NOVEL - Novel materials and system designs for low cost, efficient and durable PEM electrolysers

Project overview

The main objective of the NOVEL project is to develop and demonstrate an efficient and durable PEM water electrolyser utilising the new, beyond the state of the art materials developed within the project. The electrolyser will demonstrate a capability to produce hydrogen with an efficiency of at least 75% (LHV) at rated capacity with a stack cost below €2,500/Nm3h^{-1} and a target lifetime in excess of 40,000 hours (< 15 µVh^{-1} voltage increase at constant load).

To reach these objectives, NOVEL will develop and demonstrate enhanced components that are essential for cost-competitive, high-efficiency PEM electrolysis systems through five key concepts:

- Lower capital costs of the main stack components; membrane, electrodes and bipolar plates / current collectors
- Increase performance, in particular of the membrane electrode assembly (MEA), with reduced platinum group metals (PGM) loadings
- Longer life time of the most crucial PEM components, e.g. the membrane, catalysts and current collectors
- Novel system design for cost-efficient operation at high pressure and improved electrolyser lifetime.
- Development of accelerated stress test protocols for PEM electrolysers for lifetime evaluation and durability investigation of novel components.

The NOVEL project is a continuation of the NEXPEL project (www.nexpel.eu), taking advantage of the successes in the project and continuing the development of the most promising technical solutions as well as capitalizing on the existing, well-functioning, organisational structure of NEXPEL.

Description of the work performed and main results of the 1st period of NOVEL

During the first 12 months of the NOVEL project the consortium has worked on identification of the most important degradation mechanisms occurring in PEM electrolysers and collecting input from the industry and scientific community on the need for improved understanding of these mechanisms. Development of new membrane materials and electrocatalysts has had high activity, resulting in prototypes with promising properties. Development of MEAs and coatings for bipolar plates as well as stack design activities is on-going and a first iteration of a novel stack design has been completed.

Durability/Lifetime evaluation of PEM electrolysers

This first year was used to put in place an organization, different characterization tools and tests protocols in order to collect and analyse a large amount of information and measurements relating to the ageing mechanisms of PEM water electrolyser components (catalyst layers, membrane, current collectors and bipolar plates) and gain understanding.

The first task was to identify the most important mechanisms of degradation occurring in the PEMWE cell components out of the knowledge of each partner, a literature review and ageing tests performed on NEXPEL stacks under real operation. Very fruitful discussions and exchanges occurred during the "First International Workshop on Durability and Degradation Issues in PEM Electrolysis Cells and its Components" organized by Fraunhofer ISE and SINTEF at Freiburg (Germany) the 12th and 13th of March 2013.

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n°303484

The audience of the First International Workshop on durability and degradation issues in PEM electrolysers

Numerous tests were conducted at different levels (from 25 cm² single cell to 300 cm² stack) for thousands of hours of operation in various conditions and duty cycles. Amongst them, a 0.5 Nm^3/h AREVA stack has been tested under pressure at 35 barg for more than 2500 hours under constant current and current profile issued from renewable energy sources. This stack is integrating similar porous components as those used in the NEXPEL stack. Some degradation was observed both on cell voltages and hydrogen purity with time, pointing out the need to work on more stable membranes and coating strategies. The stack is still running, and more than 10 000 to 15 000 hours should be reachable.
Even if the results are promising, this is not enough for stationary applications, which requires at least 40 000 hours. Through the development of new components (catalyst, membrane, coatings) and improved BOP control to optimize stack lifetime, NOVEL will help reach this durability.

Identification of these degradation mechanisms allows the proposing of protocols chosen to amplify the degradation and to compare the behavior of the separated materials in these conditions, while remaining as representative as possible for the real conditions of operation of a PEMWE.

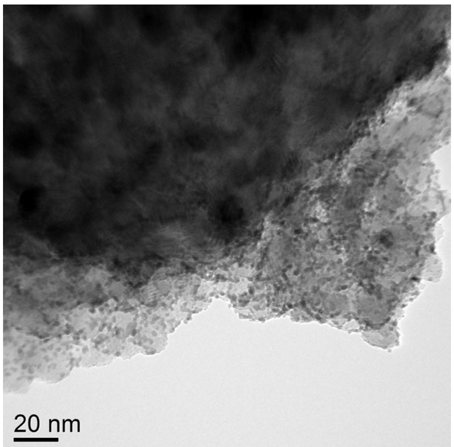
Furthermore, a multiscale modelling tool is being developed to simulate the cell behavior and materials evolution during ageing. It aims to be used as lifetime prediction tool and will have to be confronted with the experimental results.

Novel materials development

The key objectives this activity is to develop new electrocatalysts and novel membranes for PEM electrolysers. For the hydrogen electrode, different loadings of Pt or Pd on commercial carbon materials have been studied related to activity and peroxide generation. For the oxygen evolution reaction (OER) Nb doped TiO_2 support materials have been synthesised and characterized and Ir nanoparticles have been deposited by a microwave enhanced polyol method. The materials show significantly higher catalytic activity than IrO_2 and similar activity to previous catalysts using ATO as support materials.
Work is ongoing to study the long term stability of these catalysts in PEM electrolysers and to further improve the activity by alloying the catalysts with other species.
In the context of the electrolyte membrane, the objective is to develop lower resistance, low crossover and more stable membrane materials compared to the state-of-the-art perfluorinated type membranes, such as Nafion 115 and 117. Radiation grafted membranes offer the prospect of a material tailored towards the specific requirements in the electrolyser at a much lower projected cost. Initially, we established a property map relevant to the electrolyser application using the ohmic resistance and H_2 crossover as key membrane characteristics, based on which a figure of merit is obtained. Using this metric, adequately designed radiation grafted membranes show a clear advantage over perfluorinated membranes. Work on the preparation of radiation grafted membranes using 50 µm thick ETFE base film has commenced and preliminary grafting kinetics have been established.

Development of low cost MEAs

The key objective of this activity is to create an MEA with better than state of the art performance at significantly reduced cost. In order to reach this objective, the new, lower-cost, components developed in the project will need to be combined successfully.



TEM micrograph of $Ir/Ti_{(0.9)}Nb_{0.1}O_2$ oxygen evolution catalyst. The 2nm large Ir particles are well dispersed on the support.

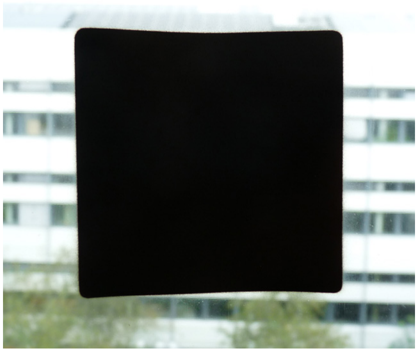
It is also possible to reduce the cost of the MEA by improving the processes used to coat the catalyst layers on to the membrane.

The generation of new materials is underway, but still in the early stages, and in the first four months work has focussed on optimising the process for fabricating the baseline MEAs for supply to the partners to benchmark cell testing. For both the cathode and anode catalyst layers, processing routes have been developed to combine the metal black powders with ionomer and to reduce the particle size significantly. A range of different processing routes and ink formulations have been studied to obtain inks that are suitable for spray coating and that are stable over an extended time period. Inks have been successfully made for both the platinum black cathode and iridium oxide anode that can be left for several days without settling of the metals. This stability allows large print runs to be performed and will reduce wastage of ink.

Methods for direct coating of the catalyst inks on to the membrane have also been developed. Direct coating of the membrane removes the need for a decal transfer step which takes place at >120 ºC and at high pressures. It also opens up a wider range of membrane materials with better mechanical stability such as commercially available hydrocarbons or the radiation grafted membranes being developed by PSI. Initial parts have been made via this method and supplied to partners for evaluation. Once the performance has been confirmed as acceptable, baseline MEAs for the previously built NEXPEL stacks and for laboratory tests will be made.

Bipolar plates and current collectors

The objective of this activity is the improvement or replacement of the expensive titanium material used for porous current collectors and bipolar plates.



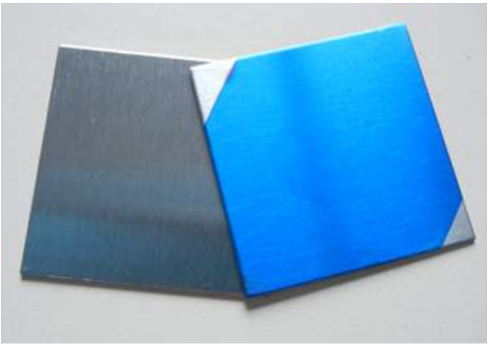
25 cm^2 benchmark electrolyser MEA

Coating strategies shall be developed and candidate materials for bipolar plates and current collectors shall be selected. For this, a review of state of the art for thin film coatings on electrolysers, leading to an agreed prioritized list of candidate coatings for evaluation was given, and benefits and drawbacks for different coatings methods available were described, including possibilities for integration of coatings for catalytic recombination to increase gas purity.

Physical and electrochemical methods of evaluation of the coatings and materials are being developed. The focus is on a fortified stress test, which allows comparing a set of coated bipolar plates with respect to their corrosion stability. Such a test method is needed for the optimization of corrosion protective coatings. As a large number of samples have to be compared in s short period of time, the test has to be simple and fast, and cannot estimate life time, but can only yield a ranking of relative stability of a set of coated bipolar plates.
Later in the project, upscaling and process optimization will have priority in order to be able to coat larger scale bipolar plates and current collector for a demonstration stack as well as ensuring a high batch reproducibility.

Stack design and system optimisation

There were no planned activities in this area for the first year. Nevertheless, an AREVA electrolyser stack producing up to 5 Nm^3/h of hydrogen was assembled and some preliminary tests were done to qualify it on an existing AREVA system. The stack is based on the same design tested successfully by AREVA for more than 2500 hours under the lifetime/durability activity and will be used to test new components developed during the project. The system will also be used for system optimization with the objective to improve stack durability.



Uncoated (left) and coated Ti sheets

Dissemination activities

Dissemination activities have a high focus in the project and the consortium acknowledges the importance of promotion of the development of technologies for sustainable hydrogen production. Our public webpage (www.novelhydrogen.eu) is continually updated with news from the project, the latest dissemination activities and scientific presentations and papers.

Expected final results and potential impacts and use

The results obtained in the first period of NOVEL are promising and demonstrate a high probability for achieving improved performance and reduced cost of PEM water electrolysers. The main expected outcomes from the technological developments are:

- A new generation polyaromatic membranes for PEM electrolysers with significant enhancement in membrane lifetime and cost.
- New oxygen evolution catalysts with significant improvement in catalytic activity and potential for noble metal thrifting.
- Novel stack design, reducing construction material costs and easing assembly.

In addition, performed market analyses of the utilization of PEM electrolysers in different application areas (micro wind & PV for telecom, green H_2 stations and large scale H_2 production from renewable energy sources), will give a better understanding of the role of PEM electrolysers in a future hydrogen economy.

AREVA stack used for system and lifetime evaluations. 35 cells, 6 Nm³/h – PED compliant

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