Structure/property relationships in polymer membranes for water purification and energy applications

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Providing sustainable supplies of purified water and energy is a critical global challenge for the future, and polymer membranes will play a key role in addressing these clear and pressing global needs for water and energy. Polymer membrane-based processes dominate the desalination market because they are more energy efficient than thermal desalination processes, and polymer membranes are crucial components in several rapidly developing power generation and energy storage applications that rely on membranes to control rates of water and/or ion transport. Much remains unknown about the influence of polymer structure on even basic intrinsic water and ion transport properties, and these relationships must be developed to design next generation polymer membrane materials. For desalination applications, polymers with simultaneously high water permeability and low salt permeability are desirable in order to prepare selective membranes that can efficiently desalinate water. A tradeoff relationship between water/salt selectivity and water permeability suggests that both sorption (thermodynamic) and diffusion selectivity properties contribute significantly to water/salt permeability selectivity. The sorption component of this tradeoff can be modeled using an electrostatic (or dielectric) exclusion approach, and the diffusion component can be modeled using hindered diffusion and free volume theories. Additionally, membranes are often characterized using sodium chloride, which is widely prevalent in nature, but several applications expose membranes to a variety of different ions. In electric field-driven processes, ion transport properties are sensitive to the specific nature of the ions present in the system. The properties of and ion-polymer interactions involving specific ions appear to influence the ion transport properties of charged polymer membrane materials. The observed ion specific effects can be understood in terms of both the thermodynamic and kinetic (mobility) contributors to the overall ion transport process. This seminar presents an overview of research aimed at further understanding fundamental structure/property relationships that govern water and ion transport in polymeric materials considered for desalination and electric potential field-driven membrane applications that can help address global needs for clean water and energy.