Molecular Design Aspect of Anion Exchange Polymer Electrolytes

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Anion exchange polymer electrolytes are one of the key components of alkaline membrane fuel cells (AMFCs) and have been extensively studied in recent years.[1] Anion exchange polymer electrolytes play an important role both in separator (membrane) and in electrode binder (ionomer). Depending on their role, polymer electrolytes must possess certain properties which are essential to improve AMFC performance & durability. In this talk, we will present molecular design aspect of anion exchange polymer electrolytes for the use of membranes and ionomeric binders. Impact of molecular structure of polymer electrolytes on AMFC performance will be discussed as well.

Alkaline stability, conductivity and mechanical properties are three key properties of anion exchange membranes. Those properties, in general, strongly depend on the molecular structure, polymer architecture (ca. random vs. multi-block vs. graft copolymer) and processing parameters. In the molecular design aspect, the selection of the cation functional group has been regarded as most crucial consideration since the cation structure will directly influence the chemical stability and anionic conductivity of the membranes. However, many research groups including us also have demonstrated that polymer backbone structure and the linkage between the cation group and polymer backbone are non-negligible.[2] For example, the mechanical properties of anion exchange membranes greatly influenced by polymer backbone degradation (Figure 1). In the first part of this talk, we will discuss about polymer backbone and cation stability under high pH conditions and their impact on conductivity and mechanical properties of anion exchange membranes. Quantum chemical computations[3] will provide the activation energy of the polymer / cation group degradation and compared with experimental data.

For the use of ionomeric binder, on the other hand, other properties such as chemical inertness, hydrophobicity and gas permeability of the polymer electrolytes also need to be taken into consideration. The interfacial phenomena between cation functional groups and electro-catalysts and specific adsorption of other polymer components onto the catalyst surface determine the efficiency of electro-chemical reactions at the electrodes. Reactant and water transports which are necessary for electro-chemical reactions and proton transports are strongly influenced by the concentration of cation functional group, nature of polymer structure and porous electrode structure. In the second part of this talk, we will demonstrate the impact of cation groups on oxygen reduction kinetics (ORR) and ORR inhibition by possible adsorption of polymer electrolytes using selected model compounds.[4] Oxygen permeability difference between hydrocarbon-based and perfluorinated ionomeric binders will be reported.

In the third part of this talk, we will demonstrate the AMFC performance and durability using the polymer electrolytes we have synthesized. Issues associate with the processing of membrane electrode assembly, water management, carbonate / bicarbonate effect and operating conditions will be addressed in light of molecular structure of the anion polymer electrolytes. Finally, the limitations and future challenges of current materials will be briefly discussed.
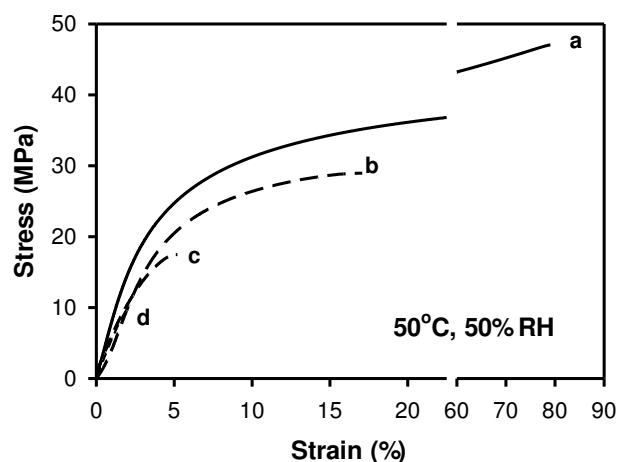

Figure 1. Stress-strain curves of quaternized poly(arylene ether sulfone)s (a) bromide form; (b) after 0.1 M NaOH treatment (1 h, room temperature); (c) after 0.5 M NaOH treatment (0.5 h, room temperature); (d) after 0.5 M NaOH treatment (1 h, 80°C)

References
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