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Temperature/Solvent Annealing Effect on Nanostructure of Ionomer Thin Films Revealed by Multi-Prove Experiments

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Polymer electrolyte fuel cells used in electric vehicles convert the chemical energy of hydrogen into electricity to power motors, in which the electricity is generated in three steps: hydrogen gas is dissolved into protons at the anode, the protons are transported through an electrolyte, and the protons are reacted with oxygen at the cathode. Perfluorosulfonic acids (PFSAs) are widely used as a proton conducting ionomers not only for the electrolyte but also for the binder of the carbon black with Pt catalyst in the cathode. Therefore, the proton conductivity and oxygen permeability of PFSA can be a bottleneck of the electrochemical reaction on the Pt surface at the cathode, which depend on the nanostructure as well as the chemical structure of PFSA. Industrially, the assembly of anode, electrolyte and cathode is made by the so-called decal process, in which the stack is hot-pressed at 120-140 ℃ for 10-20 minutes. The assembly is then combined into the fuel cells and annealed by the water produced by the reaction repeatedly over a run-in period. Although the processes are empirically tuned, the nanostructure of the PFSA is expected to be controlled to optimize the bottleneck.
In this study, the effect of the thermal annealing on a Nafion® thin film, typical PFSA, on a Pt coated Si substrate in the decal process is evaluated by grazing incident angle small angle x-ray scattering (GI-SAXS) mainly for in-plane nanostructure, neutron reflectometry (NR) for out-of-plane nanostructure, positron annihilation lifetime spectroscopy (PALS) for free volume, and x-ray absorption spectroscopy (XAS) and quartz crystal microbalance (QCM) for water content in a vacuum and in air, respectively, to understand the role of the decal process. Interestingly, the drastic change in the nanostructure was observed between 10 and 20 minutes, which is consistent with the annealing time of the decal process. Also, some of the experiments are performed with changing humidity with repetitions to evaluate the effect of solvent annealing on the run-in period.
We will show and discuss the results in detail in the presentation.

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Thin films and interfaces in soft matter and materials science

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