

FCH JU Grant Agreement number: 245156

Project acronym: DEMMEA

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

Deliverable 7.1: Internal dissemination and knowledge management through a secure access site

Deliverable 7.2: Web site dedicated to the scientific community

Deliverable 7.3: Dissemination through papers in specialized and non specialized press

Deliverable 7.4: Participation in technology transfer events

Deliverable 7.5: Communication action plan to the wide public

Period covered: 01/01/2010-30/06/2011

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List of beneficiaries

Beneficiary No	Beneficiary name	Beneficiary short name	Country	Date enter project	Date exit project
1	Advanced Energy Technologies	ADVENT	Greece	M 1	M36
2	Foundation for Research and Technology Hellas-Institute of Chemical Engineering & High Temperature Chemical Processes	FORTH	Greece	M 1	M36
3	Paul Scherrer Institute	PSI	Switzerland	M 1	M36
4	Centre National de la Recherche Scientifique	CNRS	France	M 1	M36
5	FUMATECH GmbH	FUMATECH	Germany	M 1	M36
6	Institute of Chemical Technology Prague	ICTP	Czech Republic	M 1	M36
7	Next Energy - EWE-Forschungszentrum für Energietechnologie e.V.	NEXT	Germany	M 1	M36
8	Technical University of Darmstadt	TUD	Germany	M 1	M36

Project summary

The state of the art high temperature PEM fuel cell technology is based on H_3PO_4 imbibed polymer electrolytes. The most challenging areas towards the optimization of this technology are:

- (i) the development of stable long lasting polymer structures with high ionic conductivity
- (ii) the design and development of catalytic layers with novel structures and architectures aiming to more active and stable electrochemical interfaces with minimal Pt corrosion.

In this respect the objective of the present proposal is to ***understand the functional operation and degradation mechanisms of high temperature H_3PO_4 imbibed PEM and its electrochemical interface.***

The degradation mechanisms will be thoroughly studied and be focused on low loading Pt or nanostructured alloyed Pt electrocatalysts and catalytic layers, which will be supported on finely dispersed or structurally organized modified carbon supports (nanotubes, pyrolytic carbon). A stable electrocatalytic layer with full metal electrocatalyst utilization at the electrode/electrolyte interface can thus be achieved. The high temperature PEM membrane electrode assembly (MEA) will be based on a) PBI and variants as control group and b) the advanced state of the art MEAs based on aromatic polyethers bearing pyridine units. These MEAs have been developed optimized and tested at temperatures up to 200°C, where they exhibit stable and efficient operation. In the present proposal they will be studied and tested in single fuel cells with regards to their operating conditions and long term stability aiming to the development of a series of diagnostic tests that will lead in the design and development of an accelerated test and prediction tool for the MEA's performance. If we can really understand the fundamentals of the failure mechanisms, then we can use that information to guide the development of new materials or we can develop system approaches to mitigate these failures.

Section A - Dissemination activities

Dissemination strategy

Dissemination of the information to the scientific community is done through the publication of selected information from the experiments and data analysis of the project in international "peer-reviewed" journals and relevant conferences. Dissemination of the information to the relevant

industrial world follows more or less the same mechanism of publications, scientific conferences and public website. All information in order to obtain maximum transparency for all and to increase the synergy of the cooperation (monthly progress reports, minutes of meetings, relevant publications etc.) is transmitted to the project coordinator who is responsible for adequately forwarding the content to the other partners.

18 months dissemination activities

Dissemination of the information to the scientific community is done through the publication of selected information from the experiments and data analysis of the project in international “peer reviewed” journals and relevant conferences. The information is also posted in the project website, as means of mass communication with the wider public. The project was also presented in "Fuel Cells and Hydrogen Joint Undertaking Stakeholders General Assembly held in Brussels (9-10 November 2010) both as poster and as an oral presentation for boarder dissemination of the obtained results.

A detailed list of the aforementioned is provided below.

Publications

1. “Using Ordered Carbon Nanomaterials for Shedding Light on the Mechanism of the Cathodic Oxygen Reduction Reaction”, Pavel S. Ruvinskiy, Antoine Bonnefont, Cuong Pham-Huu, and Elena R. Savinova, , *Langmuir*, 27 (2011) 9018-9027.
2. “Further insight into the oxygen reduction reaction on Pt nanoparticles supported on spatially structured catalytic layers”, P. S. Ruvinskiy, A. Bonnefont, and E.R. Savinova, *Electrocatalysis* 2 (2011) 123-133.
3. “Preparation, testing and modeling of three-dimensionally ordered catalytic layers for electrocatalysis of fuel cell reactions”, P. S. Ruvinskiy, A. Bonnefont, M. Houllé, C. Pham-Huu, and E.R. Savinova, *Electrochim. Acta*, 55 (2010) 3245-3256.
4. “Mass transport effects in CO bulk electrooxidation on Pt nanoparticles supported on vertically aligned carbon nanofilaments”, Pavel S. Ruvinskiy, Antoine Bonnefont, Maryam Bayati, and Elena R. Savinova, *Phys Chem. Chem. Phys* 2010, 12 (46), 15207 – 15216.

5. "Cathode Materials for Polymer Electrolyte Fuel Cells based on Vertically Aligned Carbon Filaments", P. S. Ruvinskiy, M. Rouhet, A. Bonnefont, K.A. Friedrich, C. Pham-Huu, E.R. Savinova, ECS Transactions, accepted.
6. "Preparation and characterization of Pt on modified multi-wall carbon nanotubes to be used as electrocatalysts for high temperature fuel cell applications", Alin Orfanidi, Maria K. Daletou, Stylianos G. Neophytides, Applied Catalysis B: Environmental (doi:10.1016/j.apcatb.2011.05.043).
7. "The effect of structural variations on aromatic polyethers for high temperature PEM fuel cells" Christina Morfopoulou, Aikaterini K. Andreopoulou, Joannis K. Kallitsis, J. Polym. Sci. Part A: Polym. Chem., 2011, 49, 4325–4334.
8. "Sulfonated Aromatic Polyethers Containing Pyridine Units as Electrolytes for High Temperature Fuel Cells", Ioannis Kalamaras, Maria K. Daletou, Vasilis G. Gregoriou and Joannis K. Kallitsis, Fuel Cells, In press.

Patents

"Crosslinked or not crosslinked aromatic copolymeric proton exchange electrolytes for use in polymer electrolyte fuel cells", Aik. Andreopoulou, Ch. Morfopoulou, A. Voegelé, K. D. Papadimitriou, F. Paloukis, S. G. Neophytides, J. K. Kallitsis, Greek Patent Application, February 2011.

Conferences

- "Influence of the Molecular Structure on the Properties and Fuel Cell Performance of High Temperature Polymer Electrolyte Membranes", J.K. Kallitsis, M. Geormezi, N. Gourdoupi, F. Paloukis, A.K. Andreopoulou, C. Morphopoulou and S. Neophytides, 10th Polymer Electrolyte Fuel Cell Symposium at the 218th Electrochemical Society Meeting, 10-15 October 2010, Las Vegas, USA.
- "Imidazole bearing aromatic polyethers targeting high temperature pem-fc applications", Aikaterini Andreopoulou, George Drakos, Maria Daletou, 8th Hellenic Polymer Society Symposium, 24-29 October 2010, Crete, Greece.
- "Effect of the molecular structure on the properties of high temperature polymer electrolyte membranes", Christine Morfopoulou, Maria Geormezi, Aikaterini K. Andreopoulou, Stylianos Neophytides, Joannis K. Kallitsis, 8th Hellenic Polymer Society Symposium, 24-29 October 2010, Crete, Greece.

- “Advent TPS® proton exchange membranes and MEAs for HT PEM fuel cells: Properties and Fuel Cell performance”, S. Neophytides, F. Paloukis, M. Geormezi, G. Paloumbis, J.K. Kallitsis, Fuel Cell Seminar and exposition, 18-21 October 2010, San Antonio, Texas, USA
- “Advent TPS® High Temperature PEM MEAs”, M. Geormezi, F. Paloukis, N. Gourdoupi, G. Paloumbis, S. Neophytides, J.K. Kallitsis, 2nd CARISMA International Conference on Progress in MEA materials for Medium and High temperature Polymer Electrolyte Fuel Cells, September 19-22nd 2010, Conference Centre, Palais des Congrès, La Grande Motte, France
- Preparation and Characterization of Pt/Modified MWCNT as Electrocatalysts for High Temperature PEMFCs, A. Orfanidi, M. Daletou and S. Neophytides, 8th Greek Scientific Conference of Chemical Engineering, 26-28 May 2011, Thessaloniki, Greece
- Preparation and Characterization of Pt/Modified MWCNT as Electrocatalysts for High Temperature PEMFCs, A. Orfanidi, M. Daletou and S. Neophytides, 9th European Symposium on Electrochemical Engineering, June 19-23, 2011, Chania, Crete, Greece.
- Preparation and Characterization of Pt/Modified MWNT as Electrocatalysts for High Temperature PEM Fuel Cells, 2nd CARISMA International conference on progress in MEA materials for Medium and High temperature PEM fuel cell, 19-22 September 2010 (poster)
- Functionalized carbon nanotubes and anode degradation in high temperature PEM fuel cells, A. Orfanidi, M.K. Daletou, S. G. Neophytides, 19th Annual International Conference on Composites or Nano Engineering, ICCE-19, July 24-30, 2011 in Shanghai, China.
- “What do we understand about the oxygen reduction reaction on Pt –based electrodes?”, E.R. Savinova, A. Bonnefont, P. S. Ruvinskiy, M.V. Lebedeva, 43rd IUPAC Congress, July 30th to August 7th 2011, San Juan, Puerto Rico, USA (*Invited*)
- “Challenges for Cathode Materials for Polymer Electrolyte Fuel Cells”, International Conference “Energy Challenges for Advanced Materials and Processes: Harvesting, Storage and Efficient Utilization”, M.V. Lebedeva, P. S. Ruvinskiy, M. Rouhet, A. Bonnefont, S. Zafeiratos, V. Papaefthymiou, V. Pierron-Bohnes, C. Pham-Huu, E.R. Savinova, 25 - 29 May 2011, Cappadocia, Turkey (*invited*).
- “Role of support in Electrocatalysis”, E. R. Savinova, International conference “Fundamentals of Fuel Cell”, January 2011, Grenoble, France (*invited*).
- “Size, microstructure and texture in heterogeneous electrocatalysis”, E. R. Savinova, Frumkin Seminar, 15 October 2010, Moscow, Russia (*Invited*).

- “Electrocatalysis at supported metal nanoparticles”, Elena Savinova, ELCAT Training School on “Structural and electronic effects in electrocatalysis” 30 August –1 September, 2010, Oegstgeest, Oud Poelgeest Castle, The Netherlands (*Invited*).
- “Mass transport effects in oxygen electroreduction reaction”, P. S. Ruvinsky, A. Bonnefont, E. R. Savinova, International Symposium on Electrocatalysis: Molecular Level Approach to Modern Applications, 22– 25 August 2010, Kloster Irsee; Germany (*invited*).
- “Development of low platinum catalytic layers for PEM fuel cells”, P. S. Ruvinsky, S. N. Pronkin, A. Bonnefont, and E. R. Savinova, 18th World Hydrogen Energy Conference, May 16-21, 2010, Essen, Germany (*invited*).
- “Interplay of the electrochemical reaction and diffusion in 3D nanoparticle arrays”, P. S. Ruvinsky, A. Bonnefont, E. R. Savinova, 1st Ertl Symposium on Electrochemistry and Catalysis, 11-14 April 2010, GIST, Gwangju, South Korea (*Key-note*).
- “Nanoscopic and mesoscopic effects in electrocatalysis”, E. R. Savinova, A. Bonnefont, S.N. Pronkin, P. S. Ruvinsky, A. N. Kuznetsov, 1st Korea-EU Networking Forum on Energy and Nanobio Technologies, April 14-16, 2010, Damyang Resort, South Korea (*invited*).
- “From Metal Nanoparticles to the Catalytic Layer Architectures”, E. R. Savinova, March 22-23, 2010, Southampton Electrochemistry Group Spring Meeting, Southampton , UK (*invited*).
- “Oxygen Reduction Reaction on 3D Electrodes based on Vertically Aligned Carbon Nanofilaments”, A. Bonnefont, P.S. Ruvinskiy and E.R. Savinova, *Elecnano4-7th Echems*, May 23- 26, 2011, Paris, France (Oral presentation).
- “Electrocatalysis on 3D electrodes based on aligned carbon nano-filaments”, P. Ruvinskiy, A. Bonnefont, M. Houlle, C. Pham-Huu, E.R. Savinova, The 61st Annual Meeting of the International Society of Electrochemistry, September 26th - October 1st 2010, Nice, France (Oral presentation).
- “Cooperative phenomena in 3D nanostructured electrodes: CO bulk electrooxidation on Pt nanoparticles supported on vertically aligned carbon nanofilaments”, A. Bonnefont, P.S. Ruvinskiy, M. Bayati, E.R. Savinova, The 61st Annual Meeting of the International Society of Electrochemistry, September 26th - October 1st 2010, Nice, France (Oral presentation).
- “Oxygen reduction reaction: what can we learn by applying 3D ordered catalytic layer architectures?” P. S. Ruvinskiy, A. Bonnefont, M. Houllé, C. Pham-Huu, E.R., Savinova, Gordon Research Conference on Fuel Cells, 2010, Smithfield, USA (Oral “flash” presentation).

- "Influence du transport de protons dans des couches catalytiques ordonnées tridimensionnellement sur l'adsorption de l'hydrogène", M. Rouhet, P.S. Ruvinskiy, E.R. Savinova, A. Bonnefont, GDR PACS 3339 , Lille, France, 6-8 décembre 2010 (Oral presentation).
- "Investigation of the proton transport in a layer of vertically aligned carbon nanofilaments (VACNFs) in liquid electrolyte", M. Rouhet, P.S., Ruvinskiy, E.R. Savinova, A. Bonnefont, PMNA, 18 février 2011, Strasbourg, France (Poster).
- "Mathematical Modelling of Platinum Catalyst Dissolution and Redistribution in the PEM Type Fuel Cell. K. Bouzek, R. Kodým, S. Sunde. 61st Annual Meeting of the International Society of Electrochemistry, 26.9.-1.10. 2010, Nice, France.
- "Two-dimensional mathematical model of Pt catalyst degradation in the PEM type fuel cells" M. Drakselová, R. Kodým, S. Sunde, K. Bouzek. 9th European Symposium on Electrochemical Engineering, 19.-23.6. 2011 Chania, Greece.
- "High-Temperature Polymer Electrolyte Membrane Fuel Cells: The Effect of Compression", A. Diedrichs, P. Wagner, A. Dyck, European Fuel Cell Forum 2011, Lucerne / Switzerland, 28.06.-01.07.2011 (poster).

Events

"Understanding the Degradation Mechanisms of Membrane-Electrode-Assembly for High Temperature PEMFCs and Optimization of the Individual Components" presented at Stakeholders General Assembly 2010, Brussels, 9-10 November

Workshops:

08.10.2010: XAS, ANKA Karlsruhe.

19./26.10.2010: XAS (EXAFS and $\Delta\mu$ XANES), TU Darmstadt by Dr. C. Roth and Prof. Dr. D. Ramaker.

XAS Beamtimes:

20.-25.05.2010: Hasylab X1, Hamburg.

06.-08.09.2010: Hasylab X1, Hamburg.

27.-30.09.2010: Hasylab X1, Hamburg.

08.-12.11.2010: Hasylab X1, Hamburg.

09.-13.05.2011: Hasylab X1, Hamburg.

In the following table A.1 is a list of scientific (peer reviewed) publications relating to the foreground of the project for the first 18 month.

Table A. 1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS

LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS										
N O.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers ¹ (if available)	Is/Will open access ² provided to this publication?
1	Using Ordered Carbon Nanomaterials for Shedding Light on the Mechanism of the Cathodic Oxygen Reduction Reaction	Pavel S. Ruvinskiy	Langmuir	27 (2011) 9018-9027.	American Chemical Society				http://pubs.acs.org/doi/abs/10.1021/la2006343	
2	Further insight into the oxygen reduction reaction on Pt nanoparticles supported on spatially structured catalytic layers	P. S. Ruvinskiy	Electrocatalysis	(2011) 123-133.	Springer				http://www.springerlink.com/content/u520230427620213/	
3	Preparation, testing and	P. S.	Electrochim	55 (2010)	Elsevier				http://www.scie	

¹ A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

² Open Access is defined as free of charge access for anyone via the internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards

	modeling of three-dimensionally ordered catalytic layers for electrocatalysis of fuel cell reactions	Ruvinskiy	. Acta,	3245-3256.					ncedirect.com/science/article/pii/S001346861000940	
4	Mass transport effects in CO bulk electrooxidation on Pt nanoparticles supported on vertically aligned carbon nanofilaments	Pavel S. Ruvinskiy	Phys Chem. Chem. Phys 2010	12 (46), 15207 – 15216.	RSC Publishing				http://pubs.rsc.org/en/content/articlelanding/2010/cp/c0cp00593b/	
5	Cathode Materials for Polymer Electrolyte Fuel Cells based on Vertically Aligned Carbon Filaments	P. S. Ruvinskiy	ECS Transactions	accepted.	The Electrochemical Society					
6	Preparation and characterization of Pt on modified multi-wall carbon nanotubes to be used as electrocatalysts for high temperature fuel cell applications	Alin Orfanidi	Applied Catalysis B: Environmental	2011, 106(3-4) , 379-389	Elsevier				http://www.sciencedirect.com/science/article/pii/S0926337311002621	

7	The effect of structural variations on aromatic polyethers for high temperature PEM fuel cells	Christina Morfopoulou	J. Polym. Sci. Part A: Polym. Chem.,	2011, 49, 4325–4334	John Wiley and Sons.				http://onlinelibrary.wiley.com/doi/10.1002/pola.24897/pdf	
8	Sulfonated Aromatic Polyethers Containing Pyridine Units as Electrolytes for High Temperature Fuel Cells	Ioannis Kalamaras	Fuel Cells	In press	John Wiley and Sons.					

Section B – Exploitation activities

Exploitable results - markets

The exploitable results, as listed in Table B.1, will be addressing the needs of universities, polymer and membrane producers, electrocatalysts and electrode producers, MEA producers, stack and energy production systems manufacturers, while the expected results of the projects will lead to the optimization and low cost production of materials (electrolytes, catalysts, bipolar plates and MEAs).

Table B. 1: OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND

OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND				
Exploitable Foreground (description)	Exploitable product(s) or measure(s)	Timetable, commercial use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Preparation of a series of polymeric materials (aromatic polyethers bearing polar pyridine groups) with tailor-made physicochemical properties	Polymer Electrolytes	Depends on market evolution	Greek Patent Application, 2011010000058	ADVENT, FORTH
Preparation of well defined nanostructured catalysts with enhanced support corrosion resistance and/or higher catalyst utilization	Catalysts and Catalytic layers	Depends on market evolution	-	FORTH
Preparation of well defined nanostructured catalysts based on		Depends on market evolution	-	CNRS
MEAs testing and degradation	Protocol of MEA testing		-	ALL
Development of a mathematical model of the catalysts degradation in HT PEMFCs	A mathematical model of the catalysts degradation in HT PEMFCs		-	ICTP

Intellectual property rights management

Background information

Partners have already indentified in the signed consortium agreement all Background information which they are ready to grant Access Rights to, as well as the ones the wish to be excluded.

The list of applications for patents, trademarks, registered designs, etc that are applied for so far, is given in Table B.2:

Table B. 2: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.

LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.			
Type of IP Rights: Patents, Trademarks, Registered designs, Utility models, etc.	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Greek Patent Application, February 2011.	2011010000058	Crosslinked or not crosslinked aromatic copolymeric proton exchange electrolytes for use in polymer electrolyte fuel cells	Aik. Andreopoulou, Ch. Morfopoulou, A. Voege, K. D. Papadimitriou, F. Paloukis, S. G. Neophytides, J. K. Kallitsis

