Ion Sorption, Diffusion and Transport in Polymer Membranes

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Charged polymer membranes are widely used for water purification applications involving control of water and ion transport, such as reverse osmosis and electrodialysis. Efforts are also underway worldwide to harness separation properties of such materials for energy generation in related applications such as reverse electrodialysis and pressure retarded osmosis. Additional applications, such as energy recovery ventilation and capacitive deionization, rely on polymer membranes to control transport rates of water, ions, or both. Improving membranes for such processes would benefit from more complete fundamental understanding of the relation between membrane structure and ion sorption, diffusion and transport properties in both cation and anion exchange membrane materials. Ion-exchange membranes often contain strongly acidic or basic functional groups that render the materials hydrophilic, but the presence of such charged groups also has a substantial impact on ion (and water) transport properties through the polymer.

We are exploring the influence of polymer backbone structure, charge density, and water content on ion transport properties. Results from some of these studies will be presented, focusing on transport of salt, primarily NaCl, through various neutral, positively charged and negatively charged membranes via concentration gradient driven transport (i.e., ion permeability) and field driven transport (i.e., electrical conductivity). Our long-term goal is to develop and validate a common framework to interpret data from both electrically driven and concentration gradient driven mass transport in such polymers and to use it to establish structure/property relations leading to rational design of membranes with improved performance.

Ion sorption and permeability data were used to extract information about salt diffusion coefficients in charged membranes. Concentrations of both counter-ions and co-ions in the polymers were measured via desorption followed by ion chromatography or flame atomic absorption spectroscopy. Salt permeability, sorption and electrical conductivity data were combined to determine individual ion diffusion coefficients in neutral, cation exchange and anion exchange materials. The use of models to correlate and, in some cases, predict the experimental data is discussed.

BIOSKETCH

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Benny Freeman is the Richard B. Curran Centennial Chair in Engineering at The University of Texas at Austin. He is a professor of Chemical Engineering and has been a faculty member for 25 years. He completed graduate training in Chemical Engineering at the University of California, Berkeley, earning a Ph.D. in 1988. In 1988 and 1989, he was a postdoctoral fellow at the Ecole Supérieure de Physique et de Chimie Industrielles de la Ville de Paris (ESPCI), Laboratoire Physico-Chimie Structurale et Macromoléculaire in Paris, France. Dr. Freeman's research is in polymer science and engineering and, more specifically, in mass transport of small molecules in solid polymers. He currently directs 15 Ph.D. students and 2 postdoctoral fellows performing fundamental research in gas and liquid separations using polymer membranes and barrier packaging. His research group focuses on structure/property correlation development for desalination and gas separation membrane materials, such as new materials for water/ion separation, hydrogen separation, natural gas purification, and carbon capture. His group also studies reactive barrier packaging materials and new materials for improving fouling resistance and permeation performance of liquid separation membranes.

His research is described in more than 350 publications and 22 patents/patent applications. He has co-edited 5 books on these topics. He has won a number of awards, including the Joe J. King Professional Engineering Achievement Award from The University of Texas (2013), AIChE Clarence (Larry) G. Gerhold Award (2013), Society of Plastics Engineers International Award (2013), Roy W. Tess Award in Coatings from the PMSE Division of ACS (2012), the ACS Award in Applied Polymer Science (2009), AIChE Institute Award for Excellence in Industrial Gases Technology (2008), and the Strategic Environmental Research and Development Program Project of the Year (2001). He is a Fellow of the AAAS, AIChE, ACS, and the PMSE and IECR Divisions of ACS. He has served as chair of the PMSE Division of the ACS, chair of the Gordon Research Conference on Membranes: Materials and Processes, President of the North American Membrane Society, chair of the Membranes Area of the Separations Division of the AIChE, and Chair of the Separations Division of AIChE. He is a co-founder of Advanced Hydro, Inc. (http://www.advancedhydro.net/)