Experimental report

15/02/2022

Proposal: **1-05-44**

Council: 10/2020

Title: Probing water in Proton Exchange Membrane Fuel cell with PGM-free catalyst using neutron radiography

Research area: Materials

This proposal is a resubmission of 1-05-24

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Samples: Fuel Cell Membrane Electrode Assembly (Nafion, C, Pt, PTFE)
B5 bottle of O2 outside the bunker

Instrument	Requested days	Allocated days	From	To
NEXT	3	3	23/03/2021	26/03/2021

Abstract:

The objective of this proposal is to study, thanks to neutron imaging, the water distribution in a PEMFC based on Pt-free electrodes and operating in real conditions with unprecedented combined spatial (<5µm) and time (~1 min) resolutions thanks to the high flux of the neutron reactor of ILL along with the state-of-the-art instrumentation of D50. The final goal is to understand the reasons of the limitations in performance of such type of Pt-free electrodes in relation with water, in order to be able to improve them.

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Probing water in Proton Exchange Membrane Fuel cell with PGM-free catalyst using neutron radiography

Neutron radiography experiments have been conducted on the NEXT beamline from 23rd to 26th March 2021. For these experiments, a dedicated single cell has been designed and manufactured in order to achieve high spatial and temporal resolution. The spatial resolution is about 5µm across the Membrane Electrode Assembly (MEA) thickness and 15-20 µm perpendicularly to the flow field. The temporal resolution was 30s per frame and the images were obtained after averaging 10 frames. Thus, each images is an average over 5 minutes.

A dedicated post-treatment analysis was developed to quantify the amount of water from the images (Figure 1). Briefly, the image of the cell in operation (intensity I) is referenced to the dry cell image (intensity I_0) to attain a processed image of the water. For thin sections of water, the water thickness (t) can be approximately obtained from the Lambert-Beer Law:

$$t = \frac{1}{\mu_w} \ln\left(\frac{I}{I_0}\right) \qquad (1)$$

Where μ_w [m^{-1}] is the water attenuation coefficient measured in the calibration experiment.

From each images of water thickness, expressed in cm of water crossed-by the beam, the value of water thickness is averaged over the thickness of each rib/channel. Then, these averaged values for each rib/channel are averaged over all the ribs/channels in the field of view (between 9 and 10 ribs and between 10 and 11 channels, depending on the MEA). Thus, we obtain average water content profiles across the thickness of the MEA in front of the rib and in front of the channel for each MEA and for each operating point (Figure 2). From the water thickness, we can extract the average water volume fraction by dividing the average water thickness by the length of active area crossed by the beam (5 mm).

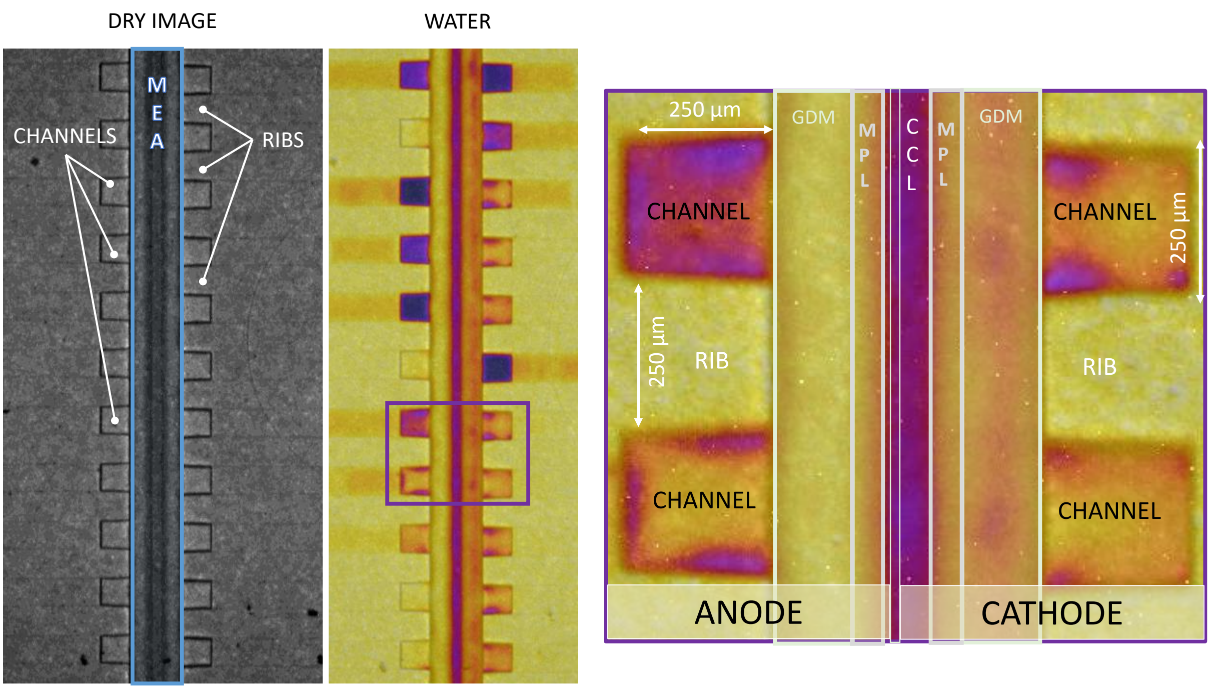

Figure 1. Images of the dry cell, water after image analysis, with zoom on water (scale ranging from red to purple). Armines-Nafion. 60°C_H_2/O_2. 100%RH_2,2bar. 1 A/cm².

Five MEAs have been tested differing only in the composition with Pt/C, or non-noble catalyst, either using Nafion or Aquivion as ionomer. Gore membrane was used from all MEAs. Sigracet from SGL was used as Gas Diffusion Layer (GDL) with a final thickness of 175 µm in front of the rib when compressed into the cell. It is made of a carbon fiber based Gas Diffusion Media (GDM) that is in contact with the monopolar plate, on which is deposited a so called Microporous Layer (MPL), that is in contact with the Catalyst Layer (CL).

Four operating conditions have been selected varying the temperature, between 60 and 80°C, the relative humidity between 95%RH (below saturation) and at 100%RH (forcing condensation into the cell), the partial pressure of O_2 and H_2 between 1 and 2 bars. The measurements were performed with pure H_2 and O_2, at the anode and cathode side respectively with a fixed gas flow of 15 Nl/h. During the experiment, Electrochemical Impedance Spectra (EIS) as well as polarization curves have been recorded to determine the ohmic resistance of the cell as well as the performance.

Not all the MEA could have been tested in all the operating conditions because of the lack of time.

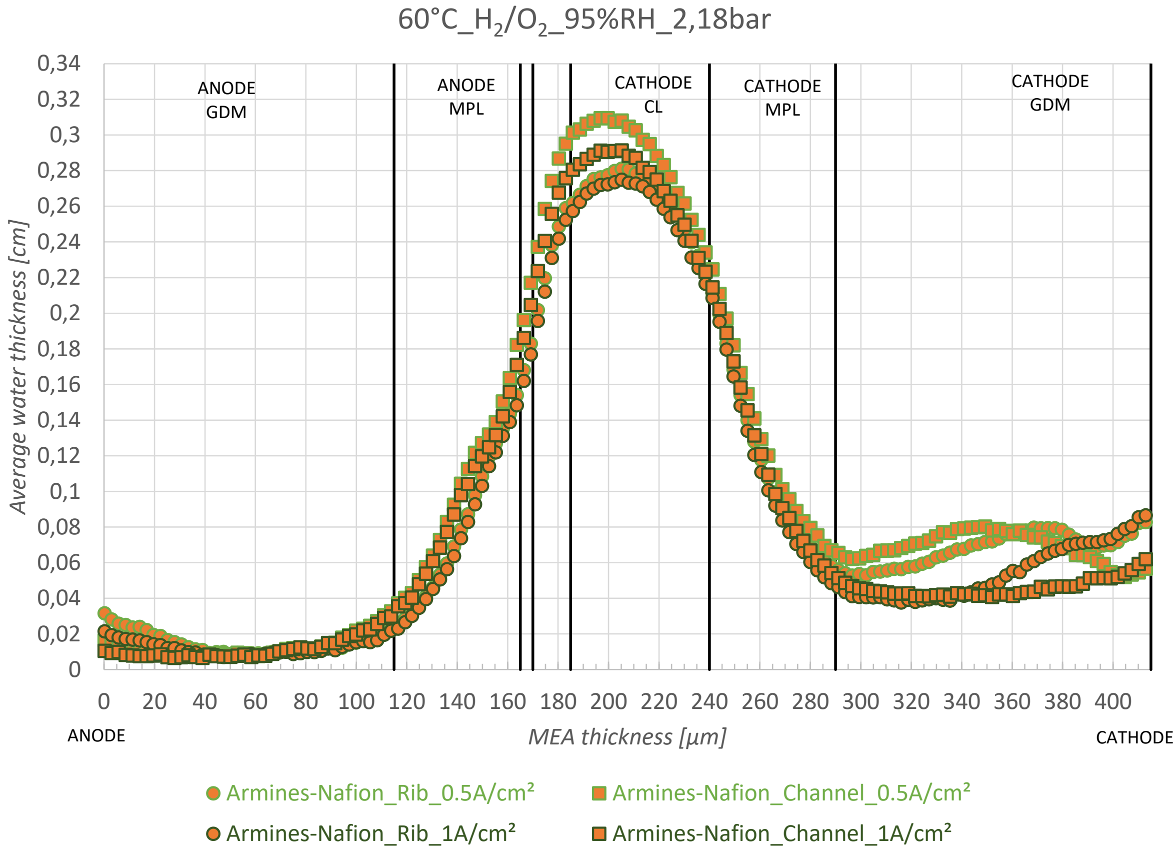

Figure 2. Average water content profiles across the MEA thickness in front of the rib and in front of the channel at 0.5 and 1 A/cm² for the nonPGDM catalyst from Armines+Nafion CCL. 60°C_H_2/O_2_95%RH_2,18bar.