NEPTUNE-PRETZEL joint workshop

Game Changer Proton Exchange Membrane Water Electrolysers
Online Workshop - 17th June 2021

The Neptune project jointly held an online workshop, together partners from with the Pretzel project, covering the topic "**Game Changer Proton Exchange Membrane (PEM) Water Electrolysers**". The aim was to discuss next generation polymer electrolyte membrane electrolysers, with novel solutions at intermediate Technology Readiness Level, contributing to step changes in performance. The workshop attracted **59 participants from several different countries with both industry and academia represented**.

The morning session was dedicated to funded projects in the field of water electrolysis, focusing on those projects with a game changing aspect to the scope.

In the afternoon session, presentations from international experts in the field focussed on specific topics such as electrocatalysts, membranes, MEAs, PTLs, stacks and systems.

Two round table discussions were held, providing opportunities for participants to interact with specific discussions about material development, degradation effects, stack, and system development. The day was concluded by an overview from Nikolaos Lymperopoulos, representing the FCH JU.

We would like to thank all the participants, it was a very interesting day with high level presentations.

Pretzel project homepage: http://pretzel-electrolyzer.eu/

NEPTUNE Consortium

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Clean Hydrogen Partnership

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NEPTUNE

NEXT GENERATION PEM ELECTROLYSERS UNDER NEW EXTREMES

Newsletter #3
June 2022

EDITO

The FCH2 JU funded Neptune project aims to achieve a significant reduction in capital costs of PEM electrolysis, increase the production rate and output pressure of hydrogen while assuring high efficiency and safe operation. During the final stage of the project, the consortium has focused on the production of the large scale MEAs and build and testing of the stack and balance of plant for the demonstration unit. During this phase, the Neptune project jointly held an online workshop, together partners from with the Pretzel project, covering the topic "**Game Changer Proton Exchange Membrane (PEM) Water Electrolysers**".

The balance of plant built for the project is capable of supporting PEM electrolysis at up to 90 °C and up to 100 bar_g, while the stack is designed to run at very high current densities of 4 to 8 A cm^{-2} with stack materials designed/tested to 140 °C and 180 bar_g. An anode integrated recombination catalyst has been employed to extend the safe working range of the thin 50µm membrane. However, a trade off was observed between reaching the very high efficiencies target within the project whilst also attempting to extend the pressure, temperature and load range of the system. Issues encountered during the final demonstration phase limited the assessment of the system durability although MEAs were evaluated at single cell level for 3500hr showing **high efficiency and low degradation**.

The relevant applications for the new PEM electrolysis technology have been analysed as well as current and forecast market sizes with the aim to evaluate the specific market potential throughout Europe. This analysis provides a **strong basis for commercialisation of the advancements made within the project showing the Neptune solutions bring a game-changing advancement to PEM-electrolysis.**

Publications

International Journal of Hydrogen Energy, , International Journal of Hydrogen Energy, Volume 47, Issue 35, 26 April 2022, Pages 15557-15570

Reinforced short-side-chain Aquivion® membrane for proton exchange membrane water electrolysis

S. Siracusano, F. Pantò, S. Tonella, C. Oldani, A. S. Aricò

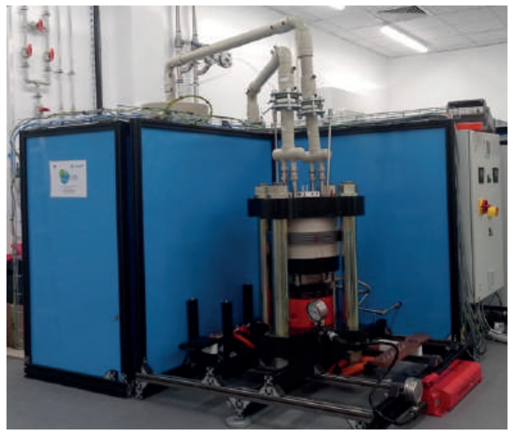
Conferences

WHEC2022 - 26-30 June 2022, Istanbul

CNR oral communication: *Chemically stabilised short side chain Aquivion membranes for operation in water electrolysis*

S. Siracusano, C. Oldani, S. Tonella, A. S. Aricò

WP6 - System Design and Prototyping



The aim of WP6 is the development of an advanced, cost-effective, rapid response PEM water electrolyser system that is able to operate at very high current densities (4–8 A/cm²), while sustaining the associated increase in operating temperature. To reduce the energy consumption necessary for external gas compression, the new system also aims to operate at high pressure (up to 100 bar). Since the last update, components for the balance of plant were procured, assembled and functionally tested. As part of this work, ITM also carried out some development work on the pressure retaining assembly that surrounds the stack, known as the "Stack Skid", to provide better and more uniform compression of the stack cells required for high pressure operation. The balance of plant is capable of supporting PEM electrolysis at up to 90 °C and up to 100 bar_g. The system is now in use testing prototype PEM water electrolyser stacks also developed during the project.

WP5 - MEA and stack engineering

To achieve the project targets, specifically those relating to operating at higher temperatures and pressures, ITM has developed and tested a new stack design. The targets addressed in the Neptune project include operation at high pressure (up to 100 bar_g) high temperature (90 °C, nominal) and high current density (4 – 8 A cm^{-2}). The stack module is based on a 'filter press assembly', in a bipolar arrangement, leading to an efficient and compact design enabling lean manufacture. A low cost, single acting hydraulic cylinder maintains pressure on the gaskets between components, providing compression for the stack module replacing a plurality of tie rods and conventional spring washers that more conventional stack designs utilise. Inside, the stack module has been configured to eliminate expensive machining costs. Traditional "bipolar plates" have been replaced by a flow-field free, laminated stack architecture, utilising lower-cost components and injection-moulded cell plates. Material was selected for the cell plates, considering high temperature resistance properties, enabling operation up to 140 °C. Mechanical testing up to 180 bar_g demonstrated that the new cell plates are capable of withstanding operation at high pressure, when accompanied by an outer pressure retaining ring and also provide support to MEAs incorporating thin membranes (<90 µm).

The aimed high efficiency at elevated current density is realised using a 50 µm thin Aquivion® membrane. The MEA manufacture has successfully been scaled up by IRD from fabrication of 8 cm² MEAs in the development phase to full Neptune size MEAs (398 cm²). 15 full size MEAs were manufactured for the final NEPTUNE stack. Small-scale testing of the prototype MEAs with the active components of the stack (PTLs and grids) demonstrated that the performance was close to the milestone targets for cell voltage at 4 A cm^{-2} and 8 A cm^{-2}, when operating at 90 °C. A degradation rate of <5 µV hr^{-1} for this MEA when operating at 4 A cm^{-2} has been demonstrated in tests by CNR-ITAE. The permeability of the Aquivion® E98-05S membrane and the resulting hydrogen crossover meant that the maximum operating pressure for a stack containing the prototype MEA was 70 bar_g, before reaching the safety limit of 2 vol.% (50 % LEL for H_2). This despite the presence of a PtCo recombination catalyst in the anode catalyst layer. Further work is required to improve the gas barrier properties of the membrane and the recombination performance of the PtCo recombination catalyst. Testing of the stack was restricted to pressures of up to 30 bar_g to provide a reasonably wide range of operation. The stack has operated at current densities of up to 4 A cm^{-2}, whilst at 70 °C, but unfortunately the occurrence of a power supply issue meant that testing at higher temperatures has not been possible within the timeframe of the project.

Catalyst achievements

A Pt-Co alloy unsupported catalyst was investigated as catalysts for recombining hydrogen and Hydrogen production through polymer electrolyte membrane water electrolysis was investigated at high current density (4 A cm^{-2}).

A PtCo recombination catalyst-based membrane-electrode assembly (MEA) was assessed in terms of performance, efficiency and durability (Table 1). The electrolysis cell consisted of a thin (50 µm) perfluorosulfonic acid membrane and low platinum group metals (PGM) catalyst loadings (0.6mgMEA PGM cm^{-2}). An unsupported PtCo catalyst (figure 1) was successfully integrated in the anode. A composite catalytic layer made of $IrRuO_x$ and PtCo assisted both oxygen evolution and oxidation of hydrogen permeated through the membrane. The cell voltage for the recombination catalyst-based MEA was about 30 mV lower than the bare MEA during a 3500 h durability test. The modified MEA showed low performance losses during 3500 hours operation at high current density (4 A cm^{-2}) with low catalyst loadings (Figure 2). A decay rate of 9 µV/h was observed in the last 1000 hours.

These results are promising for decreasing the capital costs of polymer electrolyte membrane electrolysers. Moreover, the stable voltage efficiency of about 80% vs. the high heating value (HHV) of hydrogen at 4 A cm^{-2}, here achieved, appears very promising to decrease operating expenditures.

***Table 1**: Composition and catalyst loading of the invastigated MEAs*

MEA code	Anode			Membrane	Cathode	
	IrRuOx catalyst Loading (mg_{Ir+Ru} cm^{-2})	PtCo catalyst Loading (mg_{PtCo} cm^{-2})	Aquivion® D98-06AS ionomer (wt.%)	Aquivion®	Pt/C catalyst loading (mg_{Pt} cm^{-2})	Aquivion® D98-06AS ionomer (wt.%)
Bare	0.3	–	15%	E98-05S	0.1	28%
RC mixed	0.3	0.2	15%	E98-05S	0.1	28%

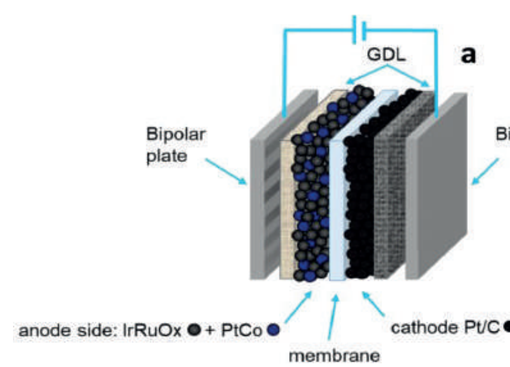


***Figure 1**: Structure of the MEAs based on the $Pt_{5.6}Co_1$ recombination catalyst.*

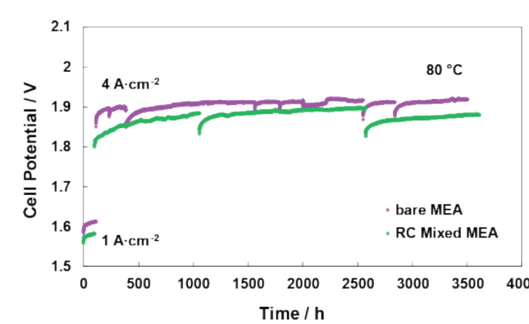


***Figure 2**: Durability test at 1 and 4 A cm^{-2} and 80 °C of the bare and RC mixed MEAs*