Experimental report

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Council: 10/2018

Title: Operando SANS investigation of water management in fuel cells made with alternative aromatic ionomers

Research area: Soft condensed matter

This proposal is a new proposal

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Samples: polyether sulfones

Instrument	Requested days	Allocated days	From	To
D22	4	4	29/07/2019	02/08/2019

Abstract:

We are exploring the development of a fully hydrocarbon fuel cell assembled using aromatic ionomers alternative to Nafion (block copolymers) as membrane and proton-conducting binder in electrodes. The fuel cell performance is expected to highly depend on the water management, e.g. the distribution of water inside the various components, in particular the membrane. Hence, we propose to perform operando SANS experiment on these new fuel cells, applying the method we developed on D22 on benchmark Nafion-containing systems.

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The main objective of this experiment was to study the influence of the structure and transport properties of membrane on the water distribution in an operating proton exchange membrane fuel cell (PEMFC). In a PEMFC, the electrochemical conversion takes place in the membrane electrodes assembly (MEA). It is made of one anode and one cathode separated by a solid polymer electrolyte that transfers proton. Not only the proton can cross the membrane but also the water. Water plays a crucial role in the PEMFC. It is not only the product of the electrochemical reactions but it is also involved in all the electrochemical, chemical and physical phenomena occurring in the fuel cell. Water management is critical in PEMFC. On the one hand, the protons transfer is enhanced as water content increases in the conducting ionomer contained in the electrode and in the membrane. On the other hand, water condensation must be avoided in the porous structure of the electrode because it blocks the access of reactants to catalytic sites. A good water balanced is mandatory to obtain the best performance and durability. The membrane acts also as a water transfer media between the anode and the cathode. The resulting water distribution depends on the membrane water transport properties. The most commonly used membrane for PEMFC is perfluorosulfonated based ionomer, such as Nafion. LEPMI has developed a new membrane. These two membranes differ in chemical structure and transport properties. The performance obtained with this membrane is slightly lower than with Nafion. In order to understand where the difference does come from, Small Angle Neutron Scattering is used to determine the water content in the membrane and the total liquid water content in the cell during operation. The measurement is conducted at the rib/channel scale (mm) and from gas inlet to outlet. The membrane water content is extracted from its unique relationship with its nanostructure, for both type of membrane. At a given water content corresponds a given nanostructure. The nanostructure is characterized by SANS to obtain water content. Reference spectra are recorded prior to the fuel cell operation. The total water content is calculated from incoherent scattering due to liquid water. The experimental setup and analysis method is described in papers published by our group.

We used a beam size of 0.5x14 mm². Taking into account the divergence of the beam (calculated from the collimation), and the slit to sample distance, the footprint of the beam is around 650 µm on the sample. Thanks to this spatial resolution, we were able to probe the water content in front of the current collecting rib (800 µm in width) and in front of the gas distribution channel (1400 µm in width). We recorded the spectra with a sample to detector of 2m. The thickness of the membranes is around 50µm.The counting time was 5 minutes for each position. We have recorded the spectra in 14 positions from gas inlets to outlets for each cell. A total of three cells have been tested, with membrane Nafion, with the new polymer as a membrane and with the new polymer both within the membrane and the electrode. Few hours are required to install and align the cell to be sure to probe solely either the channel or the rib.

The measurements were conducted at 80°C. For each cell, reference spectra are recorded prior to operation in dry state and at 70, 80, 90%RH and finally in saturated conditions. Then, the cell was operated at 80 and 100%RH at 0.2, 0.4, 0.8, 1 and 1.2 A/cm². At the end of the test, new reference spectra were recorded at 80 and 100%RH. There was no issue with the instrument or with the neutron flux.