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Interfacial Effects in Polymer Membranes for Clean Energy

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Polymeric membranes are critical components in several emerging clean energy technologies. Examples include proton exchange membranes for hydrogen fuel cells, anion exchange membranes for alkaline fuel cells, flow batteries, and even block copolymer membranes for solid electrolytes/separators in lithium ion and other battery technologies. In all of these examples the function of the membrane is to physically separate two reactive electrodes or reactants, but allow the transport or exchange of specific ions through the membrane between the active electrodes. The flow of the charged ionic species between the electrodes can be used to balance the flow of electrons through an external electrical circuit that connects the electrodes, thereby storing or delivering charge electrochemically. In this presentation I will review the use of polymeric membranes in electrochemical energy storage technologies and discuss the critical issues related to the membranes that hinder these technologies. In particular I will also focus on the role the polymer membrane interface on device performance. At some point the polymer membrane must be interfaced with an active electrode or catalyst and the nature of this interface can significantly impact performance. Simulations of device performance based on bulk membrane transport properties often fail to predict the actual performance and empirical interfacial impedance terms usually added to capture the device performance. In this presentation I will explore the origins of this interfacial impedance in the different types of fuel cell membranes (proton and alkaline) by creating model thin film membranes where all of the membrane can be considered interfacial. We then use these thin films as a surrogate for the interfacial regions of a bulk membrane and then quantify the structure, dynamics, and transport properties of water and ions in the confined interfacial films. Using neutron reflectivity, grazing incidence X-ray diffraction, and positron annihilation lifetime spectroscopy, we demonstrate that there can be substantial differences in the structure of the ion transport domains in these interfacial region. However, in-situ measurements including dynamic swelling with X-ray and neutron reflectivity, dynamic quartz crystal microbalance of mass uptake/loss, and dynamic phase modulated infrared absorption measurements and generally support both a reduced solubility and diffusivity of the ionic species in the interfacial region, consistent with enhanced interfacial impedance.