Low-Cost, High-Performance Hybrid Membranes for Redox Flow Batteries

Hongxing Hu, Amsen Technologies LLC

DOE SBIR Project, Program Manager at DOE: Dr. Imre Gyuk

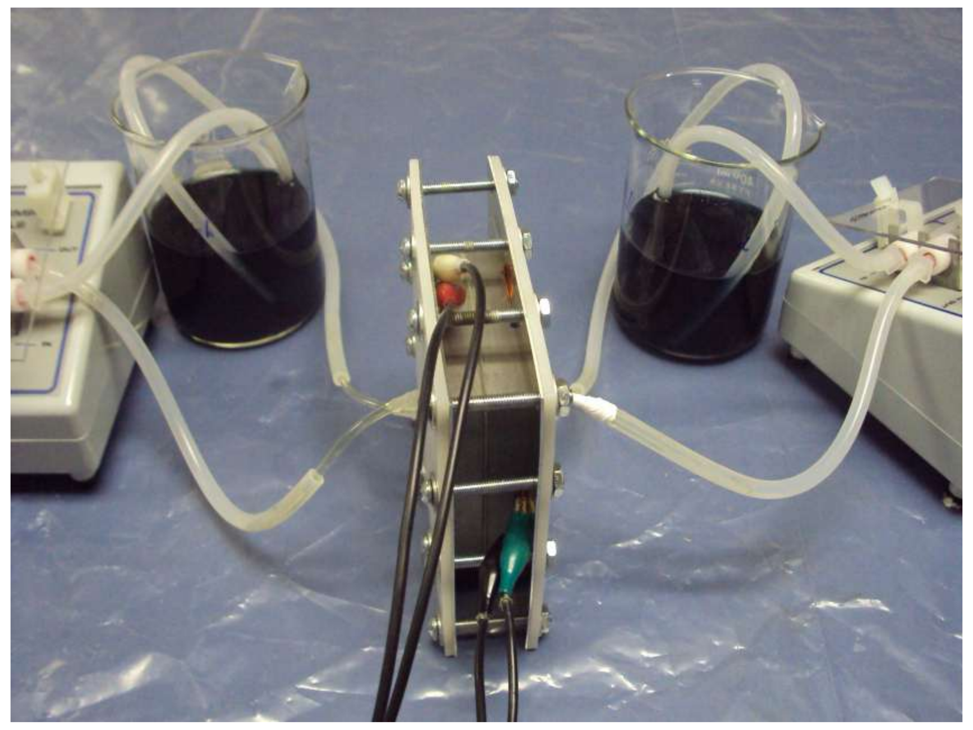
Objectives and Technical Approach

Objectives:

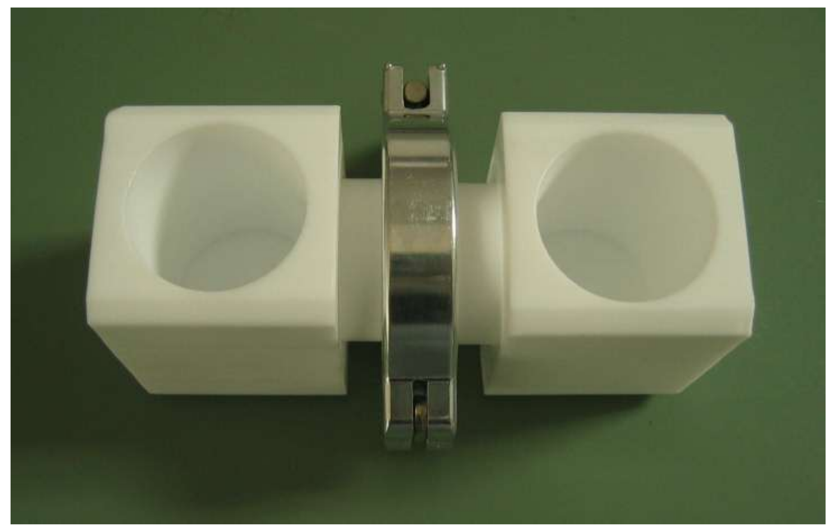
This SBIR project aims to develop low-cost, high performance hybrid polymeric PEMs for redox flow batteries (RFBs). Such membranes shall have high chemical stability in RFB electrolytes, high proton conductivity, low permeability of vanadium ions, along with high dimensional stability, high mechanical strength and durability, and lower cost than Nafion membranes.

Approach:

- Hybrid membranes of sulfonated polymers
- Balance between different types of polymers for proton conductivity and chemical stability
- Solution casting process



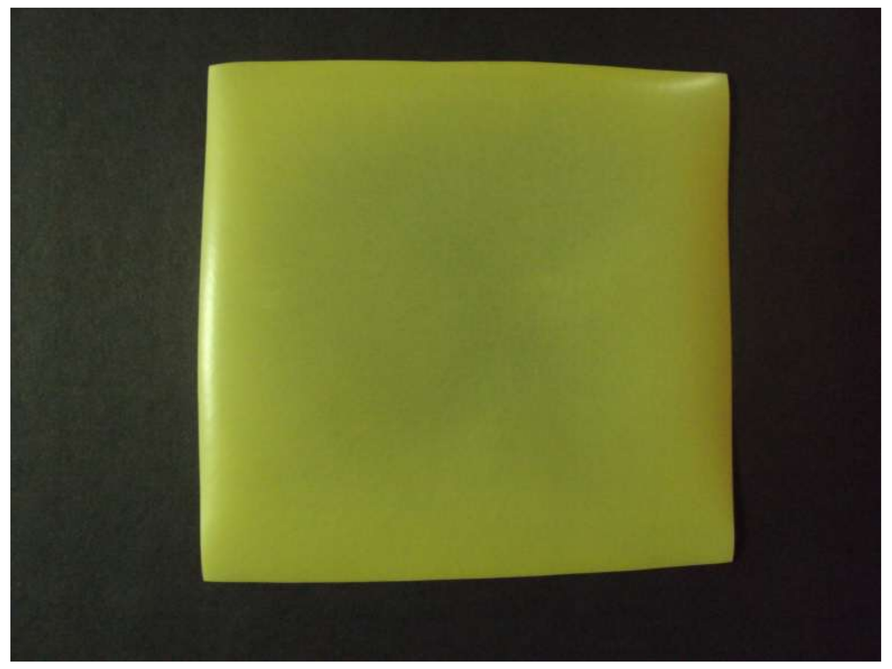
RFB testing cell and set-up



Two-compartment cell used for vanadium ion permeation tests

Focus of Phase II: Approaches to Enhance Chemical Stability and Durability

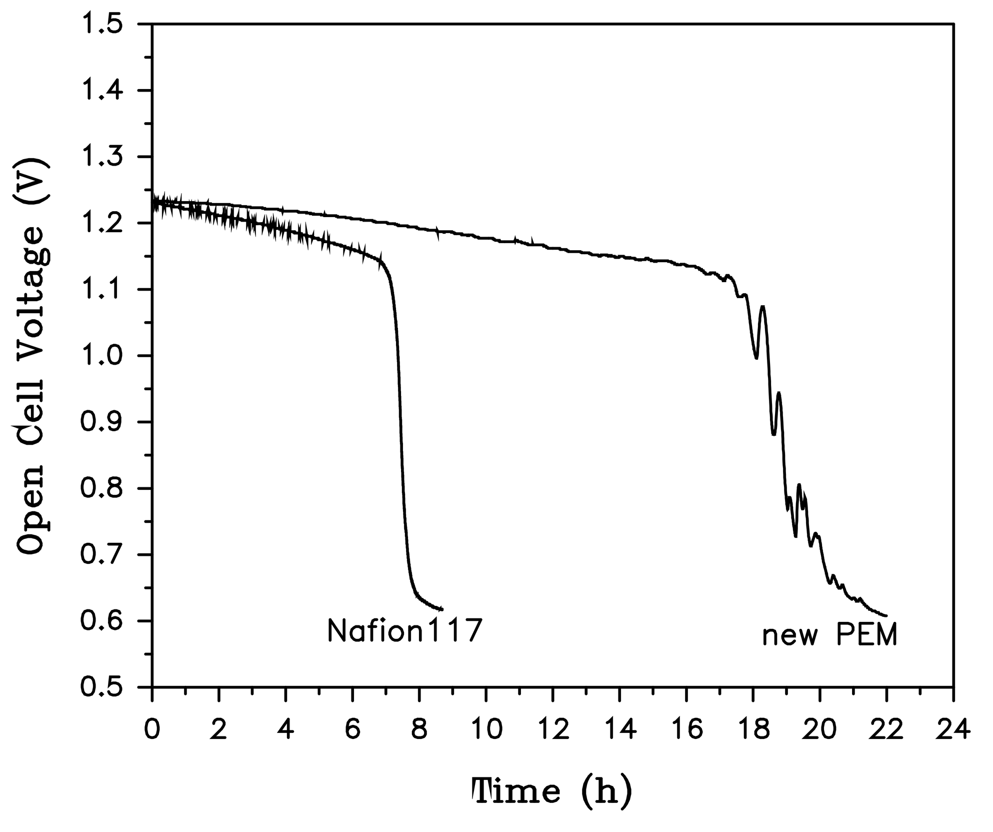
- Adding minor component additives, bringing the membrane material to a multicomponent system from the original two-component system.
- Modifying the sulfonated polymer synthesis, making grafted copolymer instead of using a physical blend of the components, seeking to attain stronger chemical bonding in the copolymer and hence higher chemical stability and durability of the membrane.
- Optimizing processing conditions for sulfonated polymer syntheses and membrane preparation by extensive comparative investigations into relations of the membrane properties with various processing conditions.



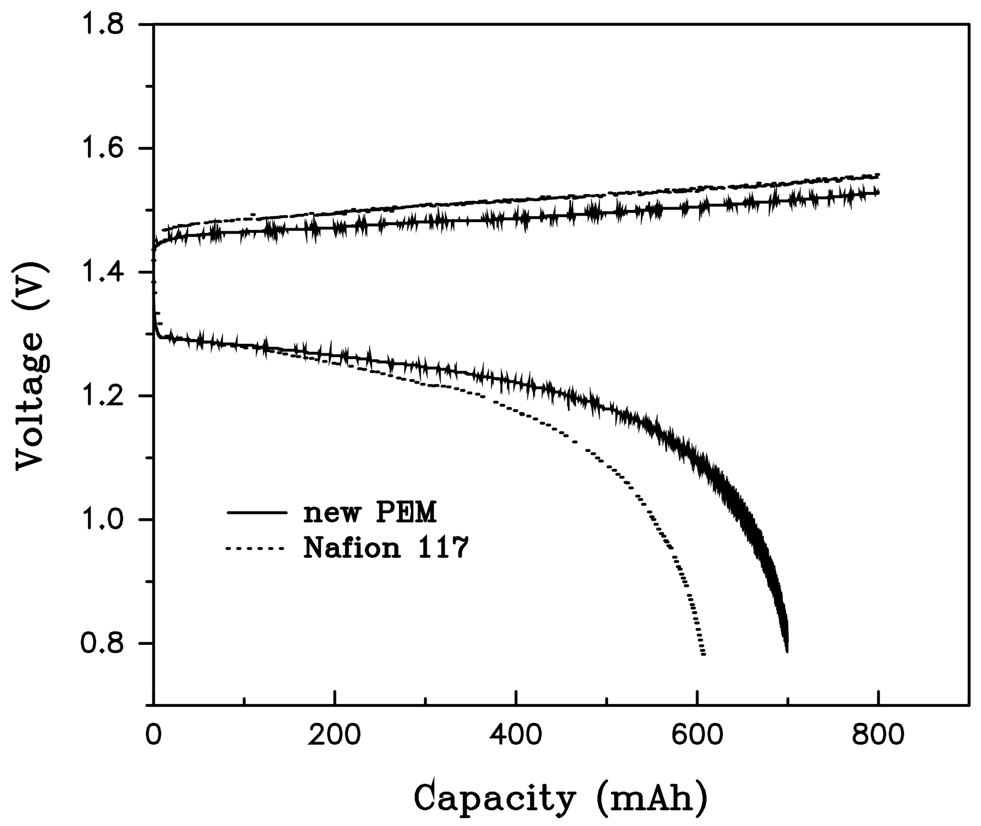
Hybrid polymeric PEM prepared in Amsen

Comparison of relevant properties between hybrid PEMs fabricated in Amsen and Nafion 117

	Nafion 117	hybrid PEMs
Ion exchange capacity (meq/g)	~1.0	2.5 – 3.1
Proton conductivity (S/cm)	0.0578	0.0612 – 0.0885
Water Swelling (%)	21.6	16.6 – 29.1
Linear expansion under full hydration (%)	11.4	8.5 – 9.9
Vanadium ion permeability, P (cm^2/min)	3.75×10^{-6} (as reported)	lower
Chemical stability	Good	Fair (focus of further improvement)
Tensile Modulus (MPa)	217	862
OCV retention in RFB cell (hour)	8	18.5
Self discharge rate in RFB cell	higher	lower



OCV retention of a RFB cell using the hybrid PEM in contract with that using Nafion 117 (under otherwise the same conditions).



Charge-discharge characteristics of a RFB cell using a hybrid PEM and that using Nafion 117 (under otherwise the same conditions).

Comparison of major properties between Phase I results and current results

	Phase I Results	Current Results
Ion exchange capacity (meq/g)	2.5 – 3.1	2.6 – 3.3
Proton conductivity (S/cm)	0.0612 – 0.0885	0.0635 – 0.0659
Water Swelling (%)	16.6 – 29.1	15.8 – 21.3
Linear expansion under full hydration (%)	8.5 – 9.9	8.3 – 9.1
Chemical stability (in 1 M V(V) and 2.5 M H_2SO_4 solution)	Slight change after 1 week at 50 °C	No change after 1 week at 50 °C
Membrane toughness	Low	higher

Project Progress to Date

- Uniform membranes with high ion exchange capacity and proton conductivity were prepared
- Relevant properties of the new membrane were characterized, including membrane microstructural morphology, protonic transport properties, water swelling and dimensional stability, vanadium ion crossover behavior, chemical stability, and mechanical strength
- Approaches to enhance the chemical stability and durability of the membrane have been explored with encouraging outcome
- Performance of the new membrane was evaluated for vanadium RFB operation, including OCV retention and charge-discharge characteristics

Future Work

- Further enhance chemical stability and durability of the hybrid membrane.
- Complete optimization of the performance of the membrane by fine tuning the different compositional and processing variables.
- Scale up the synthesis process to a level that is feasible for commercial production.
- Produce commercially viable prototype membranes.
- Demonstrate the application and performance of the membrane in real RFB settings.

Contact :

Hongxing Hu, PhD
Amsen Technologies LLC
1684 S. Research Loop, Suite 518
Tucson, AZ 85710
Ph: (520) 546-6944
Email: hhu1@mindspring.com