4cc Development of Composite Membrane Electrode Assemblies (Cmeas) for Higher Temperature Proton Exchange Membrane Fuel Cells

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The main obstacles to commercialization of PEM fuel cells are mostly related to the proton conducting materials, typically solid polymer electrolytes such as Nafion. These membranes are expensive, mechanically unfavorable at high temperature, and conduct protons only in the presence of water, which limits the fuel cell operating temperature to 80 oC. This in turn results in low fuel cell performance due to low electrode kinetics and less CO tolerance. The operation of fuel cells at higher temperature (above 100 oC) provides many advantages such as improved kinetics at the surface of electrode, which is especially important in methanol and CO-containing reformate feeds, and efficient heat and water managements. But, another problem above 100 oC is the reduction of electrochemical surface area of the electrodes due to shrinkage of electrolyte (Nafion membrane) in electrodes.

My PhD research work at Worcester Polytechnic Institute was thus focused on development of composite membranes which are chemically and mechanically stable at higher temperatures and Pt/C electrodes which can result into better fuel cell performance. This was, however, particularly challenging task because of the desired performance characteristics. During my doctoral work various experimental techniques namely, TEOM (Tapered Element Oscillating Microbalance)[1-2], Impedance Spectroscopy, MEA (membrane electrode assembly) testing, Ion Exchange Capacity, Scanning Electron Microscope (SEM), Optical Electronic Holography (OEH)[3], Thermal Gravimetric Analysis (TGA), and Dynamic Mechanical Analysis (DMA),in addition to fuel cell performance measurements, were employed to characterize the composite membrane electrode assemblies.

Nafion- MO2(M = Zr, Si, Ti) nanocomposite membranes were synthesized using sol gel chemistry with the goal to increase the proton conductivity and water retention by the membrane at higher temperatures and lower relative humidities (120 oC, 40 % RHs) and also to improve the thermo-mechanical properties[4-5]. Experimental investigations of all nanocomposite candidates showed improve water sorption properties and conductivity. They also exhibited higher thermal degradation temperatures and glass transition temperature, which is very important for higher temperature operation of PEM fuel cells. Also, these nanocomposite showed lower methanol crossover which resulted in better direct methanol fuel cell performance. The experimental results so far has been very encouraging to investigate further the long term stability of these nanocomposites. Theoretical proton transport model was developed for nanocomposite membranes based on classical mechanics. The model predicts the proton conductivity without any fitting parameters [6a-b, 7].

In summary my research interests are to develop a thorough understanding of basic proton transport and water sorption mechanism in Nafion and solid acid membrane. I also plan to develop experimental methodologies to synthesize chemically and mechanically stable composite membranes and electrodes. I plan to experimentally determine the mechanism for membrane degradation in electrodes and fuel cells using spectroscopic techniques such as IR and analyzing the outlet products, and study the long term durability of the synthesized membrane electrode assemblies.

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