H2REF
Development of a cost effective and reliable hydrogen fuel cell vehicle refuelling system

Panel 2 - Research activities for transport applications

Acronym:	**H2REF**
Project ID:	671463
Title:	Development of a cost effective and reliable hydrogen fuel cell vehicle refuelling system
Call Topic:	FCH-01.5-2014
Project total costs (€):	€ 6,5 million
FCH JU maximum contribution (€):	€ 6,0 million
Project start/end:	01 Sep 2015 - 31 Aug 2018
Coordinator:	Centre Technique des Industries Mecaniques, France
Beneficiaries:	Hexagon Raufoss, Ludwig-Boelkow-Systemtechnik, Uni. Technol. Compiegne, Haskel Europe Ltd, Haskel France, H2Nova, The CCS Global Group Ltd

Project and objectives

H2Ref addresses the compression and buffering for refuelling of 70 MPa vehicles and targets a novel cost effective, performant and reliable hydraulics-based system, from TRL 3 to 6. The new way to compress H_2 in a refuelling station is designed and a prototype compression and buffering module (CBM) is under construction. The new hydraulically-actuated compression will be tested first. Then, the full CBM including the N° of compression devices needed for the full compression and dispensing cycle will be tested in closed circuit. Later, it will be interfaced with a vehicles dispenser for demo.

Major project achievements

- High pressure bladder accumulator design for hydrogen
- Detail Design of Accumulator Test Bench and CBM prototype (full scale system): construction in progress

Future steps

- Deformation testing of accumulator critical bladder
- Finalisation of construction of Accumulator Test Bench
- Delivery of MP and HP accumulators
- Functional testing in hydrogen of bladder accumulators

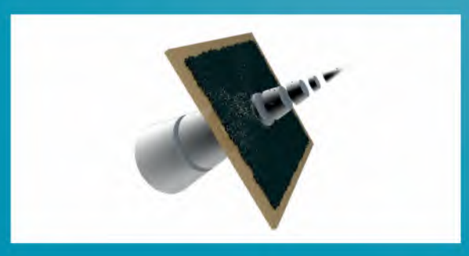
Non-quantitative objectives and status

- Techno-economic analysis based on testing results
  Not initiated (testing not begun)
- Have the technology covered by the RCS (Regulations, Codes and Standards) framework
  Contact established with CEN/TC 54. Positive test results needed to begin work on standards

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
Project's own	TRL	TRL	3	6	3	6	Due later	Through extensive component & system testing
Project's own	CBM manufacturing cost @ 50 units/year	K€	750	300		300	Due later	Through novel implementation of mature technologies (hydraulics and composite pressure vessels)
Project's own	Throughput from 7 MPa @ pumping power of 75 kW	kg/d	210	720		720	Due later	30 kg/h, 24h/day
Project's own	Energy consumption	kWh/kg	3	1.5		1.5	Due later	Through conservation of source storage pressure

EG-04-17-700-EN-P



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

Panel 2 - Research activities for transport applications

Acronym:	**IMPACT**
Project ID:	303452
Title:	Improved lifetime of automotive application fuel cells with ultra low Pt-loading
Call Topic:	SP1-JTI-FCH.2011.1.5 &SP1-JTI-FCH.2011.1.6
Project total costs (€):	€ 9,2 million
FCH JU maximum contribution (€):	€ 3,9 million
Project start/end:	01 Nov 2012 - 31 Oct 2016
Coordinator:	DLR, Deutsches Zentrum fuer Luft und Raumfahrt, Germany
Beneficiaries:	Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, Consiglio Nazionale delle Ricerche CNR, Gwangju Inst. Science And Technology, Hochschule Esslingen, Inst. National Polytech. Toulouse, ITM Power (Trading), Solvay Specialty Polymers Italy, Tech. Uni. Berlin, Johnson Matthey Fuel Cells Ltd, JRC -Joint Research Centre, European Commission, Zentrum fuer Sonnenenergie und Wasserstoff-Forschung, Baden-Wuertemberg
Website:	http://www.eu-project-impact.eu/

Project and objectives

Main project objectives are: to increase the lifetime of ultra–low Pt-loaded (< 0.2 mg/cm2) membrane-electrode assemblies (MEAs) for automotive applications to 5,000 h in dynamic operation with degradation rates <10 µVh-1 and to obtain a power density of 1 A/cm2 (performance target achieved). To achieve these targets relevant degradation mechanisms are identified and mitigation strategies are implemented though material development, structural design of cells and materials, and integration of improvements into a best MEA. The project ended in October 2016.

Major project achievements

- Demonstration of 1 W/cm2 at 0.2 mg/cm2 Pt total loading using H_2/air at 50% RH and 1.5 bar absolute pressure
- Development of new thin membranes, stable ionomers, and electrodes for low loaded MEAs
- Detailed ex-situ and in-situ analysis of the developed materials allowing a better understanding of degradation mechanism

Future steps

- Project finished

Non-quantitative objectives and status

- Irreversible and reversible degradation mechanism categorisation. Detailed study on reversible and irreversible degradation rates and performance recovery procedures has been performed. The results are published

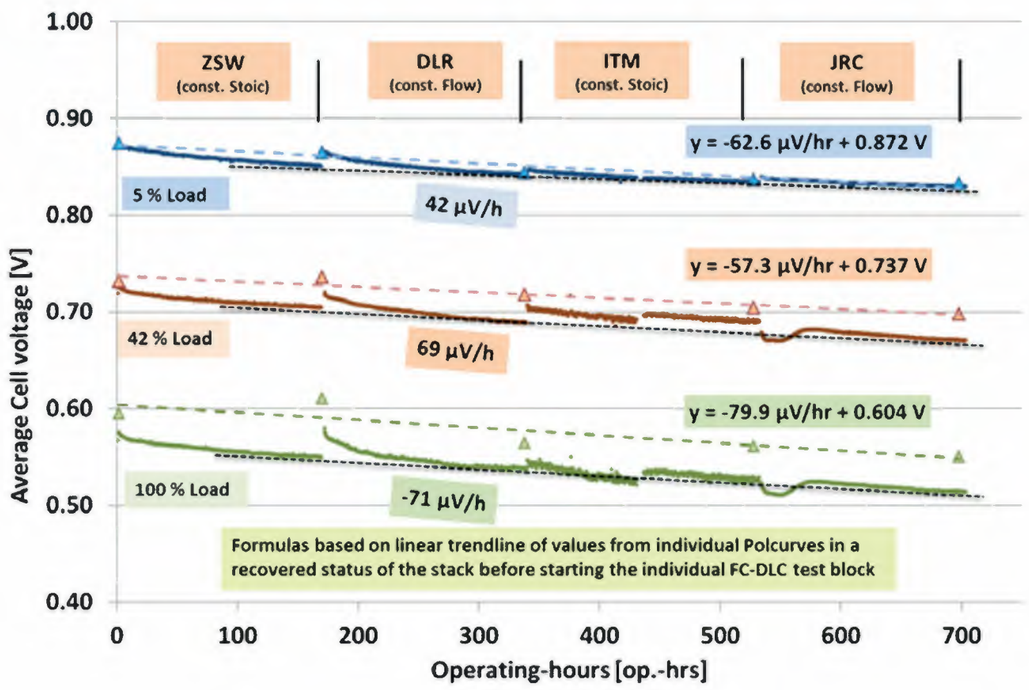
Relevant to FCH JU overarching objectives

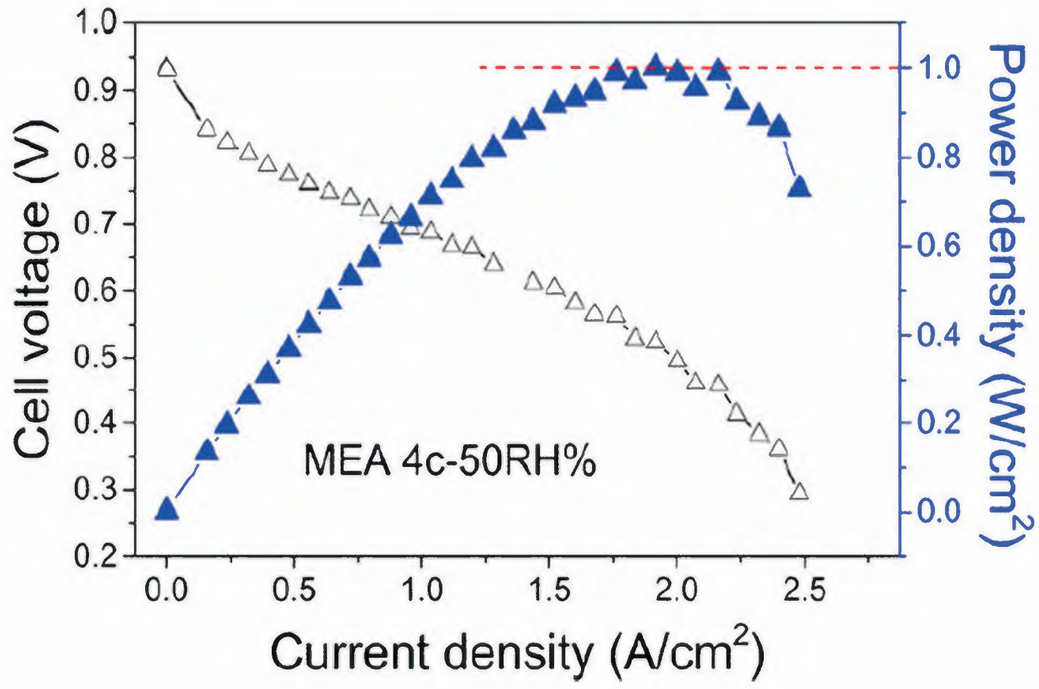
- Reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels which can compete with conventional technologies
- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs

EG-04-17-700-EN-P

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Stack durability	h	2,500	5,000	1,700	1,700	Not achieved	Test ended due to MEA degradation
AIP 2011	Pt loading	mg/cm2	0.6	0.2	0.2	0.2	Achieved	Performance target achieved at target loading but not durability
AIP 2011	Power density	W/cm2	0.6	1.0	1.0	1.0	Achieved	In a single cell test at 0.2 mg/cm2 total Pt loading.





FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

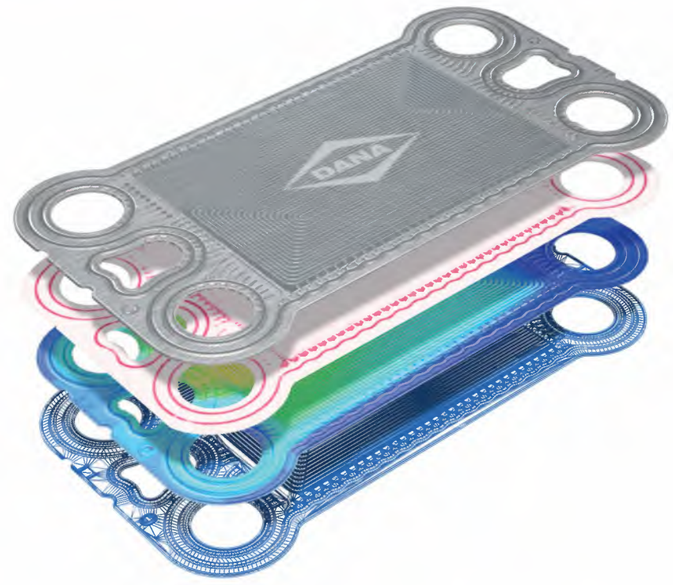
INSPIRE
Integration of Novel Stack Components for Performance, Improved Durability and Lower Cost

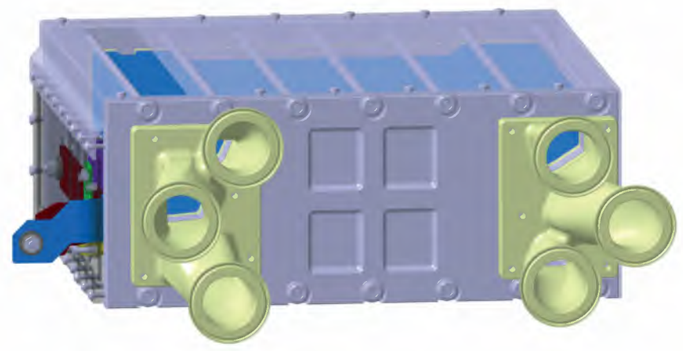
Panel 2 - Research activities for transport applications

Acronym:	**INSPIRE**
Project ID:	700127
Title:	Integration of Novel Stack Components for Performance, Improved Durability and Lower Cost
Call Topic:	FCH-01.1-2015
Project total costs (€):	€ 6,9 million
FCH JU maximum contribution (€):	€ 6,9 million
Project start/end:	01 May 2016 - 30 Apr 2019
Coordinator:	Johnson Matthey, United Kingdom
Beneficiaries:	VTT, Uni. Montpellier, Sgl Carbon, Albert-Ludwigs-Uni. Freiburg, Reinz-Dichtungs, Tech. Uni. Muenchen, Tech. Uni. Berlin, Johnson Matthey Fuel Cells Ltd, Pretexo, Bayerische Motoren Werke, Centre National de la Recherche Scientifique CNRS
Website:	www.inspire-fuelcell.eu

Project and objectives

INSPIRE is an industry-led project bringing together the most advanced critical polymer electrolyte membrane fuel cell (PEMFC) stack components capable of delivering on the most challenging performance, durability and cost targets within the next generation of automotive stacks. New catalyst alloys have now met the mass activity and durability targets and will be integrated in membrane-electrode assemblies (MEAs) going forward while new gas diffusion layer (GDL) and catalyst-coated membrane (CCM) optimisation has enabled the project to achieve the 12-month performance target in screener cells. The first generation stack design has also now been designed and is earmarked to be operational by the project mid-term.





Major project achievements

- Interim target of 1.2W/cm2 power density @ 0.6V met by new MEA designed optimised for project conditions
- New alloy catalyst has achieved the stability and power density targets at high current density
- New BPP design is meeting the project specification and is being scaled up for manufacture

Future steps

- Full stack testing for GEN 1.5
- Deliver scaled up catalyst for GEN 2.0
- Delivery of thin low EW membrane for GEN 2.0
- Delivery of GEN 2.0 GDL

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
AIP 2015	Power density @ 0.6V	W/cm2	0.87	1.5	1.2	1.5	Due later	Demonstrated in screener (new GDL and MEA optimisation); to be confirmed in stack
MAWP 2014-2020	Performance loss over 6,000 hours	%		10		10	Due later	Not yet assessed
Project's own	Mass activity (MA)	A/mg	0.24	0.6	0.42	0.6	Due later	Interim target of 0.44A/mg not yet met but very close
MAWP 2014-2020	Pt loading	mg/cm2	0.45	0.125	0.30	0.12	Due later	Interim target of 0.25mg/cm2 not chosen to maximise cost/ performance benefit
MAWP 2014-2020	Cost @ 50,000 units/ year	€/kW		50		50	Due later	Not yet assessed

Non-quantitative objectives and status

- Scale-up best performing catalyst for stack MEAs
  One alloy catalyst has passed through the performance and durability stage gate and is being scaled up for MEA optimisation and testing
- Develop two new generations of bipolar plates (BPP) for automotive stacks
  First generation BPP to be implemented in GEN1.5 and GEN 2.0 stack now designed and undergoing manufacture. Stack testing now due in September 2017
- Quantify and model the changes in catalyst structure
  Model platform agreed and initial visualisation completed
- Dissemination of project results
  2 oral presentations and 4 posters already completed, as well as setting up a public website for the project, plus announcements on partner websites

Relevant to FCH JU overarching objectives

- Reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels which can compete with conventional technologies
- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements

EG-04-17-700-EN-P

FCH_Posters_Panel_1-2_A0.indd 21 25/10/17 14:17

NANO-CAT
Development of advanced catalysts for PEMFC automotive applications

Panel 2 - Research activities for transport applications

Acronym:	**NANO-CAT**
Project ID:	325239
Title:	Development of advanced catalysts for PEMFC automotive applications
Call Topic:	SP1-JTI-FCH.2012.1.5
Project total costs (€):	€ 4,4 million
FCH JU maximum contribution (€):	€ 2,4 million
Project start/end:	01 May 2013 - 31 Jan 2017
Coordinator:	Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, France
Beneficiaries:	Ass. pour la Recherche et le Developpement des Methodes et Processus Industriels - Armines, C-Tech Innovation Ltd, DLR, Deutsches Zentrum fuer Luft und Raumfahrt, Nanocyl, Volvo Technology, Fundacion Tecnalia Research & Innovation, JRC -Joint Research Centre, European Commission, Centre National de la Recherche Scientifique CNRS, Basic Membranes
Website:	http://nanocat-project.eu/

Project and objectives

The objectives of Nano-CAT were the synthesis on new catalyst concept to reduce the loading of platinum in polymer electrolyte membrane fuel cells (PEMFC) and increase durability. The consortium synthesised innovative support (high resistance carbon nanotubes and metal oxide aerogel) and did there functionalisation with platinum nanoparticles. Those new catalysts showed good performances and durability against commercial reference (Pt/C). Finally, those materials were integrated in full 25 cm2 membrane-electrode assembly (MEA) and advantages in some specific accelerated stressed tests.

Major project achievements

- Low-loaded MEA (0.25 mgPt/cm2 total) have been produced and gave 750 mW/cm2.
- 1 W/cm2 in single cell has been achieved under 1.5 bara 50%RH and 80 °C.
- Functionalisation of highly purified carbon nanotubes with homogeneous repartition of Pt nanoparticles (4 nm) and 40 % weight

Future steps

- Project finished, nevertheless, the tests in stack continue in CEA premise

Non-quantitative objectives and status

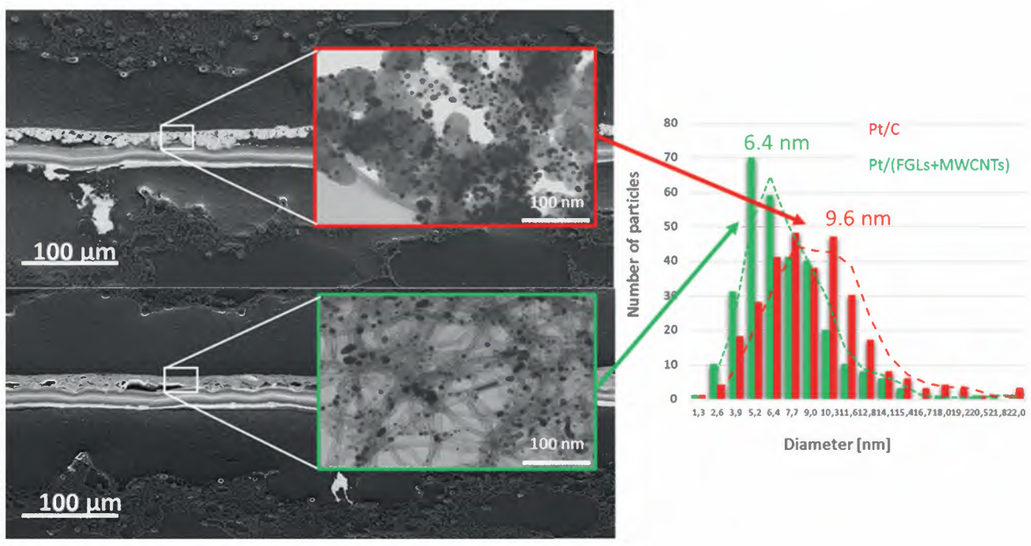
- Development and validation of testing procedures
  Participation of networking group on the harmonisation of testing procedure in single cell
- Development of catalyst deposition techniques
  Different techniques have been compared : electrodeposition, PVD, polyol, micelle in different solvents and reactants (green chemistry)

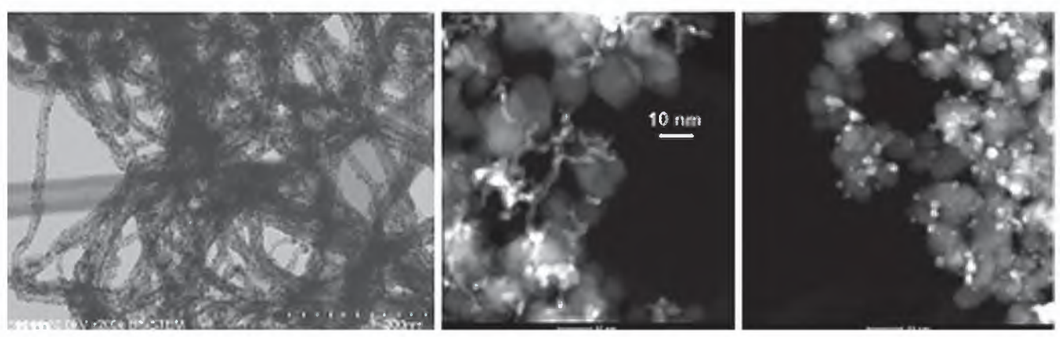
Relevant to FCH JU overarching objectives

- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
AIP 2012	MEA power density	mW/cm2	750	1000	1000	1000	Achieved	@ 2 A/cm2, achieved with 0.5 mg Pt/cm2 total
Project's own	Degradation, loss of performance	%	11	10	10	10	Achieved	For operation @ Imax (1.4 A/cm2) in ageing test
Project's own	Catalyst stability-residual electrochemical surface area (ECSA)	%	70	70	100	100	Achieved	Better degradation performance vs commercial Pt/C in RDE measurement (nanoparticles diameter 4 nm)
Project's own	Conductivity of metal oxyde aerogel	S/cm	0	0.40	0.98	0.95	Achieved	SnO2:Sb 5% aerogel (90 m2/g) has a conductivity of 0.95 S/cm
Project's own	Power density	mW/cm2	/	100	10	10	Delayed	Bioinspired catalyst for ORR performance in half cell
Project's own	Current density	mA/cm2	/	100	35	35	Delayed	Bioinspired catalyst for HOR performance in half cell
Project's own	Pt loading	g/kW	/	0.1	0.3	0.3	Delayed	MEA with 0.25 mg Pt/cm2 total give 0.3 g/kW @ P max





FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

EG-04-17-700-EN-P

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**
Project ID:	325327
Title:	Systematic, material-oriented approach using rational design to develop break-through catalysts for commercial automotive PEMFC stacks
Call Topic:	SP1-JTI-FCH.2012.1.5
Project total costs (€):	€ 4,8 million
FCH JU maximum contribution (€):	€ 2,4 million
Project start/end:	01 Jun 2013 - 31 May 2017
Coordinator:	Centre National de la Recherche Scientifique CNRS, France
Beneficiaries:	Basic Membranes, Danmarks Tek. Uni., Mxpolymers, Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, Stiftelsen Sintef
Website:	http://smartcat.cnrs.fr/

Project and objectives

The consortium aimed to build a new concept of electrodes based on new catalyst design (ternary alloys/core shell clusters) deposited on a new high temperature operation efficient support. In order to enhance the fundamental understanding and determine the optimal composition and geometry of the clusters, advanced computational techniques were used in direct combination with electrochemical analysis of the prepared catalysts. SMARTCat will thus enable to automate the MEA production and build efficient short-stack required for competitive automotive fuel cell operation.

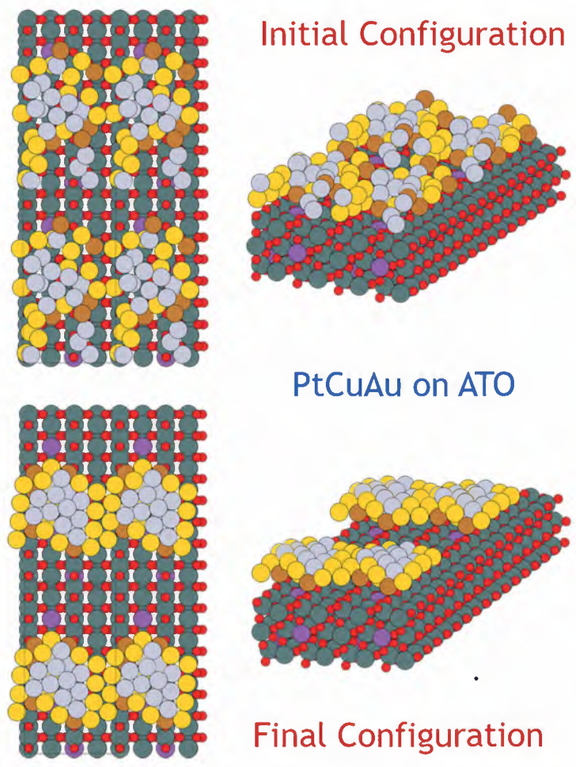
Major project achievements

- Development of ternary catalysts and supports with either higher activity or higher stability than Pt/C catalyst
- Stack 10 cells 220cm2 active area loaded with 0.18 mg.cm-2 Pt3NiAu 5Wcm-2 / 1.1 kW = performance of same stack loaded with 0.42 mg.cm-2 pure Pt
- Achievement of automated 70 MEA/day with membrane size = electrode size + 5%

Future steps

- Project finished

WP2 & WP3 SMARTCat DFT simulation



EG-04-17-700-EN-P

Quantitative targets and status

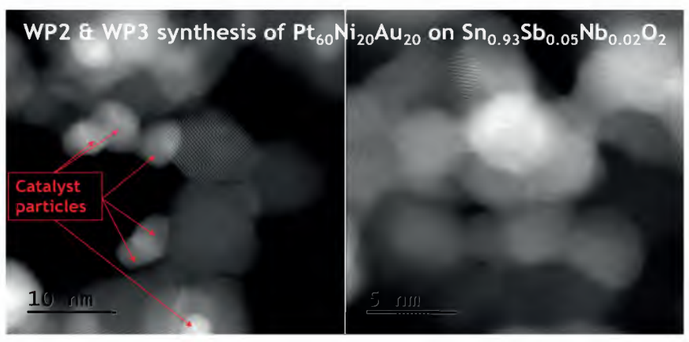
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
AIP 2012	Catalyst loading	mg/cm2	1.4	0.01	0.05	0.05	Achieved	Low loading with significant mass activity.
Project's own	Exchange current density for 0.1mg/cm2 catalyst loading	mA/cm2	0.00025	0.001	0.001	0.001	Achieved	Best value for ternary catalyst Pt3NiAu
Project's own	Kinetic current density @0.9V for 0.1 mg/cm2 catalyst loading	mA/cm2	5.3	12.3	12.3	12.3	Achieved	Best value for ternary catalyst Pt3NiAu
Project's own	Mass activity @ 0.9 V for 0.1 mg/cm2 catalyst loading	A/g	54		176	176	Achieved	Best value for ternary catalyst Pt3NiAu
Project's own	Catalyst support conductivity	S/cm	0.01	0.1	1.45	1.45	Achieved	Through cation doping strategy + modelling the conductivity and stability of the SnO2 support is tailored by addition of Sb and Nb.
Project's own	Catalyst support surface area	m2/g	38	50	100	100	Achieved	High surface area supports (>100 m2/g) are obtained by flame spray pyrolysis. Some reduction in surface area by heat treatment
Project's own	Catalyst support pore size distribution	nm	N/A	50	50	50	Achieved	Pore size distribution in the range of 20 - 150 nm targeted. Bimodal distribution achieved by flame spray pyrolysis.
Project's own	MEA production rate	MEA/day	0	60	60	70	Achieved	Using SoA supports and membranes.
AIP 2012	Short stack power density	g kW-1	0.1	0.1	0.15	0.15	Select	For Pt3NiAu 0.18 mg/cm2 catalyst loaded 220 cm2 electrodes

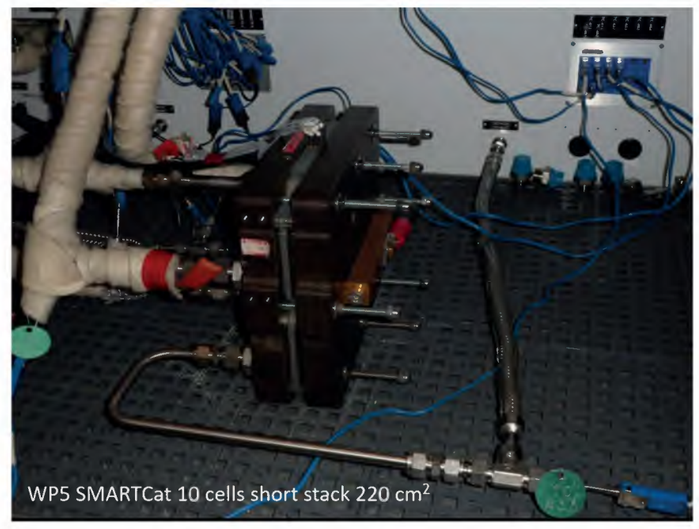
Non-quantitative objectives and status

- Stability of ternary PtMeAu/C catalysts upon potential cycling Pt3NiAu/C displays higher initial activity, whereas Pt3CuAu/C displays higher final activity
- Atomic arrangement of ternary catalysts using Molecular Dynamics MD simulations are carried out and provide atomic arrangement in line with DFT simulations and electrochemical analysis for PtMeAu (Me = Ni, Cu, Pd)
- PhD candidate training
  S. Lankiang graduated (PhD) in September 2016

Relevant to FCH JU overarching objectives

- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements





PROGRAMME REVIEW DAYS 2017

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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

Panel 2 - Research activities for transport applications

Acronym:	**VOLUMETRIQ**
Project ID:	671465
Title:	Volume Manufacturing of PEM FC Stacks for Transportation and In-line Quality Assurance
Call Topic:	FCH-01.2-2014
Project total costs (€):	€ 5,0 million
FCH JU maximum contribution (€):	€ 4,9 million
Project start/end:	01 Sep 2015 - 28 Feb 2019
Coordinator:	Centre National de la Recherche Scientifique CNRS, France
Beneficiaries:	Uni. Montpellier, Solvay Specialty Polymers Italy, Johnson Matthey, Intelligent Energy Ltd, Elringklinger, Johnson Matthey Fuel Cells Ltd, Pretexo, Bayerische Motoren Werke
Website:	http://www.volumetriq.eu/

Project and objectives

VOLUMETRIQ is developing a EU-centric supply base for PEM fuel cell stacks and their key components with volume manufacturing capability and embedded quality control. Project electrospun membrane reinforcements have been scaled up and have passed the first level of validation for their integration into the membrane casting line. Catalyst-coated membranes (CCMs) using project ionomers deliver the 24 month target current density in project hardware under target test conditions. CCM cutting and handling processes for high volume production have been identified and are compatible with the automatic stack assembly line.

Major project achievements

- Interim power density target of 1.2 W/cm2 at 0.6 V is met using project CCMs and membranes optimised for project conditions and project cell hardware
- Electrospun reinforcement scaled-up to 20 linear m rolls. Proven possible to handle the reinforcement on high volume membrane manufacturing line.
- Successful feasibility testing of feeding JMFC-produced fully converted CCM rolls into EK automatic stack assembly line

Future steps

- Integrate scaled-up electrospun reinforcement in membrane casting line and qualify the membranes produced
- Down-select final membrane construction and catalyst layer ionomer for final CCMs
- Produce CCMs for short stack using optimised ionomers in membranes and catalyst layers
- Finalise definition of production process, quality methodology, bipolar plate production and stack assembling processes
- Manufacture and validate optimised bipolar plate

Quantitative targets and status

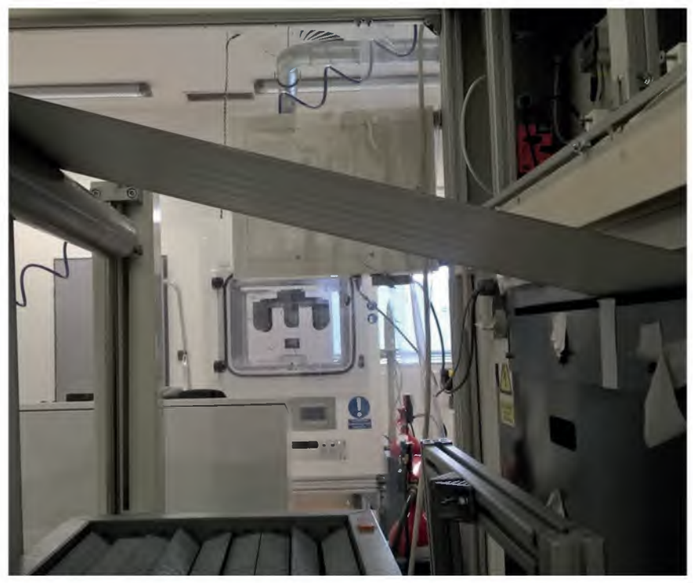
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAWP 2014-2020	Power density @ 0.6 V in single cell	W/cm2		1.50	1.23	1.50	Due later	Interim target of 1.2 W/cm2 at 0.6 V met through ionomer, CCM and GDL optimisation
Project's own	Power density @ 0.6 V in short stack	W/cm2		1.50		1.50	Due later	Not yet assessed
AIP 2014	Cost @ 50,000 units/ year	€/kW		100		100	Due later	Not yet assessed Expected through increased power density, reduced reject rates, supply chain manufacturing process development to TRL7
AIP 2014	Durability	h		5,000		5,000	Due later	Not yet assessed
AIP 2014	Stack TRL	None	5.00	7		7	Due later	Not yet assessed
AIP 2014	Scrap rate	%		5		5	Due later	Not yet assessed

Non-quantitative objectives and status

- Scale-up electrospun PBI reinforcements
  20 linear metres produced, roll-good, with successful manufacturing assessment for feed of the reinforcement into the coating line
- Develop ionomers with tuned properties for membrane and catalyst layer
  Optimisation and testing led to down-selection of Aquivion EW 750 g/mol for membranes. High oxygen permeability (CL) ionomers under development
- Selection of GDL
  The GDL type turned out to be a critical factor in successfully achieving the 24M power density target with project CCMs and project hardware
- Dissemination of project results
  The project has disseminated results through its website, brochure, newsletter, at 6 conferences and at 3 trade fairs

Relevant to FCH JU overarching objectives

- Reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels which can compete with conventional technologies
- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements



EG-04-17-700-EN-P