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New Polymer Electrolyte Membranes for Fuel Cells

Michael D. Guiver[1,2]

[1] *Institute for Chemical Process and Environmental Technology, National Research Council, Ottawa, Ontario, K1A 0R6, Canada*

[2] *WCU Energy Engineering Department, Fusion Technology Center 9th Floor, Hanyang University, Seoul, S. Korea*

Hydrocarbon PEM materials are being widely studied as replacements for Nafion-type perfluorinated polymeric materials to reduce cost and improve performance such as operating temperature in polyelectrolyte membrane fuel cells (PEMFC) and methanol crossover in the direct methanol fuel cell (DMFC) application. Among some of the important property considerations required are thermal and chemical stability, low dimensional swelling, low methanol permeability in the case of DMFC and high proton conductivity. In comparison with Nafion-type PEMs, which can be considered as 'super-acids' because of their fluoro-sulfonic acid groups, hydrocarbon PEMs are weaker acids and typically require higher ion exchange capacities (IEC) to achieve the similarly high proton conductivity for effective fuel cell performance. However, higher IEC (more proton conducting sulfonic groups) in hydrocarbon PEMs often leads to a trade-off in properties such as unacceptably high water uptake, high methanol diffusivity, and poor mechanical properties. Much of the research activity in developing hydrocarbon PEM materials is focussed on overcoming this trade-off behaviour, and a number of promising approaches have been reported in recent years.

Our research has investigated several structural design strategies for PEM materials, particularly for DMFC, which can lessen the effect of water and methanol swelling associated with increased proton conductivity brought about by increasing the sulfonic acid content or IEC. Since fuel cell membrane electrode assemblies are presently almost universally constructed by using Nafion ionomer as a glue to bind the catalyst to the PEM, a dimensional mismatch and mechanical failure leading to delamination occurs when there are significant differences in swelling behaviour over a temperature range. An obvious solution is to design hydrocarbon ionomers, though this is not a simple task. Constraining high IEC polymer electrolyte membranes by chemical crosslinking or by polar non-bonding interactions, such as nitrile, has been effective in increasing fuel cell performance. Similarly, radiation grafting onto semi-crystalline membranes shows promise. Self-organization of polymers into hydrophilic proton-conducting domains and mechanically-stronger hydrophobic domains allows good proton conduction at lower IEC values. This can be accomplished by preparing PEM materials with side-chains. The lecture will provide a discussion of selected results of all the above approaches, singly and in combination.