Synthesis and characterization of vinyl ester based room temperature ionic liquid gels for membrane applications

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Abstract:

Fuel cells have the potential for improved efficiency at elevated temperatures, but are restricted to operating at temperatures below 100°C due to the limitations of the proton exchange membrane (PEM). The PEM in fuel cells acts both as a medium for proton conduction and as a barrier between the fuels, requiring high ionic conductivities and mechanical strength. Work has been ongoing to maintain both mechanical integrity and conductivity of PEMs at higher temperatures, through numerous means, including the incorporation of room temperature ionic liquids (RTIL). RTILs offer the unique advantage of having negligible volatility, which potentially allows them to maintain ionic conductivity at high temperatures. A cross-linked polymer network was formed in an RTIL medium. The difunctional monomer, Vinyl Ester of Diglycidyl Ether of Bisphenol A (VE-DGEBA) was reacted with the monofunctional monomer 2-Acrylamido-2-Methyl-1- ropanesulfonic Acid (AMPS) in the presence of an RTIL, 1-Ethyl-3-Methylimidazolium Ethyl Sulfate [EMIM][EtSO4]. Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy was used to show the complete conversion of carbon-carbon double bonds in ~13 hours. Dynamic Mechanical Analysis (DMA) frequency sweeps showed the presence of multiple micro-scale phases, which was confirmed through Scanning Electron Microscopy. DMA temperature sweeps showed glass transition temperatures (Tg) ranging from -80°C to 5°C, with second Tgs ranging from -54°C to 64°C. Quasistatic compressive testing showed compressive moduli ranging from 2 MPa to 1127 MPa. Electrochemical impedence spectroscopy showed through-plane ionic conductivities for dry gels ranging from 4.38·10-11 S/cm to 1.54·10-3 S/cm for samples with on exchange capacities (IEC) ranging from 1 mol/L to 5 mol/L. Thermogravimetric analysis showed good thermal stability, with decomposition temperatures at 5% weight loss ranging from 208°C to 274°C, and environmental testing showed irreversible loss of RTIL and property changes when samples were submersed in deionized water. Effort was made to improve the properties of the ILG by preparation of a semiinterpenetrating network (sIPN). This was produced by forming the ILG around Poly-(2- Acrylamido-2-Methyl-1-Propanesulfonic Acid). It was found that this sample showed similar properties to the other ILGs, with a primary Tg of -28.2°C and a second Tg at 17.44°C. The compressive modulus of this sample was found to be 85.89 MPa, the ionic conductivity was 1.41·10-5 S/cm for an IEC of 2.74 mol/L, and the thermal decomposition temperature was found to be 215.2°C. The notable improvement over samples lacking Poly-AMPS was a decrease in brittleness.