NEXPEL

Next Generation PEM Electrolyser for Sustainable Hydrogen Production

1st YEAR PUBLISHABLE SUMMARY

CEA LITEN - Fraunhofer ISE - FuMA-Tech GmbH - Helion - Hydrogen Power - SINTEF - Statoil ASA - University of Reading

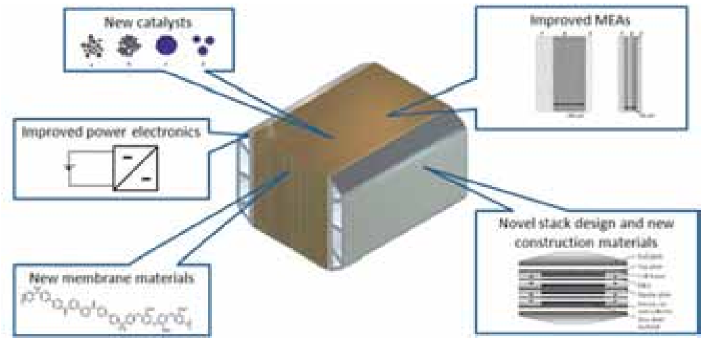
Project overview

The main objective of the NEXPEL project, a successful demonstration of an efficient PEM electrolyser integrated with Renewable Energy Sources, supports the overall vision to establish hydrogen as an energy carrier in a large range of applications in the near future.

The NEXPEL project partners consist of constitute a top class European consortium which is carefully balanced between leading R&D organizations and major industrial actors from 4 member states. The partners are devoted to developing new materials and stack design concepts to increase the efficiency and lifetime of PEM electrolysers and at the same time cutting costs. The three main targets for the NEXPEL project is are to achieve

- Electrolyser efficiency greater than 75%
- Stack life time of at least 40 000 h
- System costs below EURO 5,000/Nm3

The consortium is confident that the dissemination and exploitation of the project results will have a considerable impact especially in terms of securing Europe's energy supply, reducing greenhouse gas emission and increasing Europe's competitiveness.



Summary 1st year

During the first year of the NEXPEL project the consortium has performed initial system design and cost studies to give thereby providing the basis for cost reduction in the materials development and stack design activities. Moreover, substantial efforts have been devoted to the development of new membrane materials and electrocatalysts during the whole year, giving initial input to the upcoming MEA development and stack design activities. During the second half of the year, development of bipolar plates and the stack design activity was started.

System design, marked analysis and cost studies

A simulation tool for evaluation of system integration with renewable energy sources was developed by SINTEF. It demonstrated the possible use of an electrolyser for power quality improvement in a relatively weak system connected to the grid. Economic considerations strengthened the results and demonstrated that at today's electricity prices and expected hydrogen prices, the production of hydrogen from wind energy can become economically feasible.

A first market feedback was realized by HELION which will be updated with data from 2011 by the end of the second year. The first data gathered showed that the requirements for PEM electrolyser products, in terms of cost and technical performance, is highly dependant on the type of application, the type of clients and the compromise that these clients are ready to make between cost and performance. It also appears that the trend in PEM electrolyser developments is to increase system size and to widen the power range so that these products can take larger market shares in a longer term perspective.

Cost break down of key stack components has been achieved by Fraunhofer ISE in order to evaluate costs reduction potential for the stack. Costs of membrane, electrodes, catalyst, current collectors, bipolar plates made from titanium (see Figure 1) and frames, sealing gaskets, and finally end plates have been investigated. In a next step these data will be used to establish a complete cost break down model for the stack. This model will allow the comparison of different stack designs.

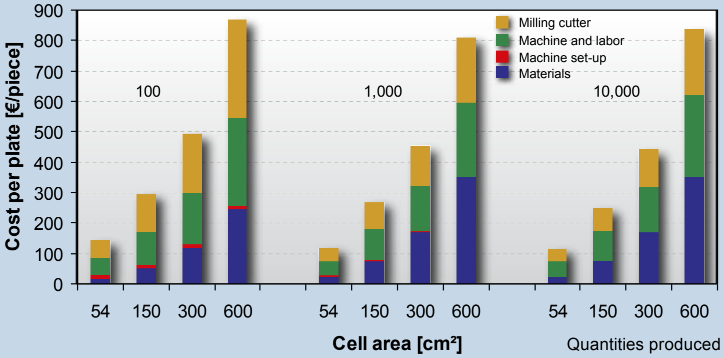


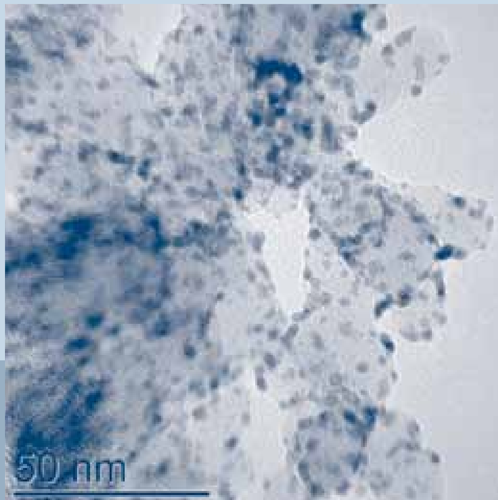
Figure 1: Cost breakdown structure of bipolar plates made of Titanium

Several aspects of a 100 Nm³/h electrolyser power plant were studied by HELION, including the optimum operation/delivery pressure without additional compressor, the modularity, and the electrical architecture. Optimum operation/delivery pressure appears to be between 30 and 60 barg but relies closely on polarization curves aspect and expectations for future performances at higher pressure. Modularity is important from an economical point of view; the unitary module size to be used to reach 100 Nm³/h has to be carefully chosen taking various market considerations into account.

Membrane development
A series of polyaromatic ionomers have been synthesised by University of Reading and are currently being tested for suitability for use within electrolyser devices. The polymeric ionomers feature both hydrophilic and hydrophobic sections and these materials have been designed via careful selection and synthesis of monomers to achieve such structures. Polymers of high molecular weight (Mn ca. 100,000) have been achieved on sufficient scale (~10 g) and then converted to their ionomeric form via direct sulfonation to enable membranes to be cast and subsequently used in MEA tests. The ionomer is soluble in suitable organic solvents such as N-Methyl-2-pyrrolidone and has been cast from a 15 % solution to a membrane of a desired thickness 60-100 µm. The polymers synthesised exhibit excellent thermo-mechanical properties with glass transition temperatures of ca. 195 °C rendering them suitable for operation under elevated temperature regimes as found in electrolyser cell assemblies.

Electrocatalyst development
SINTEF and CEA have developed a common test protocol for catalyst evaluation to ensure that results obtained by the different partners in the project are comparable. The test protocol describes experimental conditions from synthesis of catalysts to electrochemical characterization.

Figure 2: TEM micrograph of Pt/C electrocatalyst



An important activity in the NEXPEL-project has been the development of novel synthesis techniques to deposit active catalysts on a support material to reduce the total amount of expensive and rare materials such as Ir, Ru (oxygen evolution catalysts) and Pt (hydrogen evolution catalyst). SINTEF has produced catalysts consisting of Ir nanoparticles supported on antimony doped tin oxide for the oxygen evolution reaction and carbon supported Pt catalysts for hydrogen evolution reaction. By the polyol synthesis method, active catalysts have been successfully deposited on the support materials as shown in the micrograph (Figure 2) depicting Pt on carbon black.

The project goal of demonstrating supported hydrogen and oxygen evolution catalyst with improved utilisation compared to state of the art catalysts (A/mg of noble metal) has been reached (Figure 3). Further work will focus on development of up scalable methods to ensure good reproducibility at higher production rates.

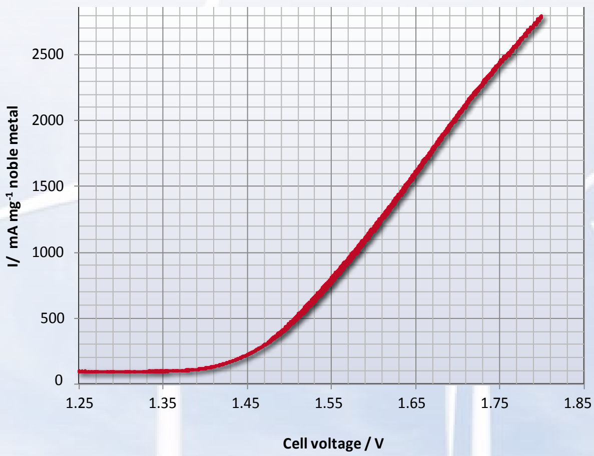


Figure 3: Polarization curve for a PEM electrolyser at 80°C, using 20wt% Ir/ATO as anode catalyst. Current normalized against noble metal loading.

Membrane electrode assembly

Fumatech has supplied two different kinds of standard-type Catalyst Coated Membranes (CCM) to the partners. One type of Fumatech's CCM, coded as fumea®EF-10, is based on a reinforced membrane of thickness 180 micron. This type of membrane shows typically high conductivity so the CCM offers good performance, with a pressure limit for operation of about 10 bar. The second type CCM coded as fumea®EF-30 is based on reinforced membrane as well. The thickness of membrane is 250 micron. This type of CCM is capable to withstand an operation pressure of up to 30 bar.
All partners involved in the project received the number of CCM according to the requests in appropriate size and they completed the testing according to their own testing protocols.
Fumatech has also received the membranes developed by University of Reading based on sulfonated PEEK. The procedure for MEA preparation based on this membrane is under development.

Bipolar plates and stack design

During the first 8 months of the year, CEA and SINTEF performed a wide bibliographic review of literature and patents to define suitable materials or coating strategies for the titanium replacement in bipolar plate and current collectors. A benchmarking activity started in the middle of the year, consisting of an evaluation of the corrosion resistance and electrical contact resistance of the most promising materials used for the bipolar plates.

A two-phase fluid transport modelling tool including electrochemical reactions and thermohydraulic transport has been developed by CEA.

Figure 5 Energy park and hydrogen refuelling station at Statoils Research Centre in Porsgrunn. Photograph: Ragnar Balterød, BIS Production Partner

It is based on capillary pressure and Darcy flow for water and gas transportation and is combined withan electrochemical model. The fluidic transport characteristics and electrical conductivity of various current collector materials has been evaluated by ex-situ characterization. Real PEM water electrolysis tests were performed on 25cm² single cells for model validation. Performance (polarisation curves) and electrical characterization (impedance spectroscopy measurements) were compared, modifying the physical properties of current collectors (thickness, porosity, wetting angle, etc).

Fraunhofer ISE, Helion and CEA started the stack design activity in the second half of the year by defining a simple and reliable stack concept for PEM water electrolysis. The NEXPEL stack should consists of up to 10 cells each with an area of 150 cm². Contrary to conventional design of a stack with bipolar plates and flow fields, the NEXPEL stack will consist of conductive separator plates without any flow channels. Water flow-through and gas removal off the two half cells will be realised by a porous multilayer structure which has a decreasing porosity from the bipolar plates towards the membrane.

The design of the cell and the stack will be assisted by the simulation tool COMSOL Multiphysics. The first simple cell model has recently been set up. For material screening a small (25cm²) laboratory test cell is currently being manufactured. Moreover, a new 10 kW/50 barg test rig for PEM electrolysis stack is under construction at Fraunhofer ISE (Figure 4).

Figure 4: 10kW / 50barg test rig for PEM electrolysis stack at Fraunhofer ISE

Stack testing with renewable energy sources

During the first year of the project, no activities related to integration and field testing with renewable energy sources were planned. There has however been a small activity for preparing Statoil's energy park for a successful integration of the forthcoming NEXPEL stack with the energy park infrastructure.

The Energy Park consists of wind turbines, solar panels and a lead-acid battery bank for energy storage. Two water electrolysers, one pressurized alkaline and one PEM, are installed. The alkaline electrolyser can supply hydrogen produced from renewable energy to the hydrogen refuelling station on site.

Dissemination activities

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

More information can be obtained by contacting the
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