Experimental report

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Proposal: **9-11-1805** **Council:** 4/2016

Title: Operando SANS study of Fuel Cells ageing and performance

Research area: Engineering

This proposal is a new proposal

Main proposer: **Nicolas MARTINEZ**

Experimental team: Fabrice MICOUD
Sylvie ESCRIBANO
Laurent JACQMIN
Sandrine LYONNARD
Nicolas MARTINEZ
Sebastien ROSINI
Gerard GEBEL
Arnaud MORIN
ANAIS FINKLER

Local contacts: Lionel PORCAR

Samples: Fuel cell membrane

Instrument	Requested days	Allocated days	From	To
D22	3	2	09/11/2016	12/11/2016

Abstract:

Proton exchange membrane fuel cells (PEMFC) represent one of the most interesting technologies for powering automobiles or small portable electronics. The repartition of water inside the fuel cell, as well as its microscopic organization inside the membrane are critical issues that impact fuel cell performance and durability. These properties change depending on the amount of current that is drained from the cell, but also of the history of the membrane. SANS is one of the best suited tools to study these issues as it informs on both water microstructure and organization, but also because measurements can be performed while the fuel cell is functioning in a non-intrusive fashion. Here, we propose to study the water distribution inside a functioning fuel cell in order to understand how local current density and membrane ageing affect the distribution of water in the PEMFC. This study could allow us to understand why PEMFC with aged membranes see a drop in performance, but also why some parts of the cell perform better than others. This information could help us adapt operating conditions so that we can have fuel cells with better performance and durability.

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In these experiments we aim at determining the total liquid water content and the water content in the membrane in an operating proton exchange membrane fuel cell (PEMFC) using small angle neutron scattering.

The neutron beam goes across the thickness the membrane electrode assembly, e.g. through the membrane, the anode and the cathode. We obtain isotropic 2D-images on the detector which is azimuthally averaged to obtain 1D spectra. These spectra are characterized by the presence of the pic, called ionomer peak, which is associated to the nanophase separation between hydrophilic and hydrophobic domains in the proton conducting membrane. Its position and intensity are univocally related to the water content in the membrane. This peak is located in the range of 0.1 and 0.2 A^{-1}. We use the incoherent scattering to estimate the total water content in the cell in the probed area.

Reference spectra have been recorded at equilibrium at different RH on the fresh and aged cell to establish the relation between the position of the ionomer peak and the RH. This helps in determining the averaged local RH knowing the position of the ionomer peak during operation. The dry cell is recoded in each position which is probed and is used as a reference. It is subtracted from the foreground in the same position in order to obtain the data of interest.

We have conducted the experiments at 80°C under H_2/Air at 1.5 bars and 50%RH with H_2 and O_2 stoichiometry of 1.5 and 2 respectively, using two sizes of beam.

a/ The spectra have been recorded with a beam of 0.5x10 mm² in different 14 different areas (7 ribs and 7 adjacent channels) of the cell from gas inlets to outlets to establish the water distribution. The measurements have been conducted on a new cell at 0.5, 1.0 and 1.25 A/cm² and in an aged cell at 1.0 A/cm². For each condition, we record 10 spectra of 1 minutes which have been averaged and which can be used to follow a kinetic after change in load. After correction spectra like those shown in Figure 1 are obtained.

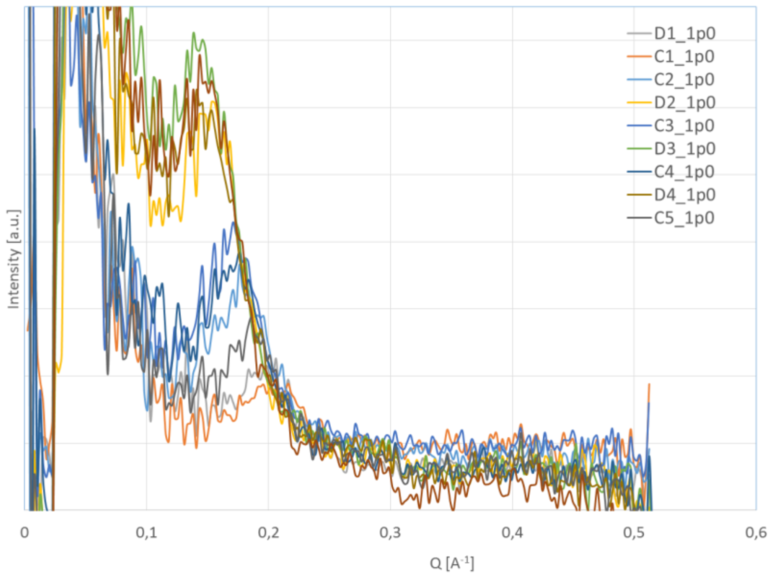

Figure 1: Spectra recorded at 1A/cm² with a 0.5x10 mm² beam. 80°C_H_2/Air_1.5 bars_50%RH_st. H_2/O_2 = 1.5/2. D = In front of the rib. C = In front of the channel. 1 : close to the Air Outlet. 5 : close to the Air Inlet.

The position of the ionomer peak and the incoherent background are extracted from the data by fitting with a function equals to the sum of an exponential decay, a Gaussian peak and a constant background.

The swelling behavior of the membrane is known. Then, this is possible to extract from the position of the ionomer peak the membrane water content, quantified in λ, which corresponds of the average number of water molecules per sulfonic acid group.

The relation between incoherent background and equivalent water thickness has been established previously on D22 for the wavelength of interest. Then, after extraction of the incoherent background, we calculate the equivalent water thickness in the cell (e). We could have used the transmission but it is less accurate considering the small amount of water and the small variations in transmission.

From these calculated values of λ and e, we have plotted the evolution of water distribution in the cell from Air inlet to Air outlet, as shown in Figure 2.

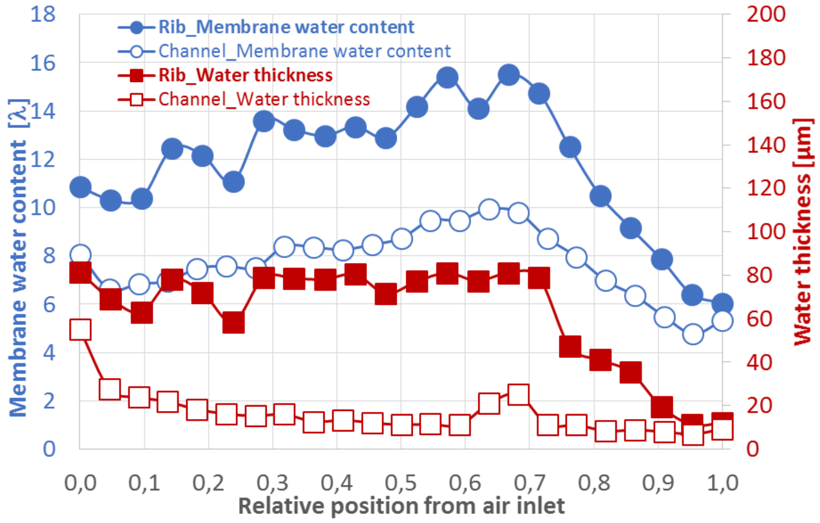

Figure 2: Evolution of the membrane water content and the total liquid water content in the cell from Air inlet to Air outlet, in front of the rib and in front of the channel. 80°C_H_2/Air_1.5 bars_50%RH_st. H_2/O_2 = 1.5/2. 1A/cm²

b/ Spectra have been recorded with a 0.1x20 mm beam during 10 minutes in order to increase the spatial resolution. The water distribution was quantified from the middle of the channel to the middle of the adjacent one, close to Air inlet. The results are shown in Figure 3.

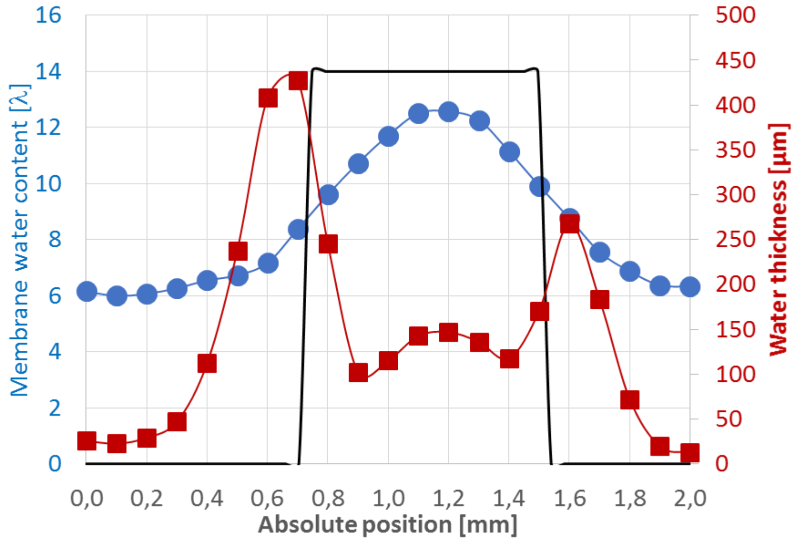

Figure 3: Evolution of the membrane water content and the total liquid water content in the cell from the middle of a channel to the middle of the adjacent one, close to Air inlet. 80°C_H_2/Air_1.5 bars_50%RH_st. H_2/O_2 = 1.5/2.