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Influence of MEA composition (membrane reinforcement, MPL) on membrane water content during operation

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Presentation of SolviCore

SolviCore is a joint venture between Umicore and Solvay for the development, production and sales of PEM Fuel Cell MEAs. It was founded 2006 and Solvay brought in its expertise in membrane development whilst Umicore put in the expertise in the design and manufacturing of MEAs. SolviCore has excellent prerequisites for a successful MEA development as it comprises membrane as well as catalyst know-how.

SolviCore is operating a state-of-the-art MEA production plant in Hanau Germany. SolviCoreŁ??s well equipped MEA testing center is conducting MEA performance and endurance tests under all latest state testing protocols and conditions for all relevant PEMFC applications.

SolviCore currently employs 50 co-workers.

General Context

Water management in PEM fuel cell constitutes either a clear limitation to operation flexibility or a major source of degradation. Moreover, the influence of the component properties on the water repartition during operation is not clearly known and understood. To validate the acceptable operation conditions that allow both good performance and durability, in-situ characterizations are of most interest. This is especially true for applications such as transportation and Combined Heat and Power (CHP) which are emerging and growing markets for Proton exchange membrane fuel cells (PEMFC). They require a nominal operating temperature above 90°C whereas current PEMFC prototypes are operated at a maximum temperature of 80°C mainly because the proton conducting membrane (typically Nafion) dehydrates at higher temperatures inducing a significant loss of performance. Solvicore has developed a medium temperature MEA but little is known on the way the PEMFC operate above 90°C. There is a need of information on the water repartition inside and outside the membrane during operation and especially on the presence of liquid water above 90°C.

Context of the proposal

EDIP experiment is suitable to quantify the water repartition in an MEA either with or without presence of liquid water in the cell.

In the framework of the JRA activities, different series of experiments were conducted to improve the EDIP installation. Especially, new 25 cm² cells have been designed for Small Angle Neutron and X-Ray Scattering. These cells allow studying the water repartition in different areas of the active surface both in front of the rib and in front of the channel of the monopolar plate. 4 cells are available for SANS experiments and 2 cells are available for SAXS experiments.

Experiments have been conducted by CEA at ESRF (European Synchrotron Radiation Facility, Grenoble, France) for SAXS and at ILL (Institut Laue Langevin, Grenoble, France) for SANS to determine the water repartition during operation. Thanks to the High Flux Reactor at ILL, the in-plane spatial resolution of SANS experiments is 0.5 x 8 mm² and the time resolution of 30s for a 50 µm thick membrane. Submillimeter and subsecond resolution can be achieved by SAXS with a 50 µm thick membrane using the ID2. However, for SAXS experiment the Gas Diffusion Layer must be removed in the probed area (400 µm hole) in order to be able to perform the analysis. So, if SAXS allows higher time and spatial resolution than SANS, it is a little bit more intrusive. Nevertheless, the modification of the MEA is on a very small area (6 holes) compared to the total surface and this does not affect the overall water repartition. These results confirmed the feasibility of the experiment with membranes as thin as 15 µm which correspond to the state-of-the art in commercial MEA.

SolviCore has heard about this experiment and contacted CEA in order to perform study of water repartition during operation with SolviCore MEA. CEA proposed to SolviCore to perform the experiments in the frame of the European project H2FC. The experiments have been defined and the proposal has been drafted in common.

Objective of the proposal

The goal of the proposal is to study the influence of the kind of membrane (reinforced or not) and of the presence of a microporous layer of the gas diffusion layer on the water management through the combined determination of the water distribution with the measurement of the electrochemical performance and impedance spectra.

This experiment will bring crucial and new information, both on the scientific and technological point of view, on the water content in membrane, either out of or during operation, especially at medium temperature. Only very few data on membrane water content at high temperature are available in the literature especially during fuel cell operation.

Methodology and organisation

The water content outside the membrane will be determined from the value of the transmission which will be calibrated using 3 different thicknesses of liquid water as references. The water content within the membrane will be determined from the position and the intensity of the ionomer peak of the membrane on the scattering spectra. Reference spectra of membrane electrodes assembly (MEA) equilibrated at different relative humidity from 10% up to 100%. These reference spectra will be recorded during the experiment for each kind of membrane within in the single cell.

Three samples will be studied and provided by SolviCore to CEA:

- 1st sample: SC MEA with reinforced membrane + GDL with 5%PTFE MPL
- 2nd sample: SC MEA with reinforced membrane + GDL with 20%PTFE MPL
- 3rd sample: SC MEA with extruded membrane + GDL with 20%PTFE MPL

The water repartition will be determined at different current densities in three different operating conditions:

- H2/Air, 60°C 1.5 bars 100%HR st. 1.5/2
- H2/Air, 80°C 1.5 bars 50%HR st. 1.2/2
- H2/Air, 95°C 1.5 bars 25%HR st. 1.5/2

The current density will be increased stepwise up to 1 A/cm² (0.1, 0.2, 0.4, 0.6, 0.8 and 1 A/cm²) and the kinetic of the evolution of water repartition will be followed between each current step.

SolviCore will measure and exchange with CEA the membrane normalized water transport capability and conductivity under similar relative humidity for the 3 types of samples.

The two first samples will be assembled in the single cell before the experiment. The break-in of the MEA will be performed outside of the beam-line. So, 3 days are required to prepare the experiment. The third sample will be assembled in the cell during the beam time. The break-in procedure will also be done during the beam time and will take about 8 hours. The evolution of water repartition during this break-in procedure can be followed.

3 full days are required to perform the experiments:

- The set-up of the experiments require around 8 hours
- It takes about 8 hours to record the reference spectra. Since two membranes will be used, the recording of the reference will take around 16 hours
- The break-in procedure will take about 8 hours for the third cell.
- The empty cell must be recorded for each test. This requires about 1 hour characterizing the empty cell. So, 3 hours are required total
- It takes about 6 hours to record all the spectra for each operating conditions and the transition between two operating conditions require around 1 hour. So, 8 hours are necessary to perform a complete characterization in a given operating condition. The total requires around 24 hours per MEA. So, 72 hours total.

This means that 5 full days (120 hours) are required to perform the entire experimental plan.

Finally, the reproducibility will be checked outside of the beam line in the same set-up. If performance is the same, the water repartition will be considered to be the same and the results obtained on the beam-line considered to be reliable. So, 6 days are required to test the cell.

The data treatment will require about 7 days.

The study will be conducted by SAXS. So, we will apply for beam time at the ESRF on ID2 beamline in parallel to the proposal in the H2FC project.

Dissemination

All results will be published and SolviCore wishes to validate the publications before submission.