Water uptake in proton exchange membrane fuel cells

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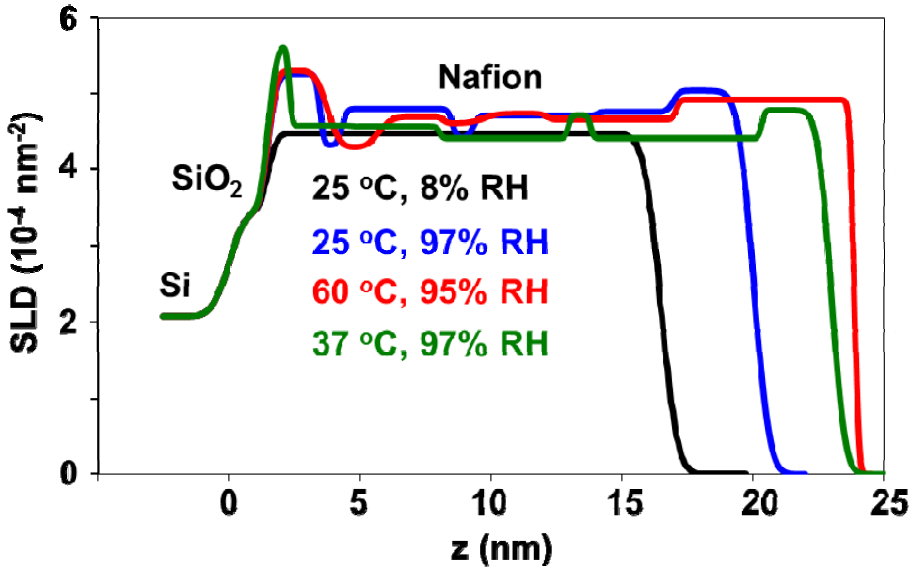
Proton conduction in proton exchange membrane fuel cells (PEMFCs) is facilitated by a perfluorinated sulfonic acid type polymer, namely Nafion™. Proton conductivity is a very strong function of water content within the polymer matrix which will swell/shrink, absorb/release water when the ambient humidity increases or decreases, respectively. Inside the catalyst layers, Nafion exists as nanometer-scale filaments and its behavior on these length (thickness) scales is thus of fundamental importance in fuel cell research. Because of the high sensitivity of neutrons to (heavy) water and the ability to determine layer thickness with very high precision, neutron reflectometry is the most suitable technique to study these phenomena. We investigated 15-25 nm Nafion films on three substrates, SiO_2 (native oxide), carbon and ultrathin Pt-on-carbon under different temperature-humidity conditions. Interestingly, the layer on SiO_2 absorbs large quantities of water not only upon increasing humidity, but also upon heating from 25 to 60°C, which is within the operating range of fuel cells. Part of the water and most of the swelling remains after cooling. The behavior on C and Pt substrates was very different and the work as a whole can be expected to have significant impact in the field of catalyst optimization and water management in PEMFCs.

The first part of the work has recently been submitted to Chemical Communications[1] (RSC publishing), write-up of the remaining results is currently in progress.

[1] W.P. Kalisvaart, H. Fritzsche, W. Merida, Water uptake and swelling hysteresis in a Nafion thin film measured with neutron reflectometry, submitted to Chemical Communications (ref. CC-COM-01-2015-000002)



SLD profiles of 150 Å Nafion layer on native SiO_2 as a function of temperature and humidity. Note the large step in the thickness, both between 8 and 97% RH and 25 and 60°C at 97-95% RH.