AUTOMOTIVE PEMFC RANGE EXTENDER WITH HIGH TEMPERATURE IMPROVED MEAS AND STACKS

Collaborative Project - *FCH JU GRANT AGREEMENT N° 303482*

SP1-JTI-FCH.2011.1.5 Next generation European MEAs for transportation applications

***Start date**: 01.10.2012 – **Duration**: 36 months*

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PUBLISHABLE SUMMARY RP1

• Description of the project context and main objectives

There is increasing industrial interest in developing HT-PEMFC systems in conjunction with Diesel or methanol-reformer to continuously charge batteries on-board of automotive vehicles, thus extending the range to several hundred kilometers, using the existing infrastructure for hydrocarbon fuels. HT-PEMFC systems are being developed commercially for backup systems in remote areas or developing countries where a long operation time is required when the grid fails. Hydrogen supply for those applications is rather difficult and expensive, leading to the combination of reformers with HT-PEMFC as an attractive option. High temperature fuel cells offer advantages for the overall system as they require less balance of plant components and offer high tolerance to CO and other pollutants. Unlike low temperature PEM fuel cells that depend on perfluorosulfonic acid type membranes, HT-PEM fuel cells need no humidification and their use therefore eliminates water management issues. However, due to the temperature range of operation, the challenge is to improve all the materials involved in the complete stack. It goes from the polymer membrane that should offer excellent conduction, mechanical and thermal properties to the stack components (seals, bipolar plates and coolant). The catalyst layers and gas diffusion layers (anode and cathode), while including low catalyst content, have to avoid corrosion, dissolution or aggregation, which would lead to a decrease in performance or a failure of the system. The purpose of ARTEMIS is to develop and optimise alternative materials for a new generation of European MEAs to be integrated into a 3 kWe high temperature PEMFC stack. The MEAs will be based on new and alternative polybenzimidazole type membranes and improved catalytic layers providing low catalyst loading and high efficiency at high temperature as well as a high tolerance to pollutants (CO, H_2S). The MEAs should offer long and stable properties under various conditions of operation relevant to the range extender application, in particular start/stop. MEAs will be produced at pilot level, using roll to roll equipment available within the partnership. Costs will be reduced since the technology avoids the use of fluorine-based chemistries (low temperature PEMFC). Hydrocarbon polymer-based chemistries and corresponding membranes are significantly less costly. High temperature properties will be maintained in non-pressurised cell hardware and without gas humidification. Due to their operation at 150-180 °C, HT-PEM stacks are the most appropriate PEM technology for a transportation range extender. However, it is critical not only to develop new and less expensive materials, but also to understand the failure mechanisms that occur in all the parts of the stack (membrane, stack components, catalysts and supports). The understanding of such mechanisms will lead to increased durability and lifetime of the system by improved understanding of the different failure modes. The operation conditions of a fuel cell for the range extender application differ from those when the PEMFC stack is used for the power train. Thus the stack is subjected to less transients and operates in semi-continuous mode. But stop/start events corresponding to the normal start up and shut down of vehicle operation are present. Particular attention is paid to the definition and use of appropriate accelerated stress testing protocols. Accelerated degradation tests are intended by the all partners to obtain a first assessment and validation of the MEAs and bipolar plates. Such tests will feed input to the development of alternative and improved materials (characterised by in situ and ex-situ methods) that will be integrated in a complete MEA. Selected materials (membrane, catalysts, support, plate composite materials, seals and gaskets) will be first integrated in a 0.3 kwe stack. Thereafter, decision will be made on scale-up to a 3 kWe stack.

- **Description of the work performed since the beginning of the project and the main results achieved**

The ARTEMIS structure is organised around five technical (RTD) work-packages, one management WP and one dissemination WP. During the first period, work has been performed on all these work packages. Project coordination (WP1) has been continuous, by the management of the different actions needed to be carried out by the partners. Project meetings first started with the kick off meeting, and were pursued by the 6, 12 and 18 months technical and progress meetings. Work has followed the defined Gantt table from Annex 1. Due to this structure, constant interactions and feedback between all the partners have been necessary, and their effectiveness assure that ARTEMIS is really a collaborative project. From the beginning of the project, significant effort has been made on WP2 by the definition and specification of the in situ and ex situ protocols and tests that will be used throughout the project. These protocols are intended to characterise, screen and validate the materials developed (membranes, catalysts, stack components) as well as the complete MEAs. In accordance with all the partners, these parametric tests have been followed assuring the relevance of the obtained results. A complete set of adapted tests and protocols are then available. WP3 has focused on the development of new specific high temperature materials such as highly acid doped polymer membranes and the anode and cathode catalysts and supports. Using the WP2 protocols, screening and validation of the developed materials is in line with the expectations of the project. Furthermore, modeling tools have given important input to the catalyst layer structure and acid loss mitigation strategies. WP4 has mainly focussed on the development of methodologies to produce electrodes and MEAs. The adopted strategy has been first to fabricate MEAs with reference commercial materials then to progressively integrate the produced ARTEMIS components (membrane and electrocatalysts) into MEAs in order to assess their compatibility and manufacturing ability. MEAs with commercial membrane and ARTEMIS electrodes have been fabricated as well as MEAs with ARTEMIS membranes and commercial electrodes. The next step is the fabrication of complete MEAs with the project materials. In parallel, activities on the stack definition associated with the range extender application and the stack components (plates, gaskets, design) have been continuously conducted in WP5. Development of the carbon-polymer cell plates has been gradually advanced by their characterisation under the harsh environment of high temperature PEM. A first production of materials has been initiated and characterised, and improvements achieved by the thickness reduction (lightweight) without losing properties in mechanical strength, chemical stability and conductivity. This second formulation will be used in the 0.3 kWe stack. Materials from WP3 and MEAs from WP4 have been tested using the WP2 protocols in WP6. At the beginning of the project, first experiments were carried out on commercial high temperature MEAs to establish the performance base for comparison of ARTEMIS MEAs. In a second stage, a large effort has been dedicated to the testing of materials and MEAs from WP3 and WP4. The results enable understanding of MEAs and materials manufacturing steps that lead to achieve high performance (higher than commercial) in steady state mode. During RP1, partners have also initiated dissemination activities, with representation in congresses and meetings with oral presentations and posters. The timeline in the first period was very ambitious, with a large number of deliverables and considerable work required on materials development. The project is clearly in line with the expected results for the majority of the activities, and milestones are achieved and respected.

- **Description of the expected final results and their potential impacts and use**

LT-PEMFCs are currently considered as the fuel cell technology choice for automotive applications, the hydrogen fuel being stored in 700 bars embedded cylinders. Indeed, still expensive and bulky hydrogen cylinders render their integration into the vehicle detrimental for habitability. In addition, the viability of such technologies for the automotive market greatly depends on the existence of a hydrogen distribution infrastructure. This network is in its earliest stages for now and will take several years to build up. However, hydrogen can also be produced on-board, via a reforming system, starting from a primary fuel which is preferably liquid (small impact on the integration into the vehicle), and this reformer combined into the complete fuel cell stack and reforming system. LT-PEMFCs are already considered in this framework for stationary applications. Such fuel cells are however very sensitive to the presence of pollutants, such as CO, H_2S, NH_3, organic sulfur-carbon and carbon-hydrogen. HT-PEMFC technologies are a very promising alternative. Due to their higher operating temperature range (150-180 °C), they are much more tolerant to CO, allowing a few percent of CO without irreversible performance losses. High temperature PEM fuel cells have the potential to overcome some of the issues of low temperature PEM fuel cell technology, while still realizing its inherent advantages concerning mass production, simplicity and flexibility. A HT-PEMFC-based electric generator could then possibly be integrated into a vehicle by using available liquid fuels (LGP, gasoline, methanol etc.), allowing a more rapid access to the automotive market.

HT-PEMFC can contribute the ambitious targets of the European Energy Policy of reducing GHG emissions by 20 % and improving energy efficiency by 20 %. ARTEMIS will help to develop more performant and robust materials, understand the lifetime fundamentals and operational conditions, and to integrate the new materials into MEAs and stacks.

ARTEMIS will set standards and testing procedures and improve MEA stability under technically relevant conditions. It helps to offer appropriate stack technologies for this application. Consequently, ARTEMIS helps the new innovative HT-PEMFC technology to develop new products, industries and job opportunities, and to disburden the environment by introducing the fuel cell technology to the market.

As a conclusion, in ARTEMIS, new membrane, electrocatalysts, support, and bipolar plate materials will be developed specifically for MEAs for application as a range extender for transportation application. Final results will help in:

- The development of membrane materials with properties appropriate for transportation fuel cell application.

- The validation of the membranes high temperature properties (conductivity and mechanical robustness) at operation temperatures above 100 °C, in non pressurised cells and stacks, without humidification. The stability of the membranes and MEAs will be such that they can be operated significantly above these temperatures (to 180 °C), with concomitant huge benefits in terms of CO tolerance (and tolerance to other pollutants within the hydrogen feed).

- The development of novel catalysts, their supports, and electrode layers allowing for significant reduction in platinum group metal catalyst loadings, compared with those currently used in HT-PEM.

- The optimisation and demonstration of MEA processing at pilot scale

- The demonstration of performance and long-term stability under automotive range extender fuel cell conditions of HT-PEM Stack.

- The development of multi-scale modelling tools to increase understanding of performance and degradation phenomena in HT-PEM fuel cell.