ARTEMIS

Automotive PEMFC range extender with high temperature improved MEAs and stacks

PANEL 2
Research activities for transport applications

ACRONYM	ARTEMIS
CALL TOPIC	SP1-JTI-FCH.2011.1.5: Next generation European MEAs for transportation applications
START DATE	1/10/2012
END DATE	31/12/2015
PROJECT TOTAL COST	€2,8 million
FCH JU MAXIMUM CONTRIBUTION	€2,8 million
WEBSITE	http://www.artemis-htpem.eu/

PARTNERSHIP/CONSORTIUM LIST

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, NEDSTACK FUEL CELL TECHNOLOGY BV, FUNDACION CIDETEC, CENTRO RICERCHE FIAT SCPA, POLITECNICO DI TORINO

MAIN OBJECTIVES OF THE PROJECT

ARTEMIS aimed at the development of new materials having higher performance and greater stability than current commercial materials for High Temperature PEMFC (130-180 °C) including a membrane, anode and cathode catalysts, and their implementation in MEAs and the MEAs in stacks, for application in an automotive range extender. The project plan included scale-up up to a 0.3 kW stack and consideration of scale-up to a 3 kW_e stack.

PROGRESS/RESULTS TO-DATE

- Cross-linked polybenzimidazole membrane with electrospun cross-linked reinforcement has conductivity >130 mS/cm at 130 °C, scaled-up to 400 cm^2.
- Electrodes fabricated after ink optimisation. Full size (200 cm^2) ARTEMIS MEAs produced by optimising the assembly parameters and sub-gaskets.
- ARTEMIS MEAs exceed 0.5 W/cm^2 at 1 A/cm^2 in 25 cm^2 single cells, and can be operated to 2 A/cm^2 (0.4 V) at ambient pressure, no humidification, 160 °C.
- ARTEMIS MEAs comprising ARTEMIS membrane and GDEs operated with range extender protocol >2200 hours without failure.
- Four-cell HT PEMFC stack produces >0.3 kW_e at 160 °C at ambient pressure and without humidification for currents over 165 A (825 mA/cm^2).

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:		MAWP 2008-2013	
New materials for high temperature MEAs and stacks	Membrane, catalyst, GDE, plate materials development	Membrane, electrode and plate materials with target specifications.	100 %
Automotive range extender application, 130-180 °C	Transport application, high temperature operation	MEAs operating 130-180 °C on RE protocol >2200 h to EoT	100 %
0.3 kW stack	MAIP 1- 10 kW built stack	0.3 kW_e stack built with ARTEMIS MEAs and tested	100 %
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:		AWP 2012	
MEA power density of 0.5 W/cm^2 @ 1 A/cm^2	Quantitative MEA target	MEA power density of 0.55 W/cm^2 @ 1 A/cm^2. Operation possible to 2 A/cm^2.	100 %
Acid loss and degradation understanding	Development of modelling tools	Models developed and used to assess FC performance and GDL degradation	100 %
(c) Other project objectives			
Dissemination of project results	Not applicable	Organisation of an ARTEMIS dissemination workshop	

AUTO-STACK CORE

Automotive Fuel Cell Stack Cluster Initiative for Europe II

PANEL 2

Research activities for transport applications

ACRONYM	AUTO-STACK CORE
CALL TOPIC	SP1-JTI-FCH.2012.1.2: Next Generation European Automotive Stack
START DATE	1/05/2013
END DATE	28/02/2017
PROJECT TOTAL COST	€14,6 million
FCH JU MAXIMUM CONTRIBUTION	€7,7 million
WEBSITE	http://autostack.zsw-bw.de/index.php?id=1&L=1

PARTNERSHIP/CONSORTIUM LIST

ZENTRUM FUER SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG, BADEN-WUERTEMBERG, BELENOS CLEAN POWER HOLDING AG, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, REINZ-DICHTUNGS GMBH, FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, FREUDENBERG FCCT SE & CO. KG, PAUL SCHERRER INSTITUT, Powercell Sweden AB, SOLVICORE GMBH & CO KG, SYMBIOFCELL SA, VOLKSWAGEN AG, VOLVO TECHNOLOGY AB, FREUDENBERG VLIESSTOFFE KG, SWISS HYDROGEN SA

MAIN OBJECTIVES OF THE PROJECT

Development of an automotive PEM fuel cell stack developed to automotive standards. Two stack evolutions will be built and tested in hardware, a third evolution will be designed. Component development is carried out based on industrial manufacturing concepts. Cost engineering is carried out to ensure the design meets automotive cost targets.

PROGRESS/RESULTS TO-DATE

- Stack evolution 1 designed, built and tested in more than 20 short stacks and one full sized stack.
- Design of evolution 2 stack completed. Significant reduction in weight and volume achieved.
- Evolution 2 component manufacturing and stack roll-out started. Evolution 2 test program started.
- Evolution 2 cost engineering study completed. Specific cost of <€38.31/kW .
- Evolution 3 design phase started.

FUTURE STEPS

- Completion of evolution 2 roll-out and test program.
- Improve CCM and GDL-selection.
- Completion of evolution 3 design.
- Continuation of benchmark studies.

Evo1 Evo2 Evo2b

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Evolution 1 hardware successfully designed, built and tested as short and full sized stacks.
- Evolution 2 hardware successfully designed and built.
- Evolution 2 testing campaign started, initial results indicate high power density at low PGM-loading: (>2.75 kW/kg; >3.1 kW/kg @ 0.32 g/kW PGM).

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
	Integrate the fragmented PEM stack research and development activities in Europe	Consortium formed from OEMs, supply industry, system integrators and research	100 %		Objective achieved
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2012
Gross power 95 kW	Gross power 95 kW	Evo 2: 98 kW (extrapolated)	100 %	114 kW (TOYOTA)	Evo 3 design will consider increased power demand
Specific power 2.15 kW/kg	Specific power >2 kW/kg	Evo 2 (extrapolated) >2,75 kW/kg	100 %	2.0 kW/kg (TOYOTA)	Objective achieved
(c) Other project objectives:					
PGM-loading Evo 2 0.4 g/kW	Not applicable	Eva 2: 0,32 g/kW	100 %	~ 0.3 g/kW (TOYOTA)	Improve power density by use of thinner membrane and improved GDL
<€30/kW @ 500,000 units p.a.	Not applicable	Eva 2: <€38,31/kW @ 30,000 units p.a.	100 %	36.05 US$ x kW-1 @ 30,000 units p.a. (US DoE)	Achievement of cost target expected from learning curves

CATAPULT

Novel catalyst structures employing Pt at Ultra Low and zero loadings for automotive MEAs

PANEL 2

Research activities for transport applications

ACRONYM	CATAPULT
CALL TOPIC	SP1-JTI-FCH.2012.1.5: New catalyst structures and concepts for automotive PEMFCs
START DATE	1/06/2013
END DATE	31/05/2016
PROJECT TOTAL COST	€4,6 million
FCH JU MAXIMUM CONTRIBUTION	€2,2 million
WEBSITE	http://www.catapult-fuelcells.eu/

PARTNERSHIP/CONSORTIUM LIST

UNIVERSITE DE MONTPELLIER, JOHNSON MATTHEY FUEL CELLS LIMITED, VOLKSWAGEN AG, BENEQ OY, TECHNISCHE UNIVERSITAET MUENCHEN, Teknologian tutkimuskeskus VTT Oy, UNIVERSITAET ULM, PRETEXO

MAIN OBJECTIVES OF THE PROJECT

The objective of CATAPULT is to develop ultra-low Pt loading cathode catalysts with mass activity exceeding that obtained with reference Pt/C using ultra-thin extended film coatings on novel nanostructured (fibrous) corrosion-resistant supports, and non-PGM catalysts and integrate the novel catalysts into MEAs. Modelling efforts support the materials development and provide fundamental insights into catalyst surface and crystallographic properties and the oxygen reduction reaction. The final aim is to achieve a platinum specific power density of 0.1 g/kW Pt.

PROGRESS/RESULTS TO-DATE

- Nanofiber supports and tie-layers using electrospinning and atomic layer deposition are corrosion-resistant, electronically conducting, scalable.
- Pt films deposited by atomic layer deposition on corrosion resistant fibrous supports exceed target mass activity, >0.5 A/mg Pt.
- Novel non-PGM catalysts with ultra-low Pt content demonstrate high stability in MEAs.
- Most mature catalyst has been scaled-up and integrated into novel electrode designs, and MEAs of size 50 cm^2 active area.
- DFT-validated force-field model of the oxidative disruption of Pt (111) crystal facets shows they are unlikely to persist in fuel cell operation.

FUTURE STEPS

- Complete technical assessment against incumbent conventional Pt/C catalysts.
- Complete final MEA performance, in situ accelerated stress test and catalyst durability testing.
- Finalise reports.
- CATAPULT ends 31/05/2016 – most promising technologies will be pursued in FCH 2 JU INSPIRE.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Pt thin films or nano-islands deposited on fibrous supports show high mass activity in ring disk electrode (RDE).
- Catalyst layer development with fibrous architecture electrocatalysts requires better understanding of the limiting factors.
- Future focus is needed also on use of alternative tie-layer compositions favouring Pt deposition as ultra-thin films.
- Current catalyst layer designs comprising novel extended thin layer catalysts show much higher stability to voltage cycling than conventional Pt/C.
- A means to stabilise highly active non-PGM catalysts against voltage loss with time shows high promise for future development.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:				MAWP 2008-2013
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:				AWP 2012
Nanometric supports with σ >10-2 S/cm	Development of robust and corrosion resistant supports	Nanofibrous supports with σ $>10^{-2}$ S/cm and 10 times lower corrosion current than carbon black	100 %	
Development of ultra-low Pt loading catalysts by atomic layer deposition and electrochemical methods	Development of catalysts and electrode layers for significant reduction in precious metal loadings	Development of thin extended platinum surfaces having RDE mass activity >0.5 A/mg Pt.	100 % mass activity target reached in RDE.	Current status for MEA: 0.25 g Pt / kW at 70 % and 30 % RH
Development of iron-based and hybrid non-PGM-ultra-low Pt loading catalysts	Development of non-platinum based catalysts	Fe-based catalysts with high BoL performance, and stable hybrid non-PGM-ultra-low Pt catalysts.	100 % for development of new catalysts	MEA performance under automotive relevant conditions is 50 % of the target, however it exceeds the international SoA.
Supporting theoretical modelling to understand catalytic processes & catalyst-support interactions	Supporting theoretical modelling to understand catalytic processes & catalyst-support interactions	Pt-support tie-layers for Pt wettability and catalytic activity predicted by modelling.	100 %	
Catalysts integrated into novel electrode designs and MEAs	Demonstration of long-term stability under automotive fuel cell conditions	MEA performance 60 % of target with current catalyst layer design. High stability to voltage cycling	60 %	MEA performance is 60 % of the target with the current catalyst layer designs comprising the novel extended thin layer catalysts. Much higher stability to voltage cycling than with conventional Pt/C.
Techno-economic assessment	Techno-economic assessment	Techno-economic status report made of five CATAPULT catalyst developments	100 %	The technologies are all significantly less mature than conventional Pt/C meaning that this assessment is a status report and not a final assessment.
(c) Other project objectives:				
International workshop	Not applicable	Intern'l conference "Challenges for Zero Pt for Oxygen Reduction", 13-16/09/2016, 170 participants.	100 %	La Grande Motte, France. Joint session CATAPULT – CATHCAT – NanoCat – SMARTCAT

CATHCAT

CATHCAT

Novel catalyst materials for the cathode side of MEAs suitable for transportation applications

PANEL 2
Research activities for transport applications

ACRONYM	CATHCAT
CALL TOPIC	SP1-JTI-FCH.2011.1.5: Next generation European MEAs for transportation applications & SP1-JTI-FCH.2011.1.6: Investigation of degradation phenomena
START DATE	1/01/2013
END DATE	31/12/2015
PROJECT TOTAL COST	€3 million
FCH JU MAXIMUM CONTRIBUTION	€1,8 million
WEBSITE	http://www.cathcat.eu/

PARTNERSHIP/CONSORTIUM LIST

TECHNISCHE UNIVERSITAET MUENCHEN, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, UNIVERSITE DE POITIERS, DANMARKS TEKNISKE UNIVERSITET, CHALMERS TEKNISKA HOEGSKOLA AB, UNIVERSITA DEGLI STUDI DI PADOVA, ION POWER INC CORP, FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS, TOYOTA MOTOR EUROPE

MAIN OBJECTIVES OF THE PROJECT

Development of improved MEAs for low and intermediate temperature PEM, based on binary alloy catalysts with reduced Pt loading for the oxygen reduction reaction (ORR), and advanced support materials. Based on density functional theory (DFT) calculations and experimental studies of bulk analogues of Pt and Pd – Rare Earth Element alloys full understanding of these materials should be achieved. Synthesis of promising catalysts was to be up-scaled and integrated with advanced supports into MEAs for single cell testing. MEAs based on Nafion and on high temperature polymer electrolytes were applied.

PROGRESS/RESULTS TO-DATE

- Theoretical studies for all Pt-RE alloys of interest were carried out and validated with experimental studies. Pt5Gd best catalyst.
- Pt-Gd nanoparticles are 3.6 x more active than Pt nanoparticles, from RDE tests a current density of 0.8 – 1.4 A cm^2 at 0.9 V extrapolated.
- Several techniques explored for fabrication of Pt-RE nanoparticles. Pt-Y catalyst upscaled for MEA manufacture.
- Modified supported materials have been developed and upscaled for MEA testing.
- Several catalysts have been tested in MEAs, but not yet with Pt-RE alloys. MEAs tested so far not better than benchmark MEA.

FUTURE STEPS

- Testing of MEA with Pt-Y- alloy catalyst
- Continuation of catalyst synthesis efforts in the framework of other projects.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Pt-rare earth alloys represent a group of improved catalysts permitting a reduction of noble metal content of MEAs by a factor of 4-5.
- Modified support materials can cause a further increase in catalytic activity.
- Pt-rare earth nanoparticles show the maximum mass activity at larger particle diameter reducing problems with agglomeration.
- DFT calculations can serve as a guide for the development of new catalyst materials.
- Preparation of these alloys in nanoparticulate form by non-vacuum based methods successful, but further work required for upscaling.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
New improved MEAs based on stable catalysts for the ORR in PEMFCs	Electrochemically stable and low-cost catalysts for MEAs	Benchmarks MEAs and first CathCat MEA with modified Catalyst and Support tested	0 %	n/a	With a reduced Pt loading, advanced C-based and oxide-based support materials
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2011
Development of catalysts based on Pt or Pd – RE element alloys, based on DFT calculations	Development of catalysts for reduction in precious metal loading	Successful materials development and physical understanding. Not tested in normal MEA	100 %	n/a	PtxY & PtxGd nanoparticles improved mass activity (x3.6) and activity at larger particle size, synthesis of large amounts difficult
Development of advanced C and oxide based supports	Development of catalysts for reduction in precious metal loading	Successful RTD and half cell testing	100 %	n/a	Good performance of ring disk electrodes, contrary of MEA tests where amount of material didn´t suffice to optimize catalyst layer composition
Use of HT membranes and testing of catalysts under these conditions	Demonstration of HT properties	HT MEAs fabricated and tested	100 %	n/a	Pt-Co alloys on MWCNT synthesized, MEAs with Pt/C and Pt/MWCNT fabricated and tested up to 180 °C. No Pt-Y alloy tested.
Durability studies carried out using Surface Science and microscopic techniques	Demonstration of long-term stability under automotive FC conditions	Half cell testing demonstrated stability of the catalyst materials under relevant conditions	0 %	2500 h / DOE Annual Merit Review 2015	Durability of new catalysts in MEA poor (Pt-Y2O3) or not tested (Pt-Y) due to lack of material
<0.1 g/kW Pt, activity increase by factor 10	Pt loadings <0.15 g/kW, BoL>55% efficiency, >1 W/cm^2 @ 1.5 A/cm^2	0.4 g/kW; efficiency: 56% @1 A cm-2; 50% @ 1.5 A cm-2, power density: >0.9 W cm-2 @ 1.5 A cm-2	0 %	0.9 W cm-2 @ 1.5A cm-2 (2010, Wagner), 0.17 g/kW Pt US (NSTF) DOE Fiscal year 2014 Budget at a glance, (2012)	Benchmark MEA with 20 µm Nafion gave best results
(c) Other project objectives					
Development of Synthetic Procedures for Pt-rare earth nanoparticles fabrication	Not applicable	Methods developed, up-scaling challenging	0	n/a	Sputter-deposition techniques successfull, electrochemical methods promising, but further research required, solid state method successful.

COBRA

Coatings for bipolar plates

PANEL 2

Research activities for transport applications

ACRONYM	COBRA
CALL TOPIC	SP1-JTI-FCH.2013.1.2: Research & Development on Bipolar Plates for PEM fuel cells
START DATE	1/04/2014
END DATE	31/03/2017
PROJECT TOTAL COST	€3,8 million
FCH JU MAXIMUM CONTRIBUTION	€2,3 million
WEBSITE	http://www.cobra-fuelcell.eu/

PARTNERSHIP/CONSORTIUM LIST

COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, BORIT NV, IMPACT COATINGS AB, SYMBIOFCELL SA, FUNDACION CIDETEC, INSTITUT NATIONAL DES SCIENCES APPLIQUEES DE LYON

MAIN OBJECTIVES OF THE PROJECT

With a consortium integrating expertise in bipolar plate (BP) design and manufacturing, COBRA project aims to develop and prepare the industrialization of new metallic bipolar plates coatings, demonstrating a higher corrosion resistance (corrosion <1µA/cm²), lower electrical resistance (<25mOhm.cm²) and lower price (<2.5€/kW). The project organization emphasis the importance of field tests, using post-mortem and adapted tests procedures to understand ageing mechanisms in system conditions. This approach will help develop corrosion resistant and conductive new coatings suitable for FC applications.

PROGRESS/RESULTS TO-DATE

- Reference plates have been manufactured and tested on field in automotive and marine conditions.
- A complete post-mortem analysis have been done allowing new observations and understandings on corrosion topic.
- A model of Fuel Cells and Bipolar Plates ageing has been improved including corrosion behaviour.
- Innovative manufacturing process and coatings were developed.
- Best coatings are defined and new COBRA plates are being manufactured.

FUTURE STEPS

- New stacks, including innovative coatings, will be tested on-field in same conditions has references plates.
- A complete Life Cycle Analysis (LCA) will be provided.
- A technico-economical study will be realized.
- Following STAMPEM-COBRA joint workshop, a new workshop in Grenoble will be organized to strengthen BP stakeholder community.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Corrosion mechanisms understanding.
- Ageing tests developments.
- Innovative coatings developments.
- Innovative coatings commercialization.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Durability (h)	>5,000	N/A (test not yet finalized)	N/A	3,000	To be done during the last year of the project
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2013-1
Corrosion, anode (µA/cm²)	<10	0.119	100 %	state of the art	Part of COBRA coating selection matrix
Corrosion, cathode (µA/cm²)	<10	0.77	100 %	state of the art	Part of COBRA coating selection matrix
Areal specific resistance (m.cm²)	<25	11	100 %	state of the art	Part of COBRA coating selection matrix
Cost (production of 500,000 units)	<2,5€/kW	N/A (test not yet finalized)	N/A	20	To be done during the last year of the project

COPERNIC

Cost & performances improvement for CGH2 composite tanks

PANEL 2

Research activities for transport applications

ACRONYM	COPERNIC
CALL TOPIC	SP1-JTI-FCH.2012.1.3: Compressed hydrogen on board storage (CGH2)
START DATE	1/06/2013
END DATE	30/11/2016
PROJECT TOTAL COST	€3,5 million
FCH JU MAXIMUM CONTRIBUTION	€1,9 million
WEBSITE	http://www.project-copernic.com/

PARTNERSHIP/CONSORTIUM LIST

COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, RAIGI SAS, SYMBIOFCELL SA, HOCHDRUCK REDUZIERTECHNIK GMBH, POLITECHNIKA WROCLAWSKA, OPTIMUM CPV, H2 Logic A/S, ANLEG GMBH

MAIN OBJECTIVES OF THE PROJECT

To improve the CGH2 storage system cost, COPERNIC will provide real scale demonstration on a pilot manufacturing line and quantitative assessment of strategies including evolution of materials, components, processes and designs:

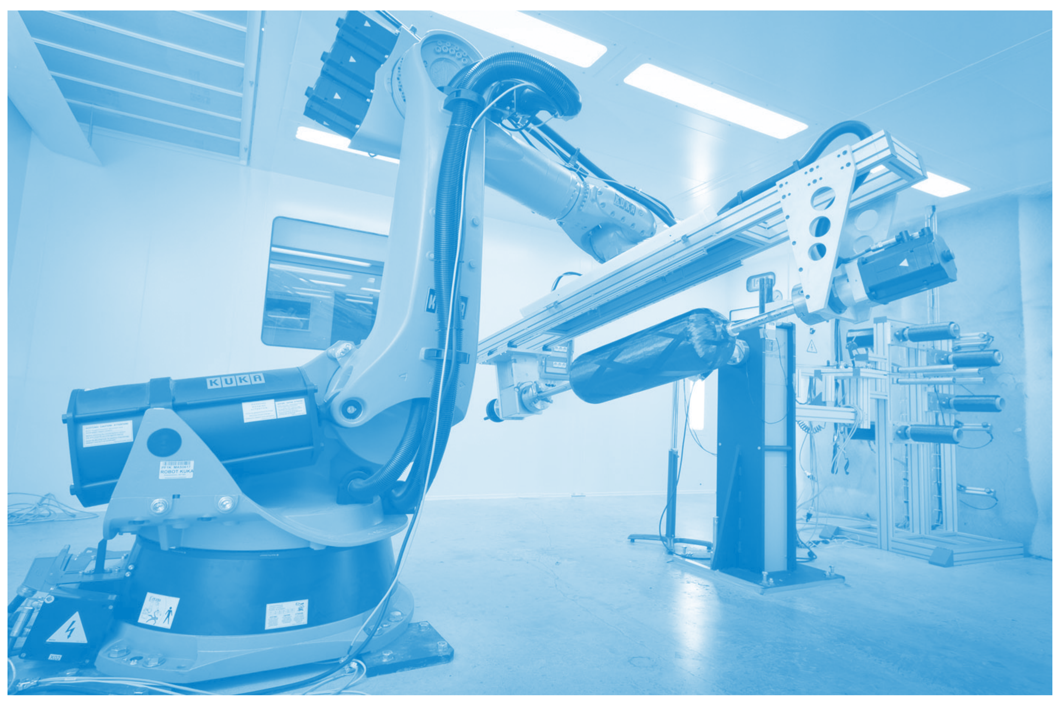
- Enhanced materials (resins, carbon fibre, inserts).
- Innovative components (all-in-one on-tank valve, on/off board structural health monitoring).
- Enhanced composite design (improved geometries).
- Improved composite quality (tank performance repeatability).
- Higher manufacturing process control and productivity (automation, winding numerical control).

PROGRESS/RESULTS TO-DATE

- Reduction costs: Optimisation of composite (-13 %), + Higher volume (37L to 61L: -40 %)+ Higher annual production (for 8,000 unit -70 %). Target achieved.
- Improvement vessel performance: Copernic Gravimetric capacity: 4.99 %; Volumetric capacity: 0.0221kg/L.
- Significant breakthroughs implemented in the on-tank valve (OTV) (reduction of mass, number of parts, power consumption). Certification process on-going.
- Productivity improvement (27kg of composite) from a 120 minutes winding time (wet winding) to 70 minutes (with 8 axes robot and prepreg).

FUTURE STEPS

- Structural health monitoring (SHM) tests activities remain on-going for manufacturing quality process.
- New target for winding time with prepreg: 54 min (-55 %).
- ComposicaD batchmode.
- Work on alternative geometries (tubes and sphere design).
- Pass the certification process – October 2016.



CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- The FCH JU 2020 target on cost= 600€/H2Kg is realistic and feasible according to actual Copernic result which is at 608€/H2Kg.
- Copernic Gravimetric capacity is in line with FCH JU 2020 target (5 %).
- Copernic Volumetric capacity is in line with FCH JU target 2017 (0.022Kg/L).
- SHM allows the identification of abnormal behaviour of the vessel before leak, and the upgrade of the SAE J2601 protocol to improve safety.
- The Copernic OTV is ready to be commercially launched

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Design/ test criteria for CGH2 storage system	Contribute to advancement of relevant test methods	Tanks and pressure components have been defined, tested and validated	100 %	(37L) System cost: 1841€/H2Kg Gravimetric capacity = 3.57 % Volumetric capacity: 0.0217kg/L	Copernic result on cost: 608€/H2Kg Gravimetric capacity: 4.99 % Volumetric capacity: 0.0221kg/L
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2012
Development activities on materials	Assess alternative materials to improve performance/ cost ratio	Alternative materials selected	100 %	– Resin SoA: 16€kg – Machining Boss SoA: 150€/ unit boss – Composite Design SoA: 27kg (37L)	– Resin: 7€ kg (-56 %) – Boss (price for 8,000 forged units): €15-20 (reduced by factor 8) – No low cost fiber Carbon for automotive application
Lower cost production processes	Assess manufacturing technology improvement strategies	Comparison of winding technologies Equipment improvement under implementation on pilot line	100 %	– Initial winding time for 37L with wet winding and 27 Kg of composite: 120 min	– Winding time reduced to 70 min with prepreg (-41 %) – Improvement of programming tool Robot interface
Improved complete tank systems and components	Reduced weight and volume. Fully integrated OTV	Innovative vessel design and all-in-one compact pressure device: defined, produced	100 %	Vessel 37L: 27kg composite OTV: – Reduction of weight: 6 kg down to 3.5 kg. – number of parts from 146 down to 80 – power consumption: /10	– Optimised design vessel: 27 to 21kg composite. – OTV: mass 1,2kg number of parts: 96 Power consumption: 10 Watt
On or off/board diagnosis systems for containers	Develop and assess non destructive examination method methods for SHM of composite overwrapped pressure vessel	Identification of abnormal behaviour of vessel before leak. Update on protocol SAE J2601	100 %		SHM allows the identification of abnormal behaviour of the vessel before leak, and the upgrade of the SAE J2601 protocol to improve safety.

H2REF

Development of a cost effective and reliable hydrogen fuel cell vehicle refuelling system

PANEL 2

Research activities for transport applications

ACRONYM	H2REF
CALL TOPIC	FCH-01.5-2014: Development of cost effective and reliable hydrogen refuelling station components and systems for fuel cell vehicles
START DATE	1/09/2015
END DATE	31/08/2018
PROJECT TOTAL COST	€6,4 million
FCH JU MAXIMUM CONTRIBUTION	€5,9 million
WEBSITE	

PARTNERSHIP/CONSORTIUM LIST

CENTRE TECHNIQUE DES INDUSTRIES MECANIQUES, H2NOVA, HASKEL FRANCE, HEXAGON RAUFOSS AS, THE CCS GLOBAL GROUP LIMITED, Ludwig-Boelkow-Systemtechnik GmbH

MAIN OBJECTIVES OF THE PROJECT

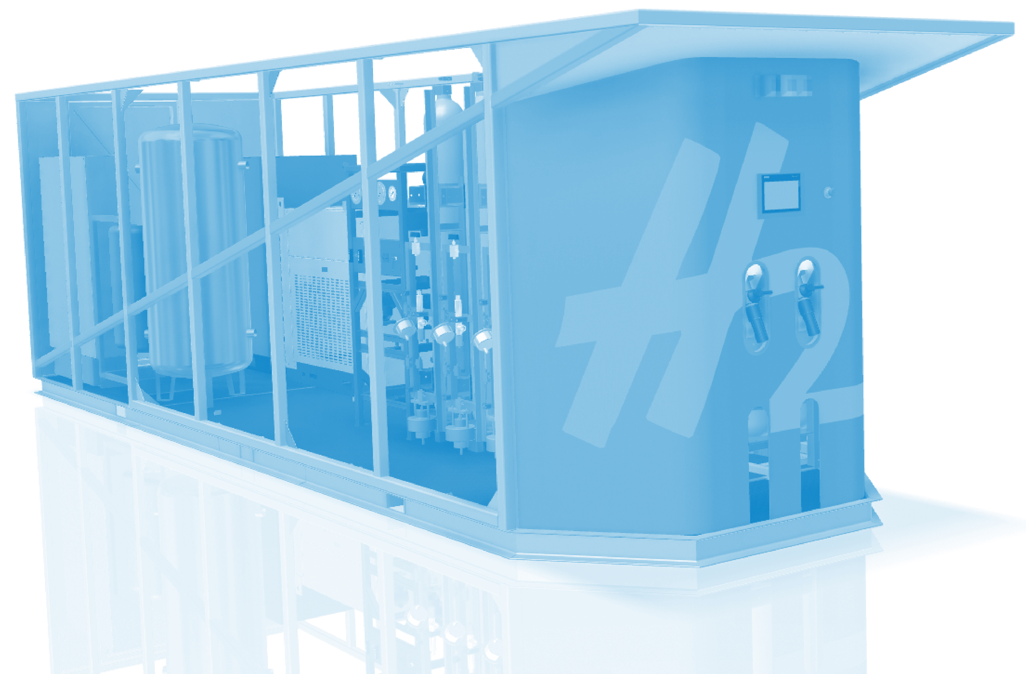
H2Ref addresses the compression and buffering function for the refuelling of 70 MPa passenger vehicles and encompasses all the necessary activities for advancing a novel hydraulics-based compression and buffering module (CBM) that is very cost effective and reliable from TRL 3 (experimentally proven concept) to TRL 6 (technology demonstrated in relevant environment), thereby proving highly improved performance and reliability.

PROGRESS/RESULTS TO-DATE

- Specification of the CBM prototype.
- Detailed specification of CBM component test bench.
- Multi physical (hydraulic, thermal, thermodynamic) model of the CBM prototype.

FUTURE STEPS

- Construction and implementation of the CBM component test bench.
- Qualification of CBM components.
- Construction of CBM prototype.



CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Not applicable, project started in September 2015.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:				MAWP 2014-2020
Bring from TRL3 to TRL6 a technical solution providing a step change in cost and reliability	Compressors are both too expensive and not reliable enough for commercialisation purposes	70 % (research and innovation action)		Work in progress (1st year of the project)
Compression and buffering module manufacturing cost: €300k assuming a production of 50 / year	Hydrogen refuelling stations cost 0,8 M€ for a 200 kg per day in 2020	70 % (research and innovation action)	€750k (50 % of the current HRS cost)	Work in progress (1st year of the project)
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:				AWP 2014
Prepare RCS framework for commercialisation worldwide	Not applicable	90 %	Gaps need to be addressed for covering the new solution developed	Work in progress (1st year of the project)

IMMEDIATE

Innovative automotive MEA development – implementation of IPHE-GENIE achievements targeted at excellence

PANEL 2

Research activities for transport applications

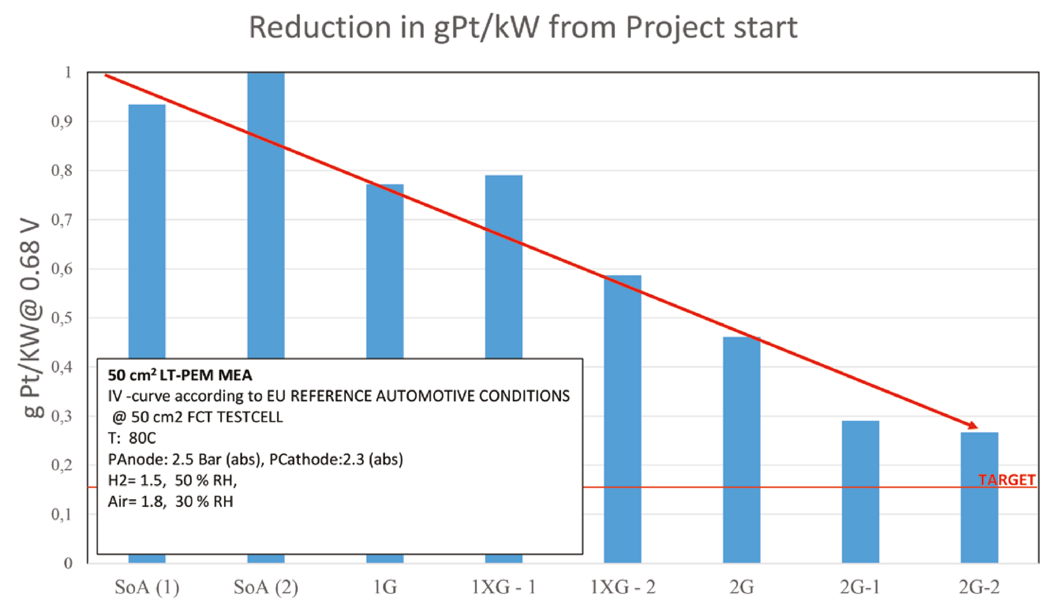
ACRONYM	IMMEDIATE
CALL TOPIC	SP1-JTI-FCH.2011.1.5: Next generation European MEAs for transportation applications
START DATE	1/01/2013
END DATE	31/03/2016
PROJECT TOTAL COST	€3,6 million
FCH JU MAXIMUM CONTRIBUTION	€2 million
WEBSITE	http://www.immediate.ird.dk/

PARTNERSHIP/CONSORTIUM LIST

IRD FUEL CELLS A/S (INDUSTRIAL RESEARCH & DEVELOPMENT A/S), USTAV CHEMICKYCH PROCESU AV CR, v. v. i., CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, FUMA-TECH GESELLSCHAFT FUER FUNKTIONELLE MEMBRANEN UND ANLAGENTECHNOLOGIE MBH, SHANGHAI JIAO TONG UNIVERSITY, VOLVO TECHNOLOGY AB, SGL CARBON GMBH, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, IMERYS GRAPHITE & CARBON SWITZERLAND LTD

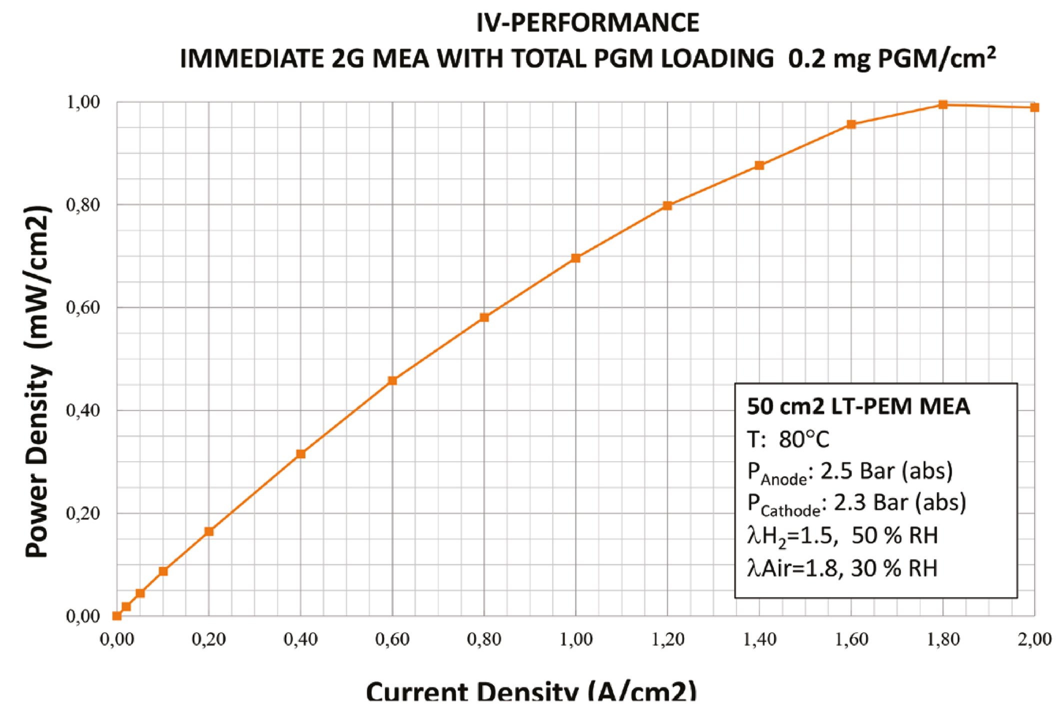
MAIN OBJECTIVES OF THE PROJECT

The overall objective of the IMMEDIATE project is to develop a medium temperature PEM MEA FC that will fulfil the OEM requirements with respect to cost, performance and durability. The prime focus of Immediate to develop MEAs aimed for transportation applications is through material R&D & process optimization and to screen and test precursor materials such as ionomers, membranes, catalyst, catalyst supports and gas diffusion layers aiming to demonstrate an optimized MEA and accomplish the target with performance >1.0 W/cm² @ automotive test conditions.



PROGRESS/RESULTS TO-DATE

- A range of carbon supports with a variety of surface properties and optimized mesoporosity have been developed
- A range of 60wt% PGM/C catalyst fabricated and evaluated (activity, accelerated stress test (AST), MEA performance)
- New short-side-chain (SSC) and cross-linkable ionomers based on perfluorosulfonic acid (PFSA) polymer have been developed
- Improved gas diffusion layer with enhanced conductivity and water retention
- MEA performance demonstrated with power density of 0.75 W/cm² @ 0.68 V

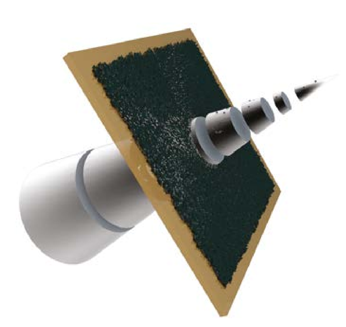


CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- MEA performance: Power density 1.0 W/cm² @ 0.20 gPt/kW.
- New industrial production processes developed.
- Durability and stability of low PGM MEAs demonstrated.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan: MAIP 2008-2013			
The overall aim is to develop Membrane Electrode Assemblies with PGM-loading of <0.15 g PGM/kW	MAIP 2008-13: Busses Vehicle PEM-FC System: <3,500€/kW	0.22 g PGM/kW	Project ended April 31 2016
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan: AIP 2011			
Membrane with proton conductivity of at least 0.1S/cm at 95ºC & 25 % RH	2015: Membrane with proton conductivity [3] 100mS/cm at £ 25 % RH, 120ºC	90 mS/cm at 100 ºC and 50 % RH	Project ended April 31 2016
GDL with through plane conductivity >2 S/cm at nominal operating conditions	GDL with area conductivity (through plane) >2 S/cm at operating conditions	GDL with conductivity of 4.4 mOhm*cm²	Project ended April 31 2016
2015. MEA with PGM-loading of <0.15 g PGM/kW	2015. MEA with PGM-loading of <0.15 g PGM/kW	0.22 g PGM/kW	Project ended April 31 2016
MEA BOL of >1.0 W/cm² @ UCell=0.68 V	MEA BOL of >1.0 W/cm² @ UCell=0.68 V	MEA BOL of 0.8 W/cm² @ UCell=0.68 V	Project ended April 31 2016



IMPACT

Improved lifetime of automotive application fuel cells with ultra low Pt-loading

PANEL 2

Research activities for transport applications

ACRONYM	IMPACT
CALL TOPIC	SP1-JTI-FCH.2011.1.5: Next generation European MEAs for transportation applications & SP1-JTI-FCH.2011.1.6: Investigation of degradation phenomena
START DATE	1/11/2012
END DATE	31/10/2016
PROJECT TOTAL COST	€9,1 million
FCH JU MAXIMUM CONTRIBUTION	€3,9 million
WEBSITE	http://www.eu-project-impact.eu/

PARTNERSHIP/CONSORTIUM LIST

DEUTSCHES ZENTRUM FUER LUFT – UND RAUMFAHRT EV, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, CONSIGLIO NAZIONALE DELLE RICERCHE, ITM POWER (TRADING) LIMITED, JOHNSON MATTHEY FUEL CELLS LIMITED, ZENTRUM FUER SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG, BADEN-WUERTEMBERG, HOCHSCHULE ESSLINGEN, TECHNISCHE UNIVERSITAT BERLIN, INSTITUT NATIONAL POLYTECHNIQUE DE TOULOUSE, GWANGJU INSTITUTE OF SCIENCE AND TECHNOLOGY, SOLVAY SPECIALTY POLYMERS ITALY S.P.A

MAIN OBJECTIVES OF THE PROJECT

Main objectives are: to increase the life-time of ultra–low Pt-loaded MEAs (<0.2 mgcm-2) for automotive applications to 5,000 h in dynamic operation with degradation rates <10 µVh-1 and to obtain a power density of 1 Acm-2. To achieve these targets relevant degradation mechanisms are identified and mitigation strategies are implemented by material development, structural design of cells and materials, and integration of improvements into a best MEA. The results of the improved durability of the cell technology will be demonstrated in a relevant PEMFC stack.

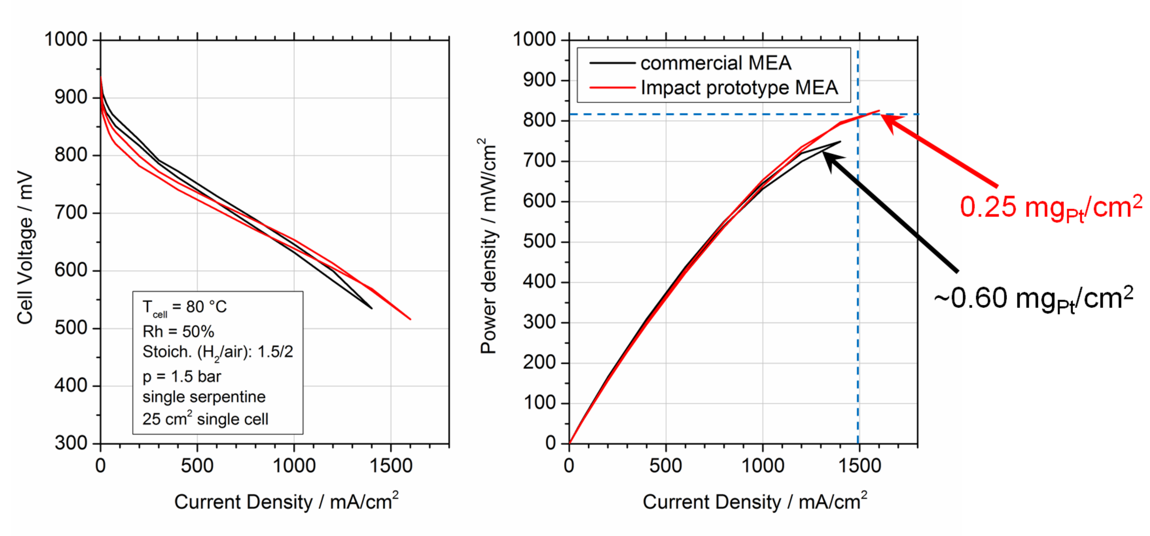
PROGRESS/RESULTS TO-DATE

- Seven iterations of MEA development accomplished allowing defining a final MEA to reach the durability objective.
- Development of i) improved thinner perfluorosulfonic acid (PFSA) membranes with stabilizing agents, ii) improved ink composition with novel ionomers.
- Reduction of irreversible degradation rate by factor >10 down to ~10 µVh-1 at 1 Acm-2 and 0.21 mgcm-2 overall Pt loading.
- Reduction of Pt loading from 0.6 to 0.25 mgcm-2 without performance losses.
- Detailed analysis of determination of reversible and irreversible degradation in dynamic conditions.

FUTURE STEPS

- Test of final project MEA in single cell and stack in dynamic conditions.
- Demonstration of durability targets in a 2,500 – 5,000 h stack test.

Performance achievements



- Organization of a workshop on degradation issues of PEMFC for automotive applications.
- Publications of a study on comparability of single cell and stack measurements.
- Publication of a study on the effect of Pt loading on performance and durability.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Stability of ionomer in the catalyst layer is the limiting factor for MEA durability and irreversible degradation.
- Reversible degradation exhibits a linear-exponential behaviour and is dominated by water management issues.
- A shutdown recovery procedure leads to a temporary elimination of reversible performance losses.
- IMPACT recommends to establish a common way to determine and report degradation rates.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Lifetime of 5,000 h in dynamic operation, with a degradation rate below 10 µVh-1	Lifetime of 5,000 h in dynamic operation, with a degradation rate below 10 µVh-1	Demonstration of 10 µVh-1 in single cell; final 2,500 – 5,000 h stack test under preparation	80 %	~4,000 h (https://www.hydrogen.energy.gov/pdfs/review15/fc,000_papageorgopoulos_2015_o.pdf)	Reduction of irreversible degradation rate by factor >10 down to ~10 µVh-1 at 1 Acm-2 and 0.21 mgcm-2 overall Pt loading
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2011
Irreversible and reversible degradation mechanism categorization	Irreversible and reversible degradation mechanism categorization	Detailed study on irreversible degradation rates and performance recovery procedures	100 %	IMPACT outcomes are setting the state-of-the-art for degradation rate determination	
Pt loadings <0.2 mgPt/cm²	Development of catalysts and electrode layers allowing for significant reduction in precious metal catalyst loadings	Pt loading 0.21 – 0.25 mgPt/cm²	50 %	Pt loading around 0.3 – 0.5 mgPt/cm² (Autostack-CORE interim results, F-Cell 2015)	This target which goes beyond state-of-the-art can be considered as reached only if target 4 is reached in parallel
1 W/cm² at 670 mV (1.5 A/cm²) single cell performances	1 W/cm² at 670 mV (1.5 A/cm²) single cell performances	For 0.25 mgPt/cm² obtained: 0.93 W/cm² at 1.5 A/cm² and 2 bar, 0.81 W/cm² at 1.5 A/cm² and 1.5 bar	80 %	~ 1 W/cm² at 1.5 A/cm² and 2.2 bar (http://ecst.ecsdl.org/content/69/17/957.full.pdf)	Cell performance is highly affected by cell design and operation conditions; performance target will be achieved independent of durability target

IMPALA

Improve PEMFC with advanced water management and gas diffusion layers for automotive application

PANEL 2

Research activities for transport applications

ACRONYM	IMPALA
CALL TOPIC	SP1-JTI-FCH.2011.1.5: Next generation European MEAs for transportation applications
START DATE	1/12/2012
END DATE	30/11/2015
PROJECT TOTAL COST	€5 million
FCH JU MAXIMUM CONTRIBUTION	€2,6 million
WEBSITE	http://www.impala-project.eu/

PARTNERSHIP/CONSORTIUM LIST

COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, DEUTSCHES ZENTRUM FUER LUFT – UND RAUMFAHRT EV, PAUL SCHERRER INSTITUT, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, INSTITUT NATIONAL POLYTECHNIQUE DE TOULOUSE, SGL CARBON GMBH, NEDSTACK FUEL CELL TECHNOLOGY BV

MAIN OBJECTIVES OF THE PROJECT

The aim of IMPALA is to produce improved GDL to increase performance (up to 1 W/cm²) of PEMFC for automotive application by a twofold approach: a) modification of homogeneous GDL (micro-porous layer (MPL), wettability, additives…); b) development of innovative non-uniform GDL.

This technological work is supported by a deep water management analysis combining the most advanced two-phase models (Pore Network Modelling) and experimental diagnostics (X-Ray liquid visualisation). This will help better understand the link between GDL properties and performance and propose design recommendations.

PROGRESS/RESULTS TO-DATE

- An improved GDL (named IMPALA#30) has been developed and will be commercialized. It allows increasing performance (12 %) and reducing stack cost (7 %).
- Numerous modifications of GDL have been done and tested: MPL, hydrophobic treatment, structuration… Most are scalable and ready for future work.
- Pore Network Modelling (PNM) has been improved (use of real 3D images, condensation effect) and 3D X-Ray images of liquid patterns have been obtained.
- Intensive comparison has been done successfully between PNM and 3D X-Ray images on ex-situ and in-operando experiments.
- Condensation scenario is the most representative one, at least when operating around 80 °C. This is in full contrast with classical publications.

FUTURE STEPS

- Optimize the combination of different improvements (MPL, hydrophobic treatment…) and correlate them with modelling and characterisation results.
- Progress on the multiscale coupling of models especially in the case of two-phase flows.
- Measure key bulk properties of GDL (wettability, binder…) by non-destructive investigation tools.
- Analyse the MPL (structure, properties, penetration…) so as to analyse its role and propose more reliable "design" recommendations of GDL .
- Numerous publications have been done, some remaining ones are to be finalized.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Performance has been significantly increased by modifying properties of the backing and/or of the MPL of commercial reference GDL.
- Improvements of GDL are not always additive and the interaction with the electrodes is important, especially at high current densities.
- Other increase of performance could be obtained with a better matching combination of improved membrane, electrodes, and GDL.
- Major advances have been done (liquid visualisation, two-phase modelling…) and allows proposing more reliable water management scenario.
- Pore Network Modelling has been improved and validated. It can help analysing the influence of properties of GDL on performance.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)[1]	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET [2]	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Reach power density >1 W/cm² @ 1.5 A/cm² (BoL)	MEA Level 0: 0.75 W/cm² MEA Level 1: 0.9 W/cm² MEA Level 2: 1.0 W/cm²	MEA Level 0/1 reached, level 2 not reached Best MEA reaches 0.93 W/cm²	MEA Level 0 and 1: 100%, Level 2: 0%	Best performance with the commercial MEA used, as far as we know	Performance have been checked under the operating conditions for automotive: H2/air, gas hydration 50%, Stoe 1.2/2, 80 °C, 1.5 bara
Optimization of GDL and MPL for handling low RH levels	Improve performance at standard automotive conditions and check improvement at other conditions	Different hydrophobic treatments improve performance	100%		#IMPALA30 leads to an increase of performance for all operating conditions. Specific hydrophobic treatments improve performance at RH 20% or RH 100%
Demonstration of long term stability under automotive conditions.	Assess degradation rate of MEA Level 2	Durability of MEA Level 0 has been tested at stack level.	90%	N/A	The same durability tests should be done with the best GDL
Optimization and demonstration of MEA processing at pilot scale based on the innovative GDL	Analyze of the market and new investments	Pilot-scale production of best candidate material has been performed.	100%	New as SGL is the sole manufacturer of #IMPALA30	Target reached and the improved GDL (#IMPALA30) is now planned to be commercialized. This improvement leads to a stack cost reduction (~ - 7%)
Development and improvement of modelling tools for understanding of performance and phenomena.	PNM includes condensation	PNM: condensation is included	100%	This is the first time condensation is included in PNM	
Conductivity >2 S/cm (in-plane) and >100 S/cm (through-plane)	Reduce through-plane resistance by 10%	reached	100%		Electrical conductivity could still be improved
Contribute to the development of European Industry solutions	Improve materials of SGL	SGL materials have been improved.	100%		SGL has now a new improved GDL (#IMPALA30) to be commercialized
(b) Project objectives relevant to annual objectives (from AIP / AWP) if different than above- please specify AIP/AWP reference year: 2011					

NANO-CAT

Development of advanced catalysts for PEMFC automotive applications

PANEL 2

Research activities for transport applications

ACRONYM	NANO-CAT
CALL TOPIC	SP1-JTI-FCH.2012.1.5: New catalyst structures and concepts for automotive PEMFCs
START DATE	1/05/2013
END DATE	31/01/2017
PROJECT TOTAL COST	€4,3 million
FCH JU MAXIMUM CONTRIBUTION	€2,4 million
WEBSITE	http://nanocat-project.eu/

PARTNERSHIP/CONSORTIUM LIST

COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, ASSOCIATION POUR LA RECHERCHE ET LE DÉVELOPPEMENT DES MÉTHODES ET PROCESSUS INDUSTRIELS – ARMINES, FUNDACION TECNALIA RESEARCH & INNOVATION, NANOCYL SA, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, C-TECH INNOVATION LIMITED, DEUTSCHES ZENTRUM FUER LUFT – UND RAUMFAHRT EV, VOLVO TECHNOLOGY AB

MAIN OBJECTIVES OF THE PROJECT

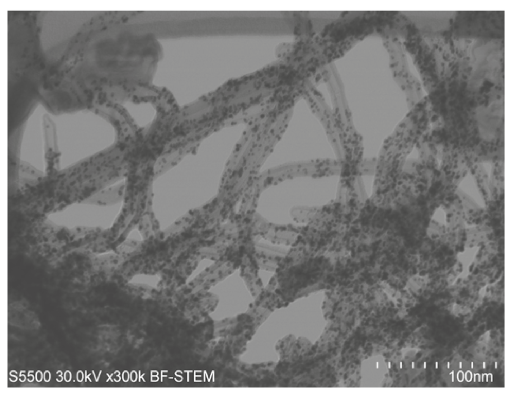
Nano-CAT proposes alternatives to the use of conventional catalyst and promotes nanostructured Pt based catalyst with a good activity and enhanced lifetime due to a better resistance to degradation. Nano-CAT will thus develop novel nanostructured on innovative supports (carbon nanotubes NCT and metal oxide).

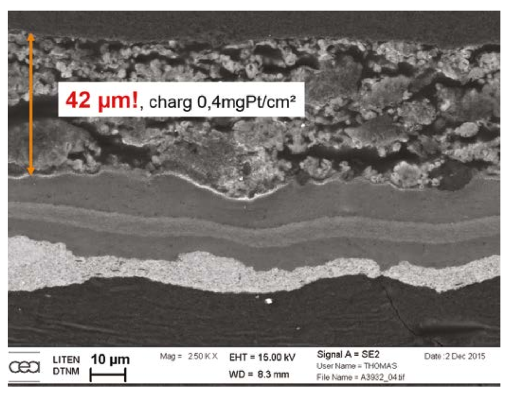
PROGRESS/RESULTS TO-DATE

- Synthesis of new support for electrocatalyst for PEMFC application.
- Deposition of homogeneously dispersed nanoparticle of Pt onto those new supports and ex-situ characterisation.
- Integration in MEA (cathode and anode). Validation of the robustness of new catalyst Pt/NCT, especially for bus application.

FUTURE STEPS

- Integration of the catalyst Pt/NTC in large area MEA for validation in short stack.
- Characterisation of Pt/NTC anode catalyst with low loaded cathode in MEA to prepare durable low loaded MEA.
- Organisation of a workshop to distribute results of the project results.





CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Anode degradation can be neglected when designing low loaded MEA and for aggressive current cycle.
- Use of NTC as catalyst support allows to stabilize the Pt particle size and the active area.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
0.1 gPt/kW @ max power	0.1 gPt/kW	0.5 gpt/kW	50 %	0.5 gPt/kW (GORE MEA)	MEA integrating Pt/NTC at anode for better durability. Decrease of cathode loading and test under harmonized EU condition
0.3 gPt/kW @ 55 % yield	0.1 gpt/kW	0.95 gPt/kW	50 %	0.64 gpt/kW (GORE MEA)	idem
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2012
1 W/cm² @ 1.5 A/cm²	1 W/cm2 @ 1.5 A/cm²	850 mW/cm² @ 1.5 A/cm²	100 %	900 mW/cm² @ 1.5 A/cm² (GORE MEA)	Testing cond: 80 °C; 50 % RH, StH2: 1.2; Stair: 2, 1.5 bara; decrease of anode and cathode loading MEA from the project integrating Pt/NTC at the anode à decrease of degradation. Validate the durability using MEA with lower Pt loading at the anode and cathode.
(c) Other project objectives					
Development of new catalyst support, improved carbon nanotubes and metal oxide	Breakthrough approaches for novel catalyst	Use of CNT as support validated (see above); synthesis of metal oxide (SnO2/Sb) validated à same pore size distribution as carbon black and conductivity 0.1 S/cm	Target reach	Not applicable	Upscale of modified NTC for Pt deposition

PHAEDRUS

High pressure hydrogen all electrochemical decentralized refueling station

PANEL 2

Research activities for transport applications

ACRONYM	PHAEDRUS
CALL TOPIC	SP1-JTI-FCH.2011.1.8: Research & Development of 700 bar refuelling concepts & technologies
START DATE	1/11/2012
END DATE	31/10/2015
PROJECT TOTAL COST	€6,3 million
FCH JU MAXIMUM CONTRIBUTION	€3,5 million
WEBSITE	http://www.phaedrus-project.eu/

PARTNERSHIP/CONSORTIUM LIST

HYDROGEN EFFICIENCY TECHNOLOGIES (HYET) BV, ITM POWER (TRADING) LIMITED, H2 Logic A/S, RAUFOSS FUEL SYSTEMS AS, DAIMLER AG, SHELL GLOBAL SOLUTIONS INTERNATIONAL B.V., BUNDESANSTALT FUER MATERIALFORSCHUNG UND -PRUEFUNG, ASSOCIATION POUR LA RECHERCHE ET LE DÉVELOPPEMENT DES MÉTHODES ET PROCESSUS INDUSTRIELS – ARMINES, HOCHSCHULE ESSLINGEN, UNIRESEARCH BV

MAIN OBJECTIVES OF THE PROJECT

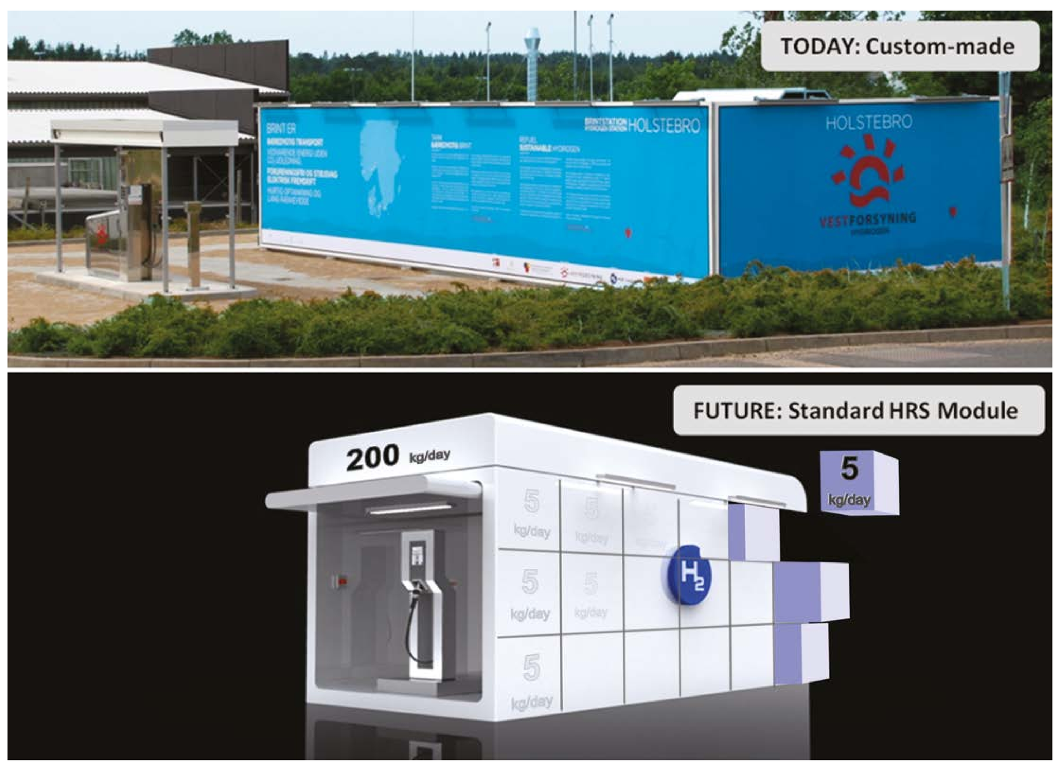
PHAEDRUS is developing an integrated 70MPa hydrogen fuelling station with reduced cost of ownership, building on high pressure electrolysis and novel Electrochemical Hydrogen Compression (EHC) technology and simplifying the system architecture through modelling and safety assessment.

PROGRESS/RESULTS TO-DATE

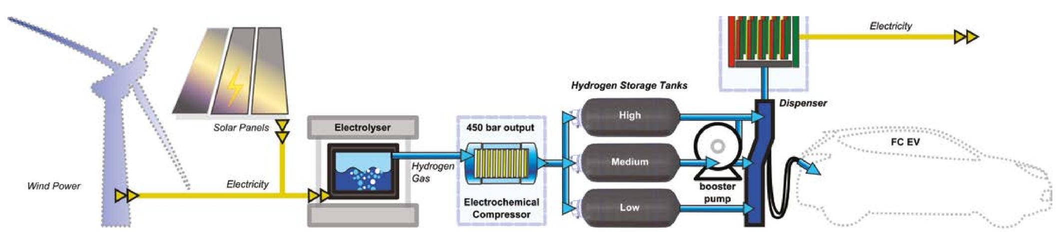
- Project has finished in Oct 2015.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- New concept for scalable 100 MPa HRS proven, enabling self-sustained infrastructure roll-out, fully compliant with existing standards (SAE J2601).
- Electrolyser producing hydrogen costing less than €7/kg inclusive of CAPEX and OPEX at 200 kg/day, mainly due to electricity cost (10c€/kWh used here).
- Electrochemical Hydrogen Compressor has high compression ratio >40, but cheapest systems configurations use booster above >50 MPa.



- Successful validation of the novel technology integration at small scale on-site at ITM, for the first time in the world, at 5 kg/day capacity.
- Modelling showed HRS configuration depends on the situation where economic feasibility in the short term, and significant cost down potential.



CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
HRS Capex 2015 target <1M€	Cascade system configuration simplified using new technology	HRS model is available as tool for optimal design before realisation	100 %	2010 at 200 kg/day: <1.5 M€	CAPEX Cost per daily dispensed H_2 around 10,000 €/kg is feasible
Hydrogen production CAPEX 2015 target: €3500 per Nm3/hr	Modular unit system, low membrane costs and Pt catalyst loadings	Components were validated, membranes and low catalyst loading evaluation complete	100 %	2010: 4,100€	Scalable unit validated at 5 kg/day, model shows large costs down potential with optimisation
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2011
Optimization of compression & storage systems with respect to cost, efficiency and capacity.	Balance component specifications in final system configuration	Components sized using model based on component test results and realistic costs	100 %		The optimum configuration is very dependent on the local situation considering supply, demand cycle and energy cost prices.
Compliancy	standardized compliance verification involving BAM evaluation	H_2 Logic developed a new refuelling control system that is adapted to the new SAE J2601 standard	100 %	SAE J2601	Full compliance with 200 kg/day capacity system
(c) Other project objectives					
Validation of new technology	Not applicable	Successful integration of critical components on-site at ITM	100 %	Novel achievement	First time PEM Electrolysers and EHC were validated together in the field at system level.
Modelled Hydrogen Price	Not applicable	<2015: 13. 7 €/kg	100 %	2010: 15-20 €/kg	>2015: 10.6 €/kg

PUMA MIND

Physical bottom up multiscale modelling for automotive PEMFC innovative performance and durability optimization

PANEL 2

Research activities for transport applications

ACRONYM	PUMA MIND
CALL TOPIC	SP1-JTI-FCH.2011.1.3: Improvement of PEMFC performance and durability through multi-scale modelling and numerical simulation
START DATE	17/12/2012
END DATE	16/12/2015
PROJECT TOTAL COST	€4 million
FCH JU MAXIMUM CONTRIBUTION	€2,2 million
WEBSITE	http://www.pumamind.eu/

PARTNERSHIP/CONSORTIUM LIST

COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, DEUTSCHES ZENTRUM FUER LUFT – UND RAUMFAHRT EV, UNIVERSITA DEGLI STUDI DI SALERNO, AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS, HOCHSCHULE OFFENBURG, ECOLE NORMALE SUPERIEURE DE LYON, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, Simon Fraser University, VODERA LIMITED, IDIADA AUTOMOTIVE TECHNOLOGY SA, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

MAIN OBJECTIVES OF THE PROJECT

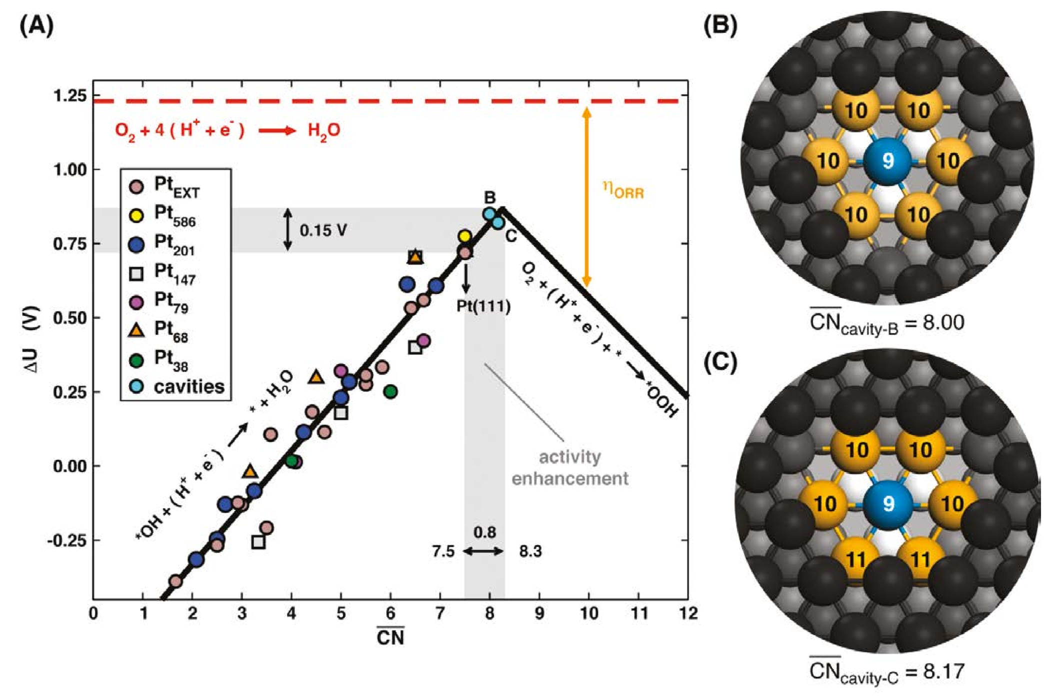
The objective of the project concerned the development of multi-scale modelling and numerical simulation tools for increasing the performance and durability of PEM fuel cells. These computer-based tools are to be validated through experimental work.

PROGRESS/RESULTS TO-DATE

- Activation Gibbs free energy barriers have been calculated in model environment conditions.
- A mesoscopic kinetic Monte-Carlo Code (KMC) devoted to study the catalyst reactivity has been developed.
- The Ostwald ripening degradation mechanism has been modelled and coupled with the performance model.
- The control-oriented ordinary differential equation (ODE) model is ready and performance indicators for online diagnostic have been derived from the model.
- Small-angle X-ray scattering (SAXS) experiments have been carried out. Trends for the water repartition have been transferred to the macromodels

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- A proof of concept has been reached by coupling various modelling scales in the field of multi-scale simulation for fuel cells
- Mitigation strategies at the system level rely on design observers to estimate the key parameters to be considered for the control of the system.



- Atomistic approaches at the nanoscale are key to understand the underlying mechanisms.
- Based on the atomistic calculations effective parameters for the higher scales can be derived.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:		MAIP 2008-2013
Development of modeling tools for PEMFC performance and durability	Multi-scale modeling and simulation tools for increasing the performance and durability of PEMFC.	DFT calculation of adsorption energies on a Pt201 nanoparticule (Nano scale).
Development of modeling tools for PEMFC performance and durability	Multi-scale modeling and simulation tools for increasing the performance and durability of PEMFC.	Kinetic Monte Carlo of the adsorbed species in the electrochemical double layer.
Development of modeling tools for PEMFC performance and durability	Multi-scale modeling and simulation tools for increasing the performance and durability of PEMFC.	Development of a mechanistic catalyst degradation model (Ostwald Ripening).
Development of modeling tools for PEMFC performance and durability	Multi-scale modeling and simulation tools for increasing the performance and durability of PEMFC.	The reduced catalyst degradation model has been coupled with a performance model.
Development of modeling tools for PEMFC performance and durability	Multi-scale modeling and simulation tools for increasing the performance and durability of PEMFC.	Indicators have been derived from a control-oriented model for on-board diagnostic tools.
Development of modeling tools for PEMFC performance and durability	Multi-scale modeling and simulation tools for increasing the performance and durability of PEMFC.	Water repartition in the PEMFC has been investigated by Small Angle Neutrons Scattering.
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:		AIP 2011

SMARTCAT

Systematic, material-oriented approach using rational design to develop break-through catalysts for commercial automotive PEMFC stacks

PANEL 2
Research activities for transport applications

ACRONYM	SMARTCAT
CALL TOPIC	SP1-JTI-FCH.2012.1.5: New catalyst structures and concepts for automotive PEMFCs
START DATE	1/06/2013
END DATE	31/05/2017
PROJECT TOTAL COST	€4,7 million
FCH JU MAXIMUM CONTRIBUTION	€2,5 million
WEBSITE	http://smartcat.cnrs.fr/

PARTNERSHIP/CONSORTIUM LIST

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, STIFTELSEN SINTEF, DANMARKS TEKNISKE UNIVERSITET, COMMISSARIAT A L ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, MXPOLYMERS BV, BASIC MEMBRANES BV, L'AIR LIQUIDE S.A.

MAIN OBJECTIVES OF THE PROJECT

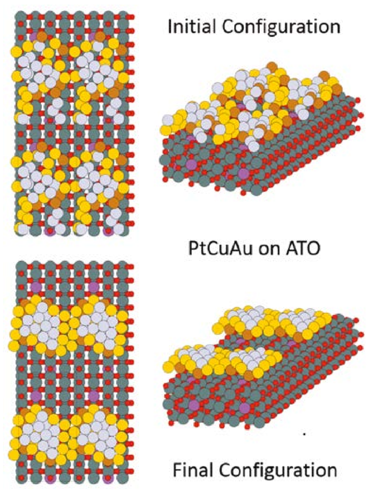
- New and innovative electrodes using tri-metallic low Pt-content (0.01 mg-2, 0.05g/kW) based catalyst nanoparticles and nano-structured layers (CL) combined with new and corrosion resistant metal-doped oxide-based materials (CL-conductivity in the range from 1 to 10 S/cm).
- Upscaling HT membranes proton conductivity >60 mS/cm @ 40 °C; >200 mS/cm @ 180 °C.
- Enable to optimize and to automate the production of MEAs (60/day).
- Prove the viability of the new concept for automotive applications (220 cm², 5,000 h durability).

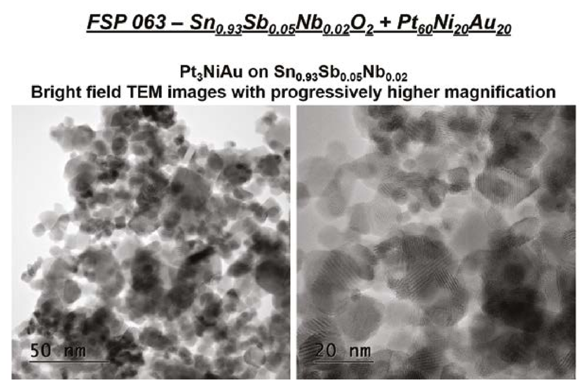
PROGRESS/RESULTS TO-DATE

- 0.1mgPtcm-2 ternary catalysts AuPt3Ni, Cu have mass activity >Pt(60 A/gPt): >200 A/gPt @0.9V.
- Other ternary catalysts have mass activity >100 A/gPt: Pt50Au33Ni17 >Pt70Au15Pd15 >Pt50Au33Co17 @0.9V .
- 160 cm-2 large area MEA with sputtered core-shell Au@Pt3Ni 0.1 and 0.01 mgPtcm-2 cathode assembled.
- Density functional theory (DFT) simulations predict Au-Cu alloy and surface Pt structure on anodic titanium oxide substrate.
- Homogenous distribution of catalyst particles on support confirmed by transmission electron microscope analysis.

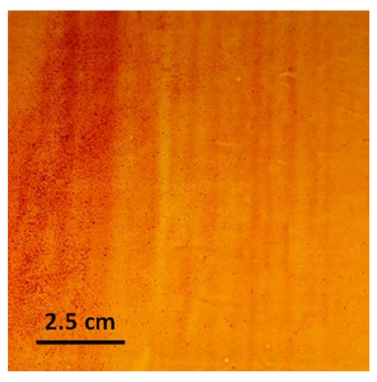
FUTURE STEPS

- Mass activity of sputtered 0.01 mgPtcm-2 ternary Au@Pt3Ni catalyst >100 A/gPt.
- 220 cm-2 MEA with AuPt3Ni ternary catalyst coated cathode.
- 5,000 h durability test with AuPt3Ni ternary catalyst cathode.
- Ministack (12 cells) with ternary catalyst AuPt3Ni cathode operation.





HT PYPO membrane



CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Performances of selected ternary catalyst are better than pure Pt and binary Pt-based catalysts. Pt3NiAu, Au@Pt3Ni provide the highest activities.
- Large area single cell and mini stack will be tested and performances increased at 120 °C.
- Large area HT membrane will be available with high proton conductivity (150 – 350 mScm-1 @150 °C).

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
25 cm² Single Cell performance of 1Wcm-2 100 cm² Single Cell performance of 0.9 Wcm-2 at EoL	25 cm² Single Cell performance of 1Wcm-2 160 cm-2 Single Cell performance of 0.9 Wcm-2 at EoL	0.7 Wcm-2 Ongoing	70 % Ongoing	1Wcm-2	Large single cell (160 cm²) selection with new catalysts is scheduled for July 2016
220 cm² short stack >2kWL-1	220 cm² short stack >2kWL-1	Ongoing	0 %	2kWL-1	Scheduled for November 2016
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2013-1
Exchange current density j0 >10-3 mA cm-2 with ternary catalyst. Reference Pt alone is 2.5 10-4	None	10-3 for Pt3NiAu, Pt3CoAu, Pt3CuAu at 0.1 mgPtcm-2	100 %	2.5 10-4	Pt3NiAu catalyst is chosen with jk maximum (12 mA cm-2), while Pt is 5.3

VOLUMETRIQ

Volume Manufacturing of PEM FC Stacks for Transportation and In-line Quality Assurance

PANEL 2

Research activities for transport applications

ACRONYM	VOLUMETRIQ
CALL TOPIC	FCH-01.2-2014: Cell and stack components, stack and system manufacturing technologies and quality assurance
START DATE	1/09/2015
END DATE	31/08/2018
PROJECT TOTAL COST	€5 million
FCH JU MAXIMUM CONTRIBUTION	€4,9 million
WEBSITE	http://www.volumetriq.eu/

PARTNERSHIP/CONSORTIUM LIST

UNIVERSITE DE MONTPELLIER, JOHNSON MATTHEY FUEL CELLS LIMITED, SOLVAY SPECIALTY POLYMERS ITALY S.P.A., BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, ELRINGKLINGER AG, PRETEXO

MAIN OBJECTIVES OF THE PROJECT

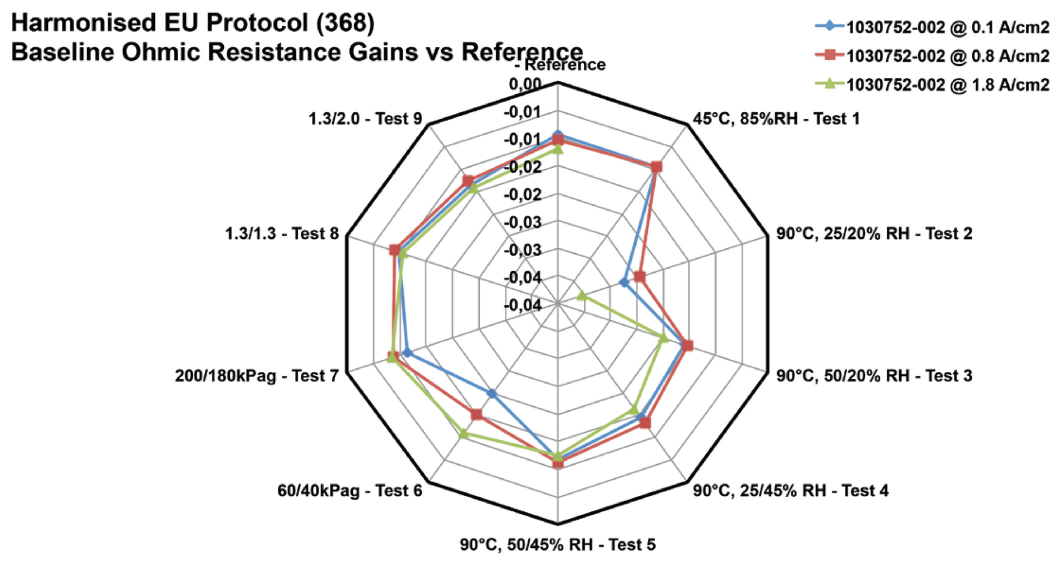
VOLUMETRIQ is developing an EU-centric supply base for PEM fuel cell stacks and their key components with volume manufacturing capability and embedded quality control at its heart. The stack and components are based on automotive PEM fuel cell technology which is presently TRL5 for component manufacturing approach and concepts. The project will deliver a TRL7 stack and component design, at TRL7 manufacturing maturity, a consistent stack power of 90 kW, and demonstrated cost reduction.

PROGRESS/RESULTS TO-DATE

- Automotive fuel cell stack requirements have been produced.
- Test protocols that will be used to generate membrane, MEA and stack performance data have been agreed upon and validated.
- Reinforcement and ionomer dispersion materials for baseline membrane and MEA development have been produced and supplied.
- A new pilot level continuous membrane casting line to produce VOLUMETRIQ membranes by volume manufacturable processes has been introduced.
- Baseline MEAs fabricated with project baseline materials demonstrate beginning of life power density of 2.0 A/cm^2 at 0.60 V in single cell testing.

FUTURE STEPS

- Complete amendments transferring stack activity to Elring Klinger (EK), and coordination activity to CNRS, following withdrawal of Intelligent Energy.
- Revise deliverable reports on stack and stack component requirements and test procedures affected by different stack operating conditions at EK.
- Re-open cross-checking activity of test results between single cell hardware to ensure consistency with results at stack development partner.



- Develop and supply new improved reinforcement and ionomer dispersion materials for first generation improved membranes and MEAs.
- Develop and test first short stack.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Superior mechanical properties of reinforced membranes using project reinforcements developed in MAESTRO over incumbent ePTFE is confirmed.
- BoL current density of 2.0 A/cm^2 at 0.60 V with project baseline MEAs allows confidence that project target of 2.5 A/cm^2 at 0.60 V can be reached.
- Stack development schedule unfortunately impacted by withdrawal of IE.
- Project duration to be increased by 6 months with alignment of all WP activities with the stack manufacturing schedule.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAWP 2014-2020
Cost reduction: €100/kW (2020)	Reduce the FC systems production cost for transport applications	Not scheduled any stack costing work	100%		N/A
Durability: 5,000 h	Increase FC systems lifetime for transport applications	Not yet scheduled any durability testing	100%	3 930 h to 10% - https://goo.gl/C9qp8X	Target is to demonstrate the capability to reach 5,000 h on an automotive drive cycle
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AWP 2014
Components form part of a manufacturing study in order to improve and optimise processes.	Design and manufacturing methods simplification of cell components, cells and stacks	Manufacturing studies underway	100%		
TRL 7: Cell component and stack manufacturing technology	Cell and stack design improvements that have been validated =>TRL 5	Progress in components formulation	100%		
Develop volume manufacturing capability/qualit controls	Improve manufacturing methods	Pre-existing manufacturing methods being used by partners.	100%		
Investigate the parameters of the key cell components influencing durability, yield, cost	Testing and validation of critical manufacturing sub-processes	Activity initiated	100%		
Review of processes and identification of failure modes	Identification of manufacturing failure modes and implementation of manufacturing control plans	Activity to start year 2	100%		With resulting control plans put in place