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Water distribution at different length scales in operando fuel cells

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Proton Exchange Membrane Fuel Cells (PEMFC) are one of the most promising technologies for powering automobiles and small portable electronics. The functional part of the PEMFC is composed of a membrane which is stacked between two electrodes: the Membrane Electrode Assembly (MEA). This MEA is held by a metallic framework composed of channels that collects the current produced and allows gasses to flow through the cell. Despite intensive research in the field, actual performance and durability of PEMFCs are important drawbacks that prevent large scale commercialization. These two aspects are linked to the way water is structured in the fuel cell at a microscopic and macroscopic scale. Our work focuses on investigating water distribution on these two length scales combining Small Angle Neutron Scattering (SANS) and neutron radiography. Indeed, the membrane present in the MEA is a nanostructured polymer with ionic domains which have a length scale that can be probed by SANS. We can thus monitor the microstructure of water inside the membrane by following the position of a so-called ionomer peak, but can also quantify the total amount of water with the incoherent background [1]. Neutron radiography nicely completes SANS as it gives information on water distribution at a macroscopic length scale, but also because it can probe the out of plane distribution of water (in contrast to SANS that is limited to in plane measurements), offering a 3 dimensional view of the system. The big advantage of SANS and neutron radiography over other techniques, such as small angle X-ray scattering, is that the signal is not very sensitive to the electrodes present in the MEA, allowing us to perform measurements while the fuel cell is functioning.

By reducing the size of the beam during the SANS experiment we can scan different parts of the MEA to get an actual mapping of water distribution inside the fuel cell [2]. This allows us to get information on water structuration as a function of the position in the membrane and amount of current drained. By completing the SANS data with neutron radiography measurements, we get information on length scales spanning from a microscopic to a macroscopic scale. Results show that while the membrane is much more hydrated near the air inlet regardless of the current drained, the amount of water outside the membrane only follows this trend when no current is drained. These results shed a new light on the different mechanisms governing water management inside a functioning fuel cell [3].

[1] Deabate S, Gebel G, Huguet P, Morin A, Pourcelly G. Energy & Environmental Science (2012) 5(10): 8824-8847

[2] Xu F, Diat O, Gebel G, Morin A. Journal of the Electrochemical Society (2007) 154: B1389

[3] Morin A, Gebel G, Porcar A,Peng Z,Martinez N, Guillermo A, Lyonnard S. under review

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