and Technology, www.ntnu.no	Norway	Catalysts
4	IHT Industrie Haute Technologie SA, www.iht.ch	Switzerland	Elektrolyser test
5	Acta S.p.a. www.acta-nanotech.com	Italy	MEA and catalyst
6	Tantalum Technologies A/S, www.tantaline.com	Denmark	Tantalum coatings
7	Danish Power Systems ApS, www.daposy.dk	Denmark	MEA fabrication
8	Institute of Macromolecular Chemistry ASCR,www.imc.cas.cz	Czech Republic	Membranes

Title: Water Electrolysis at Elevated Temperatures **WELTEMP**

Objectives: The strategic development of the WELTEMP project was an *elevated operating temperature of the PEM electrolyser* for hydrogen production. In this way the energy efficiency would be expected to be significantly improved because of enhanced electrode kinetics, the decreased thermodynamic energy requirement, and the possible integration of the heat recovery. The elevated temperature requires either that the water electrolysis is carried out on steam, or that the working pressure is raised in order to keep the water liquid.

Description of the work: The higher temperature makes the demands to all materials involved higher, fx. mechanical properties of membranes and corrosion resistance. Thus key issues to achieve the strategic target were breakthroughs of fundamental materials developments, including catalysts, membranes, current collectors, bipolar plates and other construction materials. The activities within proton conducting (*acidic*) membranes were based on modifications of two types of materials: 1) phosphoric acid doped polybenzimidazole (PBI) membranes, and 2) perfluorinated sulfonated (PFSA) membranes. The PFSA membranes (with short side chains) were the most successful. Steam electrolysis (ambient pressure and 120-130^{o}C) was carried out using PFSA type membranes, but in this case it was necessary to dope them with phosphoric acid in order to maintain their protonic conductivity.

Description of the work: Tantalum coated stainless steel could fulfill the very high demands to corrosion resistance under acidic conditions due to the elevated temperature, and maintain a low contact resistance. Such materials were prepared by a high temperature chemical vapor deposition process. For use with acidic membranes a new preparation procedure for usual IrO_2 was introduced in order to improve the durability. Highest performance was obtained using a PTFE reinforced Nafion membrane, pressure 3-7 bar, and at temperatures 120-130^{o}C. Voltages of 1.65V at 1.0 A/cm^2 and 1.85V at 2.0 A/cm^2 were oberved. For use with alkaline membranes new non-noble metal based (i.e. low cost!) catalysts were successfully developed. New membrane materials were prepared, and MEAs were tested. Good durability was obtained, but working temperature were below 100^{o}C. However, small alkaline PEM stacks containing no noble elements are now manufactured on a commercial basis!

Further research needs: Development of fiber reinforced PFSA membranes. New porous conductive and corrosion resistant materials to replace flow channels in high pressure PEM cells (also elevated temperature). New non-noble metal catalyst to replace IrO_2 and Pt - an even further elevated working temperature like 200-400^{o}C is likely to make this easier. That will however require new, primarily inorganic proton conducting materials as electrolytes, fx based on phosphates.
For the alkaline PEM cells a very important task is to develop ionomers suitable for the catalyst layers in order to get high performances. Further development of alkaline electrolysers in general to improve the performance of the large scale plants that may be required to be built soon, if a sufficient capacity for handling the growing amounts of excess renewable energy shall be provided in time.

Next Generation PEM Electrolyser for Sustainable Hydrogen Production

(Project **NEXPEL**, Helmholtz-Zentrum Geesthacht, Germany)

Grant agreement n°: 245262
Start and end dates: 01/01/2010 to 31/12/2012
Co-ordinator: Magnus Thomassen, SINTEF Materials and Chemistry, New Energy Solutions, Sem Sælands vei 12, 7465 Trondheim, Norway - tel: +47 98243439; Fax: +47 73591105

Consortium:

Partner	Beneficiary Name	Country	Role
1	Stiftelsen SINTEF	Norway	Coordinator, catalyst synthesis
2	University of Reading	UK	Membrane development
3	FuMA-Tech GmbH	Germany	MEA fabrication
4	CEA LITEN	France	Current collectors and bipolar plates
5	Fraunhofer ISE	Germany	Stack design and manufacture /field testing of PEMWE / DC//DC converter
6	Hélion - Hydrogen Power	France	market requirements and cost assessment / Integration and field testing of PEMWE
7	StatoilHydro ASA	Norway	Field testing of PEMWE with Renewable Energy Sources /efficient power electronics

Title: Next Generation PEM Electrolyser for Sustainable Hydrogen Production **NEXPEL**

Objectives: Seven European partners have joined forces in the NEXPEL Project to further develop and demonstrate proton exchange membrane (PEM) electrolyser technology suitable for highly efficient hydrogen production from renewable energy sources.

Description of the work: During the NEXPEL project an efficient PEM electrolyser integrated with Renewable Energy Sources (RES) will be constructed and demonstrated. The NEXPEL electrolyser incorporates several technological innovations, such as more active catalysts, new membrane materials, highly stable porous current collectors and bipolar plates. To further reduce cost and improve stability, an advanced stack design using components suitable for mass production and highly efficient advanced power electronics is developed.

Expected results: Cost evaluation studies and market analyses were performed in order to increase the knowledge on the possible future markets for PEM water electrolysers. During the first year, a simulation tool for evaluation of system integration with renewable energy sources was developed by SINTEF. It demonstrated the possible use of an electrolyser for power quality improvement in a relatively weak system connected to the grid. Economical considerations strengthened the results and demonstrated that at today's electricity prices and expected hydrogen prices, the production of hydrogen from wind energy can become economically feasible.
A market study performed by HELION shows that PEM electrolyser products, in terms of cost and technical performance, is closely linked to the type of application, the type of clients and the compromise that these clients are ready to make between cost and performance. It also appears that the trend of PEM electrolysers is to increase in size and to have a wider power range so that it can reach a larger market on a long term perspective.
Cost breakdown studies performed by Fraunhofer ISE shows that implementation of novel stack designs gives the opportunity to dramatically decrease the capital costs of PEM electrolysers, facilitating the market introduction of this technology.

Further research needs: Durability of electrolyzers with innovative components (catalyst, membrane, new design, advanced power electronic…) coupled with renewable energy source will be evaluated for few months. However, experiments will have to be continued and coupled with accelerated stress tests in order to estimate the useful life and identify possible degradation mechanisms.

Pressurised PEM Electrolyser stack

(Project **PRIMOLYZER**, IRD A/S, Denmark)

Grant agreement n°: 245228
Start and end dates: 01/01/2010 to 30/06/2012
Co-ordinator: IRD A/S, Denmark; Scientific coordinator, Laila Grahl-Madsen (LGM@IRD.DK)

Consortium:

Partner	Beneficiary Name	Country	Role
1	IRD A/S	Denmark	Project coordinator Manufacture of MEAs Design and construction of the PEMEC stack Long-term testing
2	ECN until 1st of Apr-11	Holland	MEA development Design, and validation of Electrolyser stack
3	VTT	Finland	Catalyst development
4	Fumatech	Germany	Membrane development and supply
5	Abengoa Hidrógeno	Spain	Specification and evaluation
6	Åbo Akademi	Finland	Microstructural and electrochemical characterisation

Title: Pressurised PEM Electrolyser stack **PrimoLyzer**

Objectives: The primary objective of the PrimoLyser project is to develop, construct, and test a cost-minimised highly efficient and durable PEM-electrolyser stack with a hydrogen production capacity of 1 Nm^3/h. The stack will be aimed for integration with domestic µCHPs. The work includes basic material R&D on catalyst & membrane and electrode optimisation to fabricate durable and high performance MEAs with low cost. PrimoLyzer is phase I in a two step development, where phase II will comprise full integration of the electrolyser with a µCHP followed by a field test.

Description of the work: The catalyst development includes modelling of the OER focusing on different catalyst surfaces. The aim is to map out trends of binary or ternary metal oxides for the anode catalyst. The molecular modelling has been used to explain the functionality of the catalysts in the OER, but has not yet proven to be suited as a rapid screening method for developing and selecting. The modelling results on the (001) and (101) surfaces has given a qualitative insight to the experimentally observed synergetic effects of Ir and Ru on the mixed oxide surfaces. The theoretical work has been accompanied by synthesis of selected catalysts. The stability of these catalysts is studied using half-MEAs, prior to including them in full size MEAs. New Pt and Pd catalysts have been synthesized on carbon nanotubes (CNT) and the effect of different types of CNTs on the activity and stability of the HER is determined by cyclic voltammetry.

New composite PFSA membrane materials with barrier functionalities to gas permeability have been developed. The composite PFSA membrane offers improved mechanical property, good conductivity and very low electro-osmotic water transport as well as a lower water electrolysis cell potential. The development of a promising sPS hydrocarbon membrane cannot be completed within the PrimoLyzer project frame.

The selection of stack materials is based on a theoretical thermodynamical screening, followed by ex- and in-situ test.

The industrial partners will exploit the PrimoLyzer results. However, further RTD work must be carried out before this goal can be achieved, first through demonstration and later through commercial production.

Further research needs: Further material R&D is mandatory to make PEM-electrolysers cheap and reliable. An R&D focus in this respect on not only catalyst[2], membrane, and stack components, but also BoP components is recommended.

[2] Iridium is one of the least abundant elements in the Earth's crust, gold is 40 times and platinum 10 times more abundant

Nanostructured Photoelectrodes for Energy Conversion

(Project **NanoPEC**, Ecole Polytechnique Fédérale de Lausanne, Switzerland)

Grant agreement n°: 227179
Start and end dates: 01/01/2009 to 31/12/2011
Co-ordinator: Ecole Polytechnique Fédérale de Lausanne, Prof. Michael Grätzel, 1015-Lausanne, Switzerland, Phone +41 21 693 3112, Fax +41 21 693 6100, michael.graetzel@epfl.ch

Consortium:

Partner	Beneficiary Name	Country	Role
1	Ecole Polytechnique Fédérale de Lausanne	Switzerland	Research materials
2	Delft University of Technology	Netherlands	Research materials
3	Technion-Israel Institute of Technology	Israel	Analysis
4	University of Warsaw	Poland	Research materials
5	University of Porto	Portugal	Test Devices/Scale-up
6	Eni S.p.A.	Italy	Industry (SME)
7	University of Oslo	Norway	Research materials
8	Eidgenössische Materialprüfungs- und Forschungsanstalt	Switzerland	Research materials

Title: Nanostructured Photoelectrodes for Energy Conversion **NanoPEC**

Objectives: NanoPEC focused on developing materials for large-scale solar hydrogen production.

Description of the work: NanoPEC (http://nanopec.epfl.ch/) employed innovative concepts and new methods, enabled by nanotechnology, to design nanocomposite photoelectrodes for solar water splitting, where each component performs specialized functions to overcome intrinsic limitations of single phase materials. Advanced nanostructures that maximize performance of photoanodes and photocathodes were designed, fabricated, characterized, and optimized. Newly-developed p- and n-type semiconducting oxides and oxynitrides were explored and nanostructured into innovative structures and device architectures designed to achieve high solar-to-hydrogen (STH) conversion efficiency, balancing the tradeoff between light harvesting, charge separation and collection, stability and durability. In parallel, fundamental studies and detailed investigations of model systems were carried out to improve quantitative understanding of the effect of material properties, defects and interfaces on PEC processes taking place in water photoelectrolysis. These investigations provided guidelines for rational optimization of materials and nanocomposite electrode structures designed for high efficiency, and the performance of these structures was evaluated in operative conditions using advanced testing and analytical setups.

Results: Significant progress in PEC water splitting has been achieved during the course of the project. In particular, a new photocurrent record of 7.6 mA cm^{-2}, measured at the reversible hydrogen evolution potential under simulated terrestrial (AM1.5G) solar radiation, was achieved with small-size Cu_2O photocathodes protected against photodegradation using a novel overlayer structure. This champion photocathode can potentially reach a STH conversion efficiency of 10% in an ideal tandem configuration, exceeding the NanoPEC target milestone. Scaled-up large (63 cm^2 active area) Cu_2O photocathodes displayed a photocurrent of 4 mA cm^{-2}, reaching 87% of our target for large modules. On the photoanode front, small-size Fe_2O_3 nanostructured electrodes reached a photocurrent of 3.3 mA cm^{-2} at the reversible oxygen evolution potential under simulated solar radiation. This could yield a STH conversion efficiency of 5% in an ideal tandem configuration, breaking the highest record ever reported for stable photoanodes for solar-induced water photo-oxidation. Although the efficiency of large Fe_2O_3 photoanodes was not as high as their small-size counterparts, largely due to processing difficulties in scaling-up from small to large size electrodes, they did not show any signs of degradation for at least three days.

Further research needs: Improved nanostructuring techniques for Fe_2O_3 photoanodes and improvement in stability of the overlayers for Cu_2O photocathodes.

PCFC & SOFC

EFFIPRO - Efficient and robust fuel cell with novel ceramic proton conducting electrolyte
Coord: University of Oslo, Dept. of Chemistry, SMN, FERMiO, Norway,
Pr. Truls NORBY p.57

IDEAL Cell - Innovative Dual mEmbrAne fueL-Cell
Coord: ARMINES, France, Dr Alain THOREL p.59

RelHy - Innovative Solid Oxide Electrolyser Stacks for Efficient and Reliable Hydrogen production
Coord : CEA-LITEN, France, Dr. Florence Lefebvre-Joud,..... p.60

ADEL - ADvanced ELectrolyser for Hydrogen Production with Renewable Energy Sources
Coord : HTceramix SA (HTc), Switzerland Olivier Bucheli..... p.61

Efficient and robust fuel cell with novel ceramic proton conducting electrolyte

(Project **EFFIPRO,** University of Oslo, Dept. of Chemistry, SMN, FERMiO, Norway)

Grant agreement n°: 227560
Start and end dates: 01/05/2009 – 30/04/2012
Co-ordinator: University of Oslo, Dept. of Chemistry, SMN, FERMiO, Norway, Pr. Truls NORBY, Gaustadalleen 21, NO-0349 Oslo, Phone +47-22840654, Fax +47-22840651, truls.norby@kjemi.uio.no

Consortium:

Partner	Beneficiary Name	Country	Role
1	University of Oslo, http://folk.uio.no/trulsn/	Norway	Research materials
2	Centre National de la Recherche Scientifique; Institut des Matériaux Jean Rouxel, http://www.cnrs-imn.fr/ST2E/ST2E_Th2.htm	France	Research materials
3	Inst. Chemical Technology, U.P.Valencia/ CSIC, http://itq.upv-csic.es/	Spain	Research materials
4	SINTEF, http://www.sintef.no/	Norway	Research materials
5	Forschungszentrum Jülich, http://www.fz-juelich.de	Germany	Research materials
6	Fuel Cells and Solid State Chemistry Department, Risø National Laboratory for Sustainable Energy, Technical University of Denmark, http://www.risoe.dtu.dk	Denmark	Research materials
7	Ceramic Powder Technology AS (CerPoTech), http://cerpotech.com/	Norway	Powder provider, Industry (SME)

Title: Efficient and robust fuel cell with novel ceramic proton conducting electrolyte **EFFIPRO**

Objectives: The EU 7FWP joint Energy and NMP project EFFIPRO (Efficient and robust fuel cell with novel ceramic proton conducting electrolyte) aims to develop electrolyte and electrodes for improvement and demonstration of performance of individual components and interfaces. Originally, the project was centred around the novel Ca-doped $LaNbO_4$ (LCNO) as a proton conducting electrolyte. While this had a proton conductivity below 10^{-3} S/cm it was considered more stable and robust against e.g. reaction with CO_2 than the state of the art $BaCeO_3$-based proton conducting ceramics. Moreover, it was of interest to see whether the ferroelasticity of the low temperature monoclinic phase would give beneficial mechanical properties and counteract the stresses from the phase transformation to the tetragonal more conducting phase at around 500°C. The midterm goals to enhance the conductivity of the electrolyte to above 10^{-3} S/cm, to develop suitable anode supports, to deposit electrolyte films of less than 5 μm thickness, and to develop compatible electrodes with electrochemical resistances below 0.5 Ωcm^2 each.

Description of the work: New doping and co-doping scheme are expected to improve the proton conductivity of the electrolyte. Investigation of new classes of stable proton conductors was also considered. All steps of the assembly from substrate via electrode to electrolyte are intimately interrelated and need dedicated development for each electrolyte. It is assumed that the strategy will follow a parallel to the so-called 3G SOFCs, namely a flat plate design with metal support, a Ni-LaNbO4 or similar cermet, possibly a functional layer, and the LaNbO4 or similar electrolyte. Identifying novel electrode material for PCFCs is an essential part of EFFIPRO. It involves analyses of thermal and chemical compatibility between selected electrolytes and candidate electrodes. Requirements on low reactivity and interdiffusion, thermal expansion match, electronic and preferentially mixed protonic-electronic conduction, redox stability, low volatility and cation diffusivity, cost, and surface kinetics are all important. The ultimate goal is <0.1 Ωcm^2 as electrochemical ASR per electrode. Importantly, surface kinetics and catalysis for H_2, H_2O and O_2 is a special focus for EFFIPRO.

Expected results: At midterm the project had developed satisfactory anode supports (ceramic and metallic) with anode functional Ni-LCNO cermet functional layers and deposition of micrometer-range dense LCNO films deposited by various methods. The anode performance was acceptable, at around the targeted resistance. However, oxide cathodes and their cercer composites exhibited too high electrode impedances. The conductivity of the electrolyte could not be improved, it was difficult to keep the "line compound" $LaNbO_4$ single phase, and the ferroelasticity did not prevent micro-cracks due to temperature cycling. At midterm it was therefore decided to move to another electrolyte developed in parallel studies and verified in the electrolyte activities in EFFIPRO.

A new electrolyte, known as "La_6WO_{12}" or La-W-O, or more precisely $La_{6-x}WO_{12-y}$, where 6-x is typically 5.3 – 5.7 was introduced. The actual single phase stoichiometry range, the actual structure, and the defect chemistry that gives it ionic conduction, water uptake, and proton conductivity without a beneficial effect of dopants were evaluated. The material is nevertheless sufficiently stable against carbonatisation, carburisation, reduction, and evaporation, and exhibits proton conductivities above 10^{-3} S/cm at 800°C. Still the new electrolyte leads to new challenges regarding support and cathodes. This is due in particular to the high content of La, making La-W-O reactive towards components not saturated with La. At present, EFFIPRO has identified cathodes with promising stability and performance, while the anode side can hardly use NiO and thus Ni in the normal anode cermet way.

Further research needs

- Novel functional anode layers and barriers layers.
- Optimization of deposition techniques
- Optimization of cathode and anode polarization resistances.

Innovative Dual mEmbrAne fueL-Cell

(Project **IDEAL-Cell**, ARMINES, France)

Grant agreement n°: 213389
Start and end dates: 01/01/2008 to 31/12/2011
Co-ordinator: ARMINES, France, Dr Alain THOREL, alain.thorel@mines-paristech.fr

Consortium:

Partner	Beneficiary Name	Country	Role
1	ARMINES	France	Coordination, WP1 and WP3 leader
2	Université de Bourgogne	France	WP2 leader
3	Consiglio Nazionale delle Ricerche (CNR)	Italy	WP4 leader
4	German Aerospace Center (DLR)	Germany	WP5 leader
5	Bulgarian Academy of Sciences	Bulgaria	WP6 leader
7	NAXAGORAS	France	Nanpowders production
8	AGH University of Science and Technology	Poland	Participation to different WPs
9	Marion Technologies	France	Powders production
10	VISIMBEL	Germany	CFD calculation

Title: Innovative Dual mEmbrAne fueL-Cell : **IDEAL-Cell**

Objectives: The IDEAL-Cell project aimed at developing an innovative HT fuel cell concept based on a dual membrane (conducting both O^{-2} and H^{+}) and operating at intermediate at 600 °C. This combines the benefits of PCFCs and SOFCs while evading their disadvantages associated to the presence of water at the electrodes. It consists in assembling the anode/electrolyte compartment of a PCFC and the cathode/electrolyte compartment of a SOFC via a porous central membrane wherein pure water is formed and evacuated. The key objectives of the project were then to prove the concept, to fabricate and optimize single dual cells.

Description of the work: The technical approach tackled first the cathode compartment (WP2), then the anode compartment (WP3), then the dual central membrane (WP4) to reach the proof of concept validation after 2 years. This was strongly supported by extensive modelling (electrochemistry, kinetics, mathematical morphology, CFD). When the concept was validated after 2 years, the consortium strengthened the basic knowledge on each compartment in view of a better understanding of the basic mechanisms, improvement of materials, components and cell (alone and in a short stack), with a strong focus on the dual conducting central membrane (WP5).

Expected results: During the last 2 years, the performances of the cell have increased (1 $mW.cm^{-2}$ up to 135 $mW.cm^{-2}$) on still non-optimized cells (1 mm thick). SOFCs and PCFCs shaped under the same conditions proved to have lower performances. Modelling and extrapolation towards thinner electrolytes (i.e. 10 –15 µm) suggest that a level of performances as high as that of SOFCs can be reached easily. Reversibility of operation (electrolyser mode, production of O_2 and H_2 in 2 separate compartments) was checked to work extremely well, involving a new mechanism of conduction. The concept has been drastically simplified (3 patents). Though our effort to raise industrial interest, the concept is still found to be not mature enough.

Further research needs: Still some basic work has to be done on the understanding on the elementary mechanisms at stake. Some additional work on shaping must be carried out (diminishing the layers thickness). The operation of IDEAL-Cell as an electrolyser is highly promising and must be continued. The concept allows innovative alternative designs that should be explored.

Innovative Solid Oxide Electrolyser Stacks for Efficient and Reliable Hydrogen production

(Project **RELHY**, CEA, FRANCE)

Grant agreement n°: 213009
Start and end dates: 01/01/2008 – 31/12/2011
Co-ordinator: CEA-LITEN, Dr. Florence Lefebvre-Joud, 17 rue des martyrs, 38054 Grenoble Cedex 9 France Phone +33 438 78 40 40, Florence.lefebvre@cea.fr

Consortium:

Partner	Beneficiary Name	Country	Role
1	Commissariat à l'Energie Atomique et aux Energies Alternatives – Grenoble (CEA)	France	R&D
2	Danish Technical University (DTU-Risoe)	Denmark	University
3	European Institute for Energy Research (EIFER)	Germany	R&D
4	Energy Research Centre of the Netherlands (ECN)	Netherlands	R&D
5	Imperial College London	United Kingdom	University
6	Topsoe Fuel Cell A/S (TOFC)	Denmark	Industry/SME
7	HELION - Department H_2 Energy AREVA	France	Industry/SME

Title: Innovative Solid Oxide Electrolyser Stacks for Efficient and Reliable Hydrogen production **RELHY**

Objectives: The RelHy project targeted the development of novel or improved, low cost materials (and the associated manufacturing process) for their integration in efficient and durable components for the next generation of electrolysers based on Solid Oxide Electrolysis Cells (SOEC). It was specifically tailored for i) optimisation of novel or improved cell, interconnect and sealing materials and ii) achievement of innovative designs for SOE stacks to improve durability.

Main challenges addressed: The main challenges addressed were the simultaneous achievement of both, lifetime (degradation close to 1% for 1000 h on single repeat units at 800°C) and efficiency (0.03 to 0.04 gH2/cm2/h, i.e. approximately 1 A/cm2 with water utilisation >60%). These operation points and degradation values yield an efficiency of up to 80% (LHV) at the system level with >99% availability. Cost issues have also be addressed by considering cost effective materials and processes in order to meet the "non energy" 1€/kg H2 target.

Obtained results: The RelHy project has allowed successful material improvement: Two types of cells have been studied. With O2 electrode made of LSCF/CGO, cathode supported cells exhibited very high cell performances. Their degradation rate was found to be promising as a stabilisation plateau (around 1% per 1000h) was obtained after few 100 hours at intermediate current densities. Electrolyte supported cells with 3YSZ electrolyte showed greatest durability whereas with 10Sc1CeSZ electrolyte high performances were reached.
Protective and contact coating made of Co2MnO4 spinel deposited on Crofer by PVD and of screen-printed LSM showed stable ASR at 800°C in ex situ testing and in operation.
Several glass seals, either commercial or homemade, were shown to withstand electrolysis conditions and to ensure tightness for more than 4000h.
Two tests campaigns have been achieved with SRUs and short stacks including performances and long duration tests (4000h) on reference and improved components. Some conditions could be found with no degradation, and high current densities at degradation rates < 5% per 1000h were reached in SRU and short stack. Scaling up to 25-cell stack has been achieved and stack is being operated.

Further material research needs

- Understanding of degradation mechanisms upon electrolysis operation within cell and single repeating units (interconnect + coating and sealants)
- Development of cells and stacks dedicated to electrolysis operation

ADvanced ELectrolyser for Hydrogen Production with Renewable Energy Sources

(Project **ADEL**, HT Ceramix SA, Switzerland)

Grant agreement n°: FCH JU 256755
Start and end dates: 01 January 2011 to 31 December 2013
Co-ordinator: HTceramix SA (HTc), Switzerland Olivier Bucheli, olivier.bucheli@htceramix.ch

Consortium:

Partner	Beneficiary Name	Country	Role
1	HTceramix SA (HTc)	Switzerland	Industry/SME
2	ACCELOPMENT AG	Switzerland	Industry/SME
3	Commissariat à l'Energie Atomique et aux Energies Alternatives – Grenoble (CEA)	France	R&D
4	Deutsches zentrum Fuer Luft und Raumfahrt EV (DLR)	Germany	R&D
5	European Institute for Energy Research (EIFER)	Germany	R&D
6	Eidgenoessische MaterialPruefungs und forschungsAnstalt (EMPA)	Switzerland	R&D
7	Hynergreen Technologies S.A (HG)	Spain	Industry/SME
8	HyGear B.V. (HYG)	Netherlands	Industry/SME
9	Fundacion IMDEA Energia (IMDEA)	Spain	R&D
10	Joint Research Centre- European Commission (JRC)	Belgium	R&D
11	SOFCPOWER SPA (SP)	Italy	Industry/SME
12	Topsoe Fuel Cell A/S (TOFC)	Denmark	Industry/SME
13	EMPRESARIOS AGRUPADOS INTERNACIONAL SA (EA)	Spain	Industry/SME

Title: ADvanced ELectrolyser for Hydrogen Production with Renewable Energy Sources **ADEL**

Objectives: The ADEL project proposes to develop a new steam electrolyser concept named Intermediate Temperature Steam Electrolysis (ITSE) aiming at optimizing the electrolyser life time by decreasing its operating temperature while maintaining satisfactory performance level and high energy efficiency at the level of the complete system including the heat and power source and the electrolyser unit. The relevance of this ITSE will be assessed both at the stack level based on performance and durability tests followed by in depth post-test analysis and at the system level based on flow sheets and energy efficiency calculations.

Main challenges addressed:
In the ADEL project, it is proposed to increase the electrolyser lifetime decreasing its degradation rate to less than 1%/1000hrs by taking advantage of lower operation temperature (between 600 to 700°C), of the main outcomes of the RELHY project regarding the scaling up of current SOFC components to achieve a high temperature electrolysis stack with controlled degradation rate and of most promising cells and interconnect coatings developed in the project SOFC 600 for operation at 600°C. When transposed and adapted to ITSE conditions, they offer a good potential to reach low cell degradation rate in the range of 0.5%/1000hrs.
A special attention will be given in the ADEL project to sealing methods in order to increase the mechanical durability of the single repeating unit and to the association interconnect /coating in order to limit the cell ASR and allow current densities across the cell as high as 2A/cm2.
To have an exhaustive and quantified analysis of the integration of this "new generation ITSE" with different heat and power sources like wind, solar, geothermal and nuclear, flow sheets will be produced with adjustable parameters. For selected cases in depth energy efficiency evaluation will be performed and translated into first specifications for a demonstrator.

Further material research needs

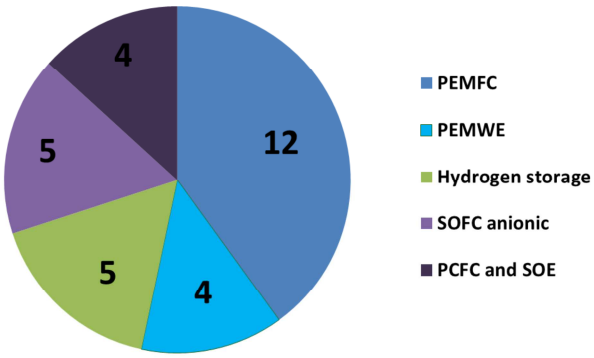
- Understanding of the influence of operation temperature on the degradation mechanisms upon electrolysis operation within single repeating unit components (cell, interconnect + coating and sealants)
- Understanding of the influence of transients on the degradation / recovery mechanisms upon electrolysis operation

Round table

Summary and main outputs

The main objectives of the workshop was: to give a complete overview of **the entire portfolio of projects on Fuel Cells Hydrogen** (FCH) in the JTI, NMP, Energy programmes end of the EU Seventh Framework Programme (FP7), to **highlight the impact of material in this area** and to **make key recommendations on future research needs in the FCH domain** to set up a **material roadmap** to foster the development of FCH in Europe.

30 projects from these various European programmes have been represented in five technical sessions.



The global number of attendees was 70 from the different European countries

The main outcomes from each topic have been presented during a round table session at the end of the workshop.

Session PEMFC

This session composed of 12 projects has been split in two main sub-sessions. The first one has been focus on material development for PEMFC and the second one focus on degradation mechanism. These two sub-sessions converged towards five main requirements:

1) Better analysis and understanding of interface phenomena between the different layers of FC component. In fact lot of project analysis are focus on one or two components (membrane/catalyst or membrane/bipolar plate,..) of the fuel cell with an advanced material development to obtain high final properties and long durability for the final fuel cell. But many times the interface mechanism between the different layers or between materials for composites structures has been less analyzed and lot of issues or leaks appear at this interface level at micro or nanoscale.
2) Substitution of high value material to decrease material cost (e.g. platinum). Some substitution have been started but if the long term vision is to move towards a low cost and high efficiency fuel cell, lot of material development to substitute the actual high cost one with a good reliability and durability need to be launched. These materials could be organic or inorganic/organic or bio based.
3) Modeling from material to degradation. Lot of model are developed in different Universities or laboratories and this model development are mainly focused on specific part of the fuel cells (membrane, catalyst system, water management,…). Discussion highlighted the interest to get the model of the complete value chain “from material to the final fuel cell” This approach could start from a first consolidation of existing modeling tools from project results in order to build up an open source software.
4) Standard test method on real work conditions in order to have reference analysis and realistic benchmark. Lot of lab analyzes their material, component, fuel cell properties and performances with internal test. Many times the test method is not exactly the same whatever the laboratory. In order to be able to compare from lab to lab whatever the place, some standard test method on real work conditions need to be implemented in a specific location in order to have a real benchmark analysis when people compare their material or fuel cell performances. The PV approach could be an example to transfer in the fuel cell business.
5) In situ material characterization is also a real need in order to have the complete understanding of material performances and ageing during the fuel cell behavior.

Session Hydrogen storage

The session was mainly dedicated to solid storage; other solutions such as high pressure gaseous storage which is considered the incumbent solution were mentioned for comparison in the session's conclusions.

Solid storage has some comparative advantages but also presents some weaknesses.
For transportation, gravimetric energy density is still a bottleneck but for stationary and heavy duty vehicle (sub-marines, tractors etc.) it has some clear interest:
- Safety (because of low storage pressure)
- Volume (high volumetric energy density)
- Energy efficiency when coupled to a fuel cell (virtually no need for compression)

Several materials do exist for the solid storage application, some already mature and other more prospective. But some major aspects still require substantial R&D, even for well-known materials:
- Reproducibility
- Reversibility and cyclability
- Sensitivity to gas impurities, both as input and output
- Kinetics, mainly for discharging
- Thermodynamics (operating temperature and pressure)

Approaches to address these challenges include:
- R&D on chemisorption, physisorption and chemical hydrides (non reversible reactions)
- R&D on composite materials, e.g. reactive hydride composites, nanocofinements in scaffolds (stability is an issue)

A link to battery materials was highlighted (spin-off projects resulted from materials R&D).

Session SOFC anionic

Two sub-sessions have been developed: one fundamental and one more applied.

1) On the fundamental point of view:

Identification of degradation mechanism of the different FC components.
Testing of well know materials together with materials with improved properties (importance of the processing technique)
Lifetime prediction models and accelerated tests needed.

2) On the more applied point of view:

Application driven research brings added value to materials research for SOFC.

In conclusion, there is room for developing new materials and for more prospective materials with specific properties. The industry wants to reply on a strong research and understanding platform with harmonized and quantified characterization approach.

Session PEMWE

Important improvements on durability, mechanical properties, conductivity, corrosion and temperature resistance have been obtained on this topic in the recent developments.

New materials for new membranes PFSA (Perfluoro-sulphonic acid polymers) have been successfully developed Nevertheless, effort have to be made in future to reduce the use of expensive materials, particularly for catalysts (Ir, Ru, Pt,…) .

Recommendations for the near future:
- An effort in the future to Substitution of expensive and rare materials with lower cost material on catalyst but also on current collectors (Ta,…)
- Modeling approach: use some know how from the PEM activities.

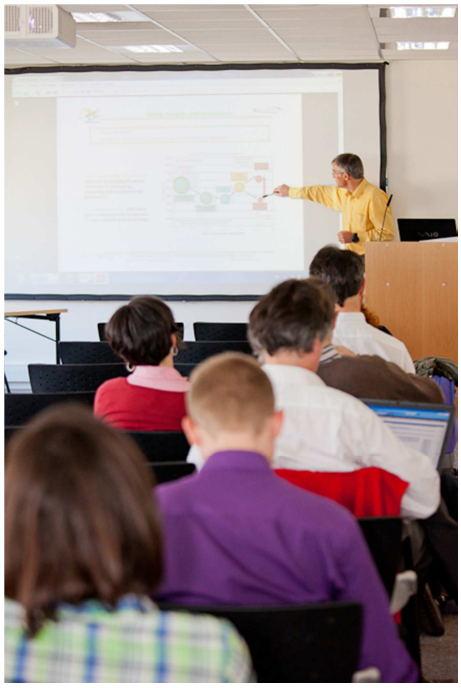
Session SOFC – SOEC

Durability remains an issue: we do not have the materials fulfilling the JTI targets simultaneously for performance and durability.
This is true for SOEC but also for SOFC. Synergies are possible between both to reach these targets.

New materials and new concepts for H2 and FC technologies need to be given some attention to prepare next generation of components. They are fully acceptable within a JTI call with application oriented research, as long as they are developed to answer clear targets and overcome identified challenges.

Material research teams seem to be quieter than system developers. But system cannot be developed if no acceptable materials are available. More focus on material related issues is needed tightly linked with system specifications

Demonstration is interesting as long as it gives feedback for improving system components but also materials components.

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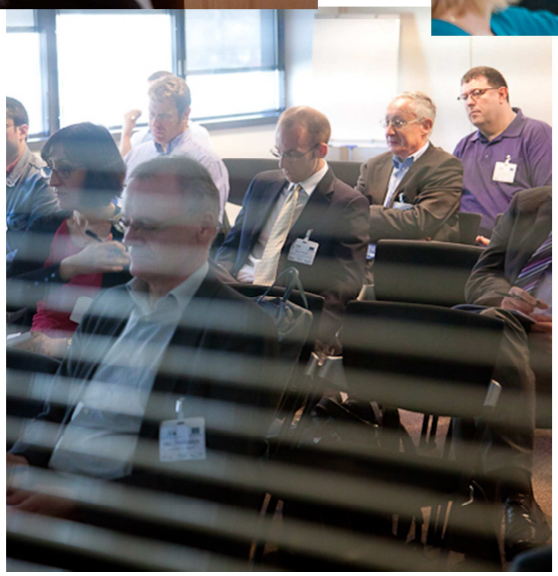
Pictures



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material issues
for fuel cell and hydrogen technologies

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