Low Cost and Highly Selective Composite Membrane for Redox Flow Batteries

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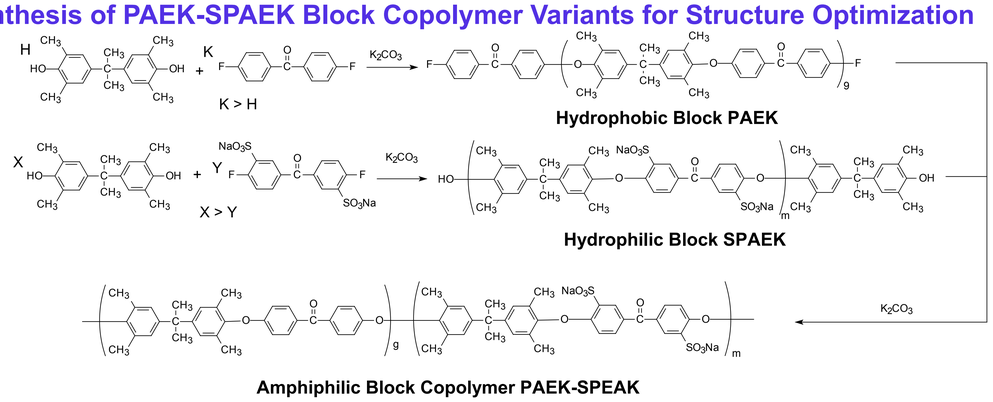
Identification of the Problem and Technical Approach

Redox flow batteries (RFB) hold great promise for large scale electrochemical energy storage. A critical component of RFB is the membrane which separates anode and cathode compartments. The current state-of-the-art membrane, NAFION is too expensive, lacks selectivity, permitting leakage between anode and cathode electrolyte compartments.

EIC is developing a novel bilayer, interpenetrating network membrane. Thin Nafion layer for anode side protection providing oxidative stability. The bulk part of the membrane consists of a block copolymer comprised of ionic and nonionic aromatic blocks that are designed to form an interpenetrating network of ion conducting and inert segments (similar to Nafion). The aromatic polymer is more resistant to leakage of active cationic species. The ionic phase forms conductive channels and inert segments providing mechanical strength. Overall built to be much less costly than pure Nafion while exceeding Nafion in selectivity.

Phase II Program Progress

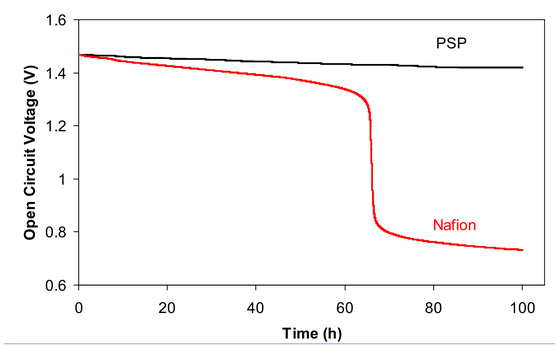
Synthesis of PAEK-SPAEK Block Copolymer Variants for Structure Optimization



Synthesis of SPAEK-PAEK block copolymer (PSP) via two pots reaction scheme

Membrane Selectivity

The PSP membrane without Nafion overcoating was investigated.

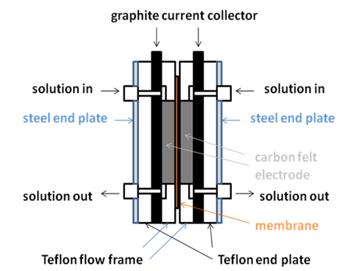


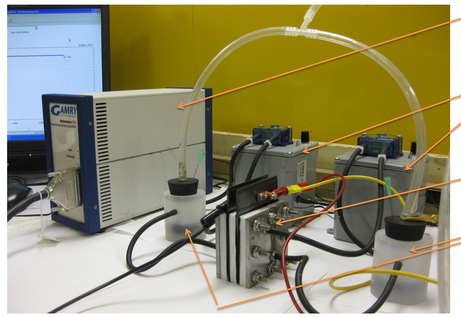
The open circuit voltage of the charged PSP membrane cell was measured over 100 hrs: V_0 = 1.469. After 100 hrs. V_{100} = 1.422
The OCV of charged Nafion cell over 100 hrs: V_0 = 1.472, V_{60} = 1.343, V_{70} = 0.803, V_{100} = 0.739

Membrane in Cell Area Resistance (impedance measurements)

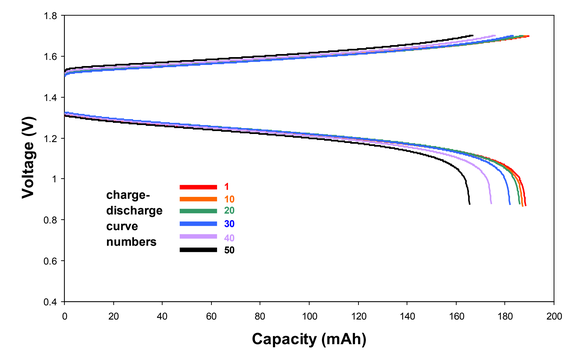
PSP R = 4.50 Ω cm^2 Nafion R = 2.54 Ω cm^2

VRB Testing Cell for Membrane

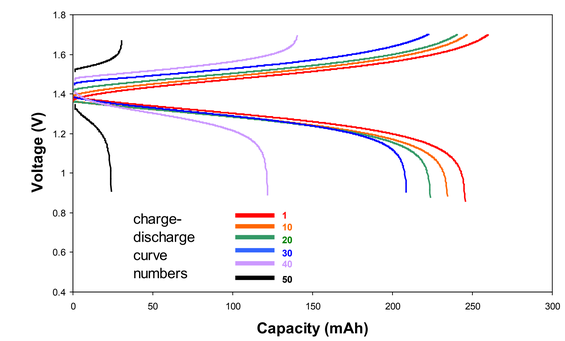




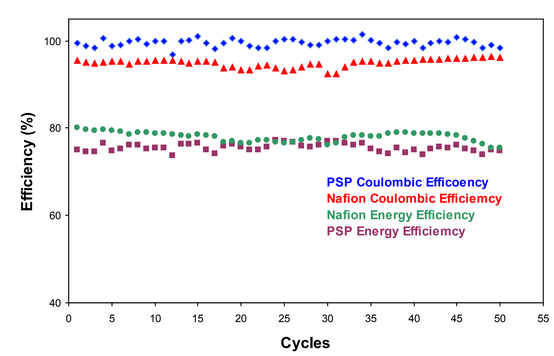
VRB Cell Performance Comparison (charge-discharge between 1.7 V and 0.8 V for 50 cycles)



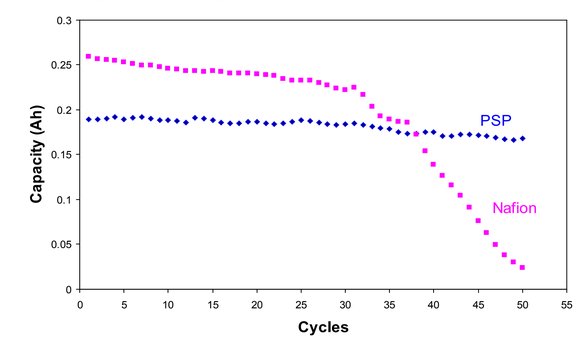
Charge-discharge curves of PSP membrane VRB cell



Charge-discharge curves of Nafion membrane VRB cell



The PSP membrane cell showed slightly higher Coulombic Efficiency and slightly lower Energy Efficiency than Nafion membrane cell.



The capacity loss over long term full depth cycles is less severe for the cell with PSP membrane than Nafion membrane.

Summary

- Successfully synthesized series of block copolymers composed of hydrophobic poly(aryletherketone) polymer blocks and hydrophilic sulfonated poly(aryletherketone) polymer blocks (PSP polymer) via a two-pot process that gives better control of the copolymer structure
- Identified optimal copolymer structure that gives excellent membrane performance
- Developed more optimized single VRB testing cell for membrane evaluation
- Better vanadium ions selectivity than Nafion demonstrated
- PSP membrane without Nafion overcoating showed excellent long term stability

Future Work

- Further improve membrane cast condition to produce a uniform large area membrane
- To explore and identify modifications to further reduce membrane costs – investigate other low cost monomers
- Incorporating Nafion coating on top of the block copolymer membrane
- Further optimization of VRB cell
- To prepare and deliver samples for testing and Phase III development

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