Project acronym: DeMStack

Project title: Understanding the Degradation Mechanisms of a High Temperature PEMFC Stack and Optimization of the Individual Components

Name, title and organisation of the scientific representative of the project's coordinator:

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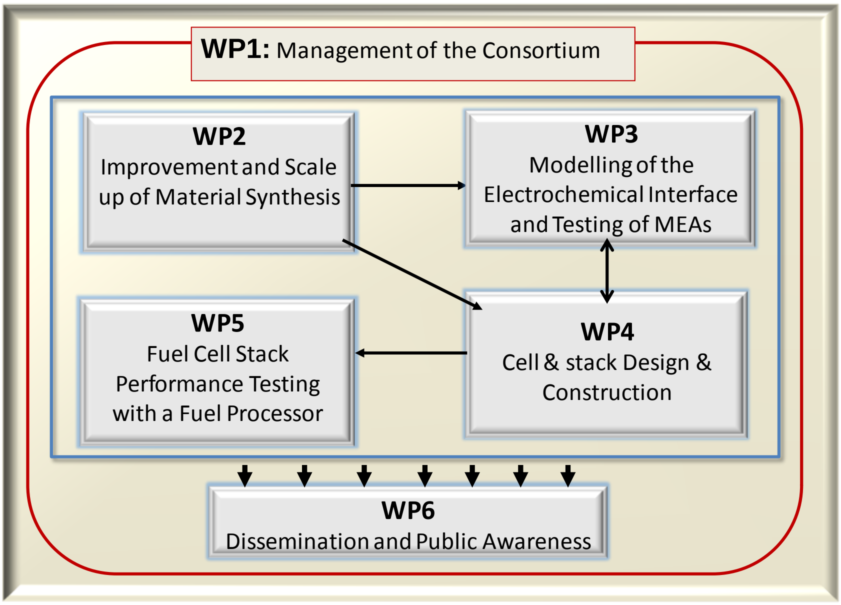
List of partners:

No	Organisation name	Country
1	Foundation of Research and Technology Hellas-Institute of Chemical Engineering Sciences (**FORTH**)	Greece
2	Fundacion CIDETEC (**CIDETEC**)	Spain
3	Institute of Chemical Technology Prague (**ICTP**)	Czech Republic
4	Advanced Energy Technologies S.A. (**ADVENT**)	Greece
5	European Commission, Directorate-General Joint Research Centre, Institute for Energy, Petten (**JRC-IET**)	Belgium
6	Helbio S.A. (**HELBIO**)	Greece
7	Prototech AS (**PROTOTECH**)	Norway

WorkPackages:



Project context and the main objectives

High Temperature Polymer Electrolyte Membrane Fuel Cells having certain advantages over the state-of-the-art low temperature fuel cells constitute a key research issue aiming at higher efficiencies, cost reduction and compactness. One of the most important issues for the market penetration of fuel cells is their reliability and long term stable operation. More specifically, the activities of the DeMStack project are on the stack optimization and construction based on the high temperature MEA technology of ADVENT S.A. and its long term stability testing in combination with a fuel processor.

DeMStack aims to enhance the lifetime and reduce the cost of the overall HT PEMFC technology. The strategy aims at improvements based on degradation studies and materials development carried out in previous (FCH JU DEMMEA 245156) and ongoing projects so that they will lead to a reliable cost-effective product that fulfils all prerequisites for relevant field uses. These improvements cope with degradation issues related to catalyst utilization, reformate feed contaminants, uniform diffusivity and distribution of reacting gases in the catalytic layer, H_3PO_4 acid depletion and distribution within the MEA, startup-stop and thermal cycles. The present proposal aims towards high electrical efficiencies of 45%+ for power units and of 80%+ for CHP units, combined with lower emissions in order to compete with existing energy conversion technologies.

The project addresses the following scientific and technological issues regarding the successful implementation of a HT PEMFC Stack into a sustainable hydrogen society:

- H_3PO_3 doped High Temperature Membrane Electrode Assemblies (HT-MEA), being able to operate on a long term basis at temperatures at or above 180^{o}C.
- Catalytic layers for the HOR and ORR of alternative architectures, chemical structures and low Pt loadings (threefold decrease).
- Bipolar plates of novel design which can promote the operating performance of the MEA, thus minimizing corrosion and prolonging endurance at the high operation temperatures. This task is assisted both through targeted modelling and innovative experimental methodologies.
- Simplified design and manufacturing of the cell and stack configurations.
- Increased efficiency, robustness, durability and drastic cost decrease in HT PEMFCs
- A “ready to use” integrated “fuel processor/fuel cell stack” system with high electrical and overall CHP efficiencies.

In this respect, DeMStack will design, manufacture and test under variable conditions a highly efficient, low-cost HT PEMFC 1 kW stack prototype constructed from the optimized components. A fuel processor will also be constructed, operating on natural gas or LPG, which will be combined and integrated with the fuel cell stack. The robustness of the stack, the simplicity of BoP, the operational stability and the user friendly operation of the integrated system into a commercially reliable product, will be demonstrated.

The “product” of the DeMStack project will be a HT PEMFC prototype stack integrated with a fuel processor with the following operating features:

Fuel cell Stack

(i) Fuel Cell Stack Power output of 1 kW operating on reformates with electrical efficiency exceeding 45% and operating temperature 180^{o}C.

(ii) Operation over a wide range of reformates, (H_2=50-100%, CO = 0-4%, steam = 0-30%).

(iii) Overall cost reduction by a factor of 2 resulting by the significant reduction of the MEA’s cost due to the lower Pt loading and the cheaper membranes.

Integrated system

(i) Power output 0.9 kW with electrical efficiency >38%.

(ii) Operation under steady state and dynamic conditions within a wide range of power output (0.5-0.9kW).

Description of the work performed since the beginning of the project and the main results achieved so far

The main highlights of DeMSTack within the first 18 months are listed below and comprise already achieved targets and the potential outcome of the ongoing studies. The understanding of the functional operation and degradation mechanisms of the fuel cell has advanced our knowledge and led to targeted modifications into a reliable product. In general the activities of the project can be summarized into three entities which refer to:

1. the manufacturing of robust MEAs with low Pt loading
2. the mathematical modelling which will assist the efficient design of the bipolar plates and stack and can be used as a diagnostic tool for the quantitative understanding of the MEA processes
3. the design and manufacturing of the fuel cell stack integrated with a fuel processor.

New materials and MEAs

New materials (Polymer Electrolyte Membranes) and electrocatalysts (Pt/(ox-MWCNTs)-Py) as well as new manufacturing procedures resulted in more efficient performance and successful scale up of the MEAs. The MEAs are more robust in terms of their thermal stability and more efficient in Pt utilization in the catalytic layers both at the anode and the cathode. Lower Pt loadings (reduced by a factor of two) are achieved through the optimization of the electrocatalyst structure. Research for further improvement of the electrocatalyst performance and stability is ongoing. In particular the new Pt catalyst supported on pyridine modified CNTs exhibits significantly higher tolerance to reformate mixtures with increased water content even up to 30kPa and 2kPa CO. Beyond the already mentioned decrease in Pt loading, this improved performance will allow for the simplification of the BoP due to the decrease of the size of the water condenser at the fuel processor's exit.

Mathematical modelling and parameters determination

The mathematical modelling is being developed on two levels. The first is to be used as a diagnostic tool in order to simulate experimental data based on potentiostatic and especially potentiodynamic experimental data, aiming to the extraction and determination of the various parameters that are related to the efficient operation of the MEA. Under this approach special attention is given on the simulation of AC impedance spectra and the detailed simulation of the electrochemical processes within the catalytic layer. The second level refers to the holistic simulation of the fuel cell stack in order to optimize the design of the bipolar plates in terms of flow distribution and mass transfer as well as heat transfer and temperature distribution along the MEA.

Different designs for the bipolar plates and materials used are being explored. Experimental setups and model cell designs have been constructed that provide data such as the mole fraction distribution of the reacting gases in the flow channels and under the ribs along the cell and their correlation with potentiostatic and AC impedance measurements. The experimental data from the model cells will be simulated by the Mathematical model in order to determine the MEA's physicochemical and electrochemical parameters which will be used for the effective bipolar design and the fuel cell stack model.

Stack and fuel processor design and construction

Two separate stack designs are under consideration. The one will be based on metallic bipolar plates (Prototech) with internal cooling and the other will use graphitic bipolar plates (Advent) with external cooling. Both incorporating a liquid cooling system adjusted to the design. The designs and selection of the materials that will comprise the stacks are close to completeness. ADVENT has already constructed a 1kW aircooled stacked which is under optimization so that the external liquid cooling system will be integrated.

In addition the system design including the fuel processor and the peripherals is now complete. The next milestone is the fuel processor which is currently under construction and the PCB control circuit with integrated microprocessor.

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

DeMStack is expected to result in lower cost, robust and highly efficient HT PEMFCs with validated high performance. Great knowledge and interface is expected to be generated that will promote the work of the research institutions involved and have significant impact on the future evolution of their research activities. The academic partners offer the scientific tools through materials development and mathematical modeling as a diagnostic and design tool for the optimization of the MEA's performance, the advanced design of the fuel cell stack, as well as the efficient system integration that will be developed by the three industrial partners of the consortium.

The successful implementation of the DeMStack product into the hydrogen existing and future infrastructure will open new perspectives in fuel cell technology, a fact that will contribute to the objectives of the European Platform to gain world leadership and offer substantial scientific, economic, energy and environmental benefits. The industrial partners – participants will ensure the fast exploitation and commercialization of the results and are expected to greatly benefit through the optimization of their commercial products and broadening of the market. Some of the HT PEMFCs possible applications are AUX power units, CHP units, battery chargers with LPG (300 W), regenerative fuel cells for space (satellites) and stationary back up power systems.

Already Advent and Prototech are advancing their level and experience into HT PEMFC stack manufacturing, which can broaden their cooperation with industrial end-users. This project is the first collaboration between these two companies and important experience and knowledge exchange is taking place. Advent is mainly a manufacturer of Membrane Electrode Assemblies (MEAs), while during the past few years they are trying to integrate their product into a HT FC stack. Prototech has fuel cells and hydrogen technologies as one of its main market areas, while has a patent on an integrated reformer – burner for HTPEM FC stacks. Their expertise is to a certain extent complementary. For both companies, this is the first stack with the specific characteristics (depicted in the DoW) that they are developing. Prototech plans to develop APUs (auxiliary power units) based on the HTPEM stack developed in the DeMStack project. Advent will broaden their activities and will result into a reliable prototype to demonstrate to potential buyers and future development partners.

Moreover, DeMStack can be already considered as the initiation of more intense joint activities between Advent and Helbio, since they are now working closely in order to construct the first fuel cell/fuel processor prototype based on their technology (a low-cost HT PEMFC 1 kW stack based on Advent PEM and constructed from the DeMStack optimized components will be integrated with a fuel processor specifically built to suit the demands of the FC stack). Being able to demonstrate the efficient operation of the prototype, the companies can jointly pursue further funding (field testing) and open a new path in the hydrogen market.

The aforementioned actions clearly demonstrate the multileveled commercialization possibilities of the DeMStack prototype.