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Structure and Conduction Properties of Polyimide-Poly (Ethylene Glycol) Materials for Fuel Cell Membrane Applications

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Polymer electrolyte fuel cells have the potential to provide cleaner and more efficient energy. Often, current polymer electrolyte membranes for these fuel cells are limited in terms of their operating conditions, especially with regard to humidity and temperature. By using different polymers than have been traditionally used, more versatile operating conditions and better efficiencies may be achieved. The structural details of current polymer electrolyte membranes is often not studied in great detail. By performing a fundamental and in depth study of the structure of potential polymer membrane materials, more insight can be gained in terms of achieving good performance through material design. A multi-polymer system has been created and analyzed in terms of the relationship between ionic conduction properties and nanometer scale structure.

In the current work, aromatic polyimide and poly (ethylene glycol) (PEG) composite membranes have been synthesized for fuel cell polymer electrolyte membrane applications. Because different properties are needed for an effective polymer electrolyte membrane, multiple polymers often need to be used. Also, these multi-polymer systems often lead to phase separation and self-assembly that can greatly impact material properties. Aromatic polyimides are known to be very stable, both thermally and mechanically. Poly (ethylene glycol) (PEG) has been known to provide proton conduction properties under certain conditions. The goal is to exploit the drastically different properties of the polymers and understand how the structure of these materials relates to the charge transport in this hybrid system. The polyamic acid precursors to these polymer systems were synthesized by a classical, random, one pot poly-condensation method that has been shown to work for many different types of polyamic acids. The poly (ethylene glycol) (Mn 990 to 3400) was used in pre-polymerized form and incorporated in the polyamic acids through chemical bonding to achieve structural self-assembly on the nanometer length scale. These polymer systems were converted to polyimide-PEG systems through thermal imidization. This thermal processing can achieve a variety of film properties easily if varied. Composition and morphology of these hybrid systems was varied to create a family of materials.

The polyamic acid precursors and polyimides were characterized using Fourier transform infrared spectroscopy. Thermal properties of the films were analyzed using thermal gravimetric analysis. Small angle x-ray scattering was used to determine the polymer structure on a length scale between 0.5 and 80 nanometers, because it has been shown that features on this length scale can often lend themselves to achieving good conduction properties. Oftentimes charge transport through materials requires control of the material structure on a very small length scale and understanding how structure can improve charge transport is important in fuel cell membranes. Since liquid electrolytes are often needed to provide any significant conduction properties for polymers, inorganic acid or ionic liquids were incorporated into the films by soaking. The films were then analyzed for proton conductivity properties using electrochemical impedance spectroscopy in conjunction with cyclic voltammetry. Effects of temperature and humidity were studied with regards to the conductivity. These composite systems were analyzed in order to determine composition-structure-property relationships for fuel cell membrane applications. Composite or hybrid systems have been studied for structure, or properties, but rarely is the relationship between structure and properties well understood.