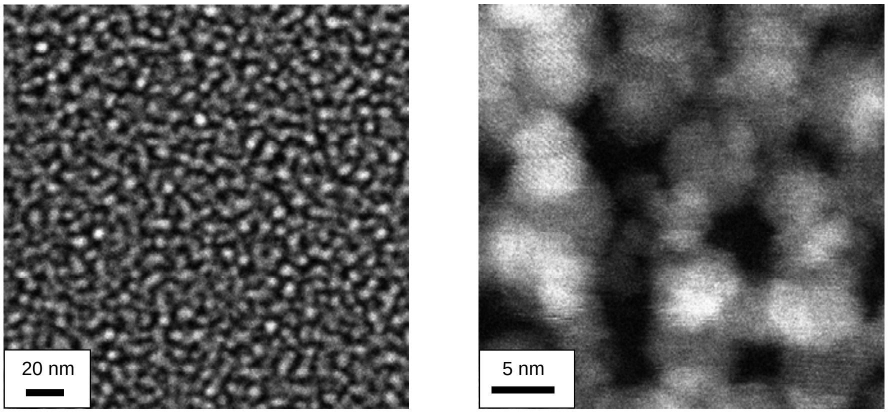
Membrane Development and Advanced Polymer Characterization

Professor Hickner's group has extensive experience in developing and applying advanced characterization methods for quantifying structure-property relationships in novel proton exchange membranes. Our current interests comprise quantification of membrane nano-structure and correlation with polymer chemical features and the resultant transport. We strive to ultimately predict the properties and performance of a membrane based on its chemical constituents and inspire new material design from this insight. Additionally, our researchers have contributed to the development of several different classes of alternative membranes and have demonstrated these membranes in both hydrogen/air PEMFCs and DMFCs as well as in other electrochemical systems (e.g. electrolyzers). Extensive characterization of materials is performed both ex-situ in ideal environments to determine the fundamental properties of membranes and in-situ in a fuel cell device to determine the membrane's influence on overall device performance.

Previous efforts:

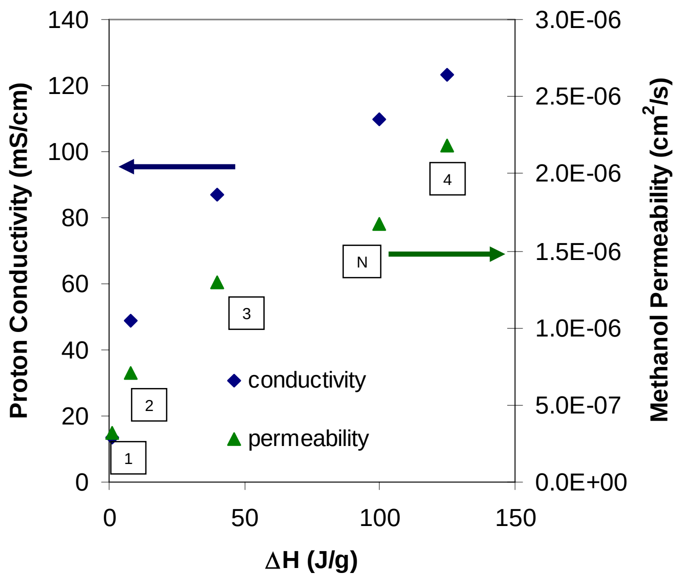
- Characterization and fuel cell testing of poly(sulfone), poly(imide), and poly(phenylene)-based proton exchange membranes
- Organic-inorganic composite membrane fabrication and characterization
- Lifetime and durability testing with focus on membrane properties
- Novel electrode compatibility studies with alternative membranes



Nano-phase separation in Nafion – Pb^{2+} stained TEM micrographs

Capabilities include:

- Proton conductivity and precision water uptake measurements as a function of temperature and relative humidity
- Characterization of ion and small molecules transport across membranes in an aqueous environment
- Water mobility measurements by nuclear magnetic resonance and dynamic scanning calorimetry
- Custom MEA fabrication with standard or novel electrodes and demonstration of alternative membranes in fuel cell devices
- Accelerated ex-situ or in-situ degradation and post-mortem structural and chemical analysis



Correlation of ΔH of absorbed water in the membrane by differential scanning calorimetry with proton conductivity and methanol diffusion. N stands for Nafion with an IEC of 0.91 meq/g; 1, 2, 3, 4 refer to sulfonated poly(phenylene)s with IECs of 0.98, 1.4, 1.8, and 2.2 meq/g, respectively.

Related Publications:

M.A. Hickner, H. Ghassemi, Y.S. Kim, B.R. Einsla and J.E. McGrath, Alternative polymer systems for proton exchange membranes (PEMs), *Chem. Rev.*, Vol. 104, pp. 4587-4612, 2004.

M. Hickner and B. Pivovar, The chemical and structural nature of proton exchange membrane fuel cell properties, *Fuel Cells*, Vol.5, No. 2, pp. 213-239, 2005.

M.A. Hickner, C.H. Fujimoto and C.J. Cornelius, Transport in sulfonated poly(phenylene)s: Proton conductivity, permeability, and the state of water, *Polymer*, Vol. 47, No. 11, pp. 4238-4244, 2006.

M.A. Hickner, N.P. Siegel, D.N. McBrayer, K.S. Chen, D.S. Hussey, D.L. Jacobson, M. Arif, Real-time imaging of liquid water in an operating proton exchange membrane fuel cell, *J. Electrochem. Soc.*, Vol. 153, No. 5, pp. A902-A908, 2006.

Y.S. Kim, L. Dong, M.A. Hickner, T.E. Glass and J.E. McGrath, State of water of disulfonated poly(arylene ether sulfone) copolymers and a perfluorosulfonic acid copolymer (Nafion) and its effect on physical and electrochemical properties, *Macromolecules*, Vol. 37, No. 17, pp. 6281-6285, 2003.

C. Fujimoto, M.A. Hickner, C.J. Cornelius and D.A. Loy, Ionomeric poly(phenylene) prepared by Diels-Alder polymerization: Synthesis and physical properties of a novel polyelectrolyte, *Macromolecules*, Vol. 38, No. 12, pp. 5010-5016, 2005.

H.A. Every, M.A. Hickner, J.E. McGrath and T.A. Zawodzinski, an NMR study of methanol diffusion in polymer electrolyte fuel cell membranes, *J. Membrane Soc.*, Vol. 250,, No. 1-2, pp. 183-188, 2004.