Dimensionally Stable High Performance Membranes

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FC 150

Overview

Timeline

- Project Start Date 2/21/2016
- Project End Date 11/21/2016

Budget

- Total Project Funding to Date: $1.3k (2/29/2016)
- Total Project Value: $150k
- Cost Share %: N/A

Barriers addressed

A. Durability
B. Cost
C. Performance

Technical Targets (DOE 2017 Targets)

- 0.02 $\Omega.cm^2$ at 1.5 kPa H_2O Air inlet
- <$20/m^2
- > 5000 h lifetime, >20,000 RH Cycles

Partners

- Rensselaer Polytechnic Institute

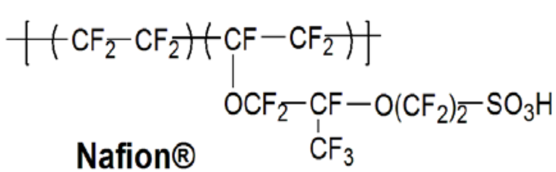
Relevence: Why New PEM?

- State of the Art
  - PSFA membranes like Nafion exhibit:
    - Poor mechanical properties at high temperature
    - Poor performance at low RH
  - Increasing conductivity of PFSA membranes by increasing charge density:
    - Makes the membranes much weaker
    - Only increases performance incrementally
- Hydrocarbon-based membranes can be tailored to low RH, high temperature operation

Design of HC Membrane

- The new advanced ionomer will have:
  - Large segregated domains
  - High localized charge density
- Chulsung Bae has already developed membranes with these properties

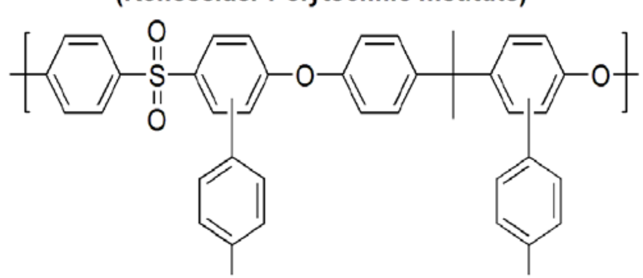
(a)



Nafion®
(DuPont)

(Rensselaer Polytechnic Institute)

(b)

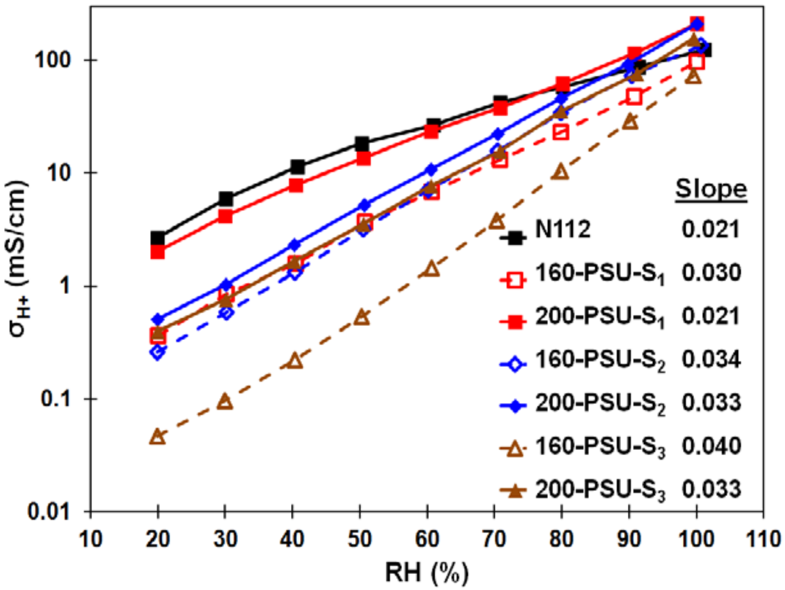


xx-PSU-S_1	$OCF_2CF_2SO_3H$	$OCF_2CF_2SO_3H$
xx-PSU-S_2	SO_3H	SO_3H
xx-PSU-S_3	$OCH_2CH_2CH_2SO_3H$	$OCH_2CH_2CH_2SO_3H$

(xx = mol% of sulfonate per repeat unit)

PSU-S_x Series

- The sulfonated polysulfones developed by Prof. Bae were tested for conductivity at 100°C and varying RH

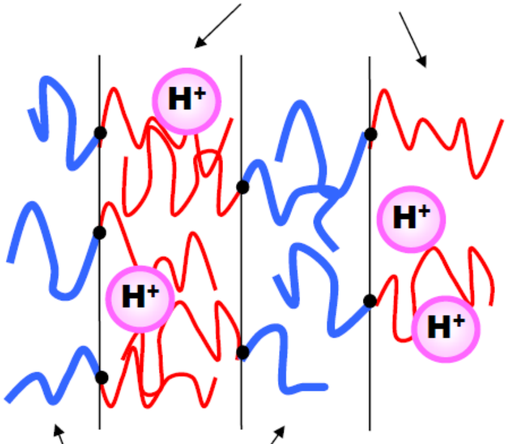


The 200-PSU-S_1 ionomer (IEC=1.94 meq/g) compared favorably with Nafion under decreasing RH conditions.

Block / Graft polymer

Advantages

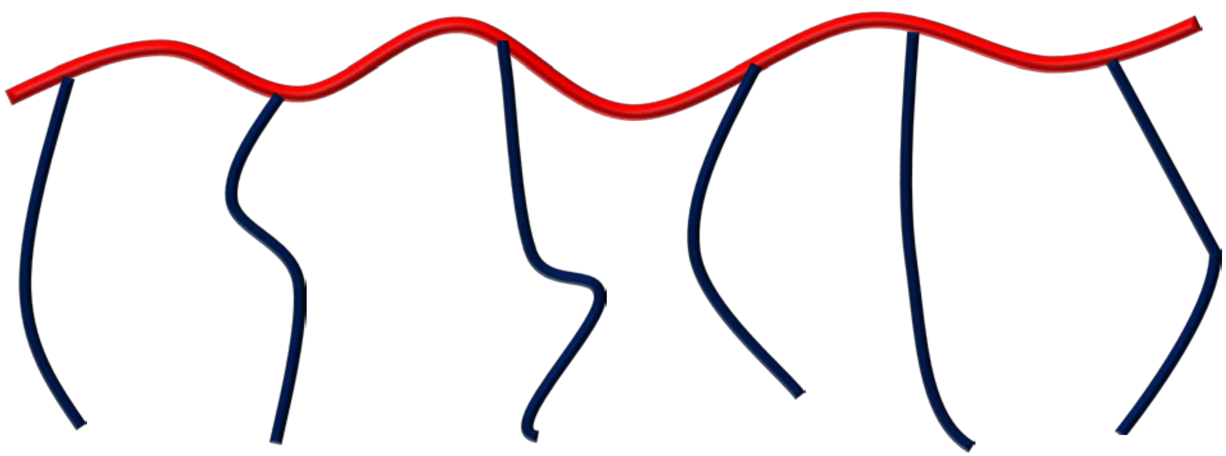
- Formation of ion conducting channels by microphase separation
- Hindering of swelling by surrounding non-sulfonated phase
- Lowering of MeOH permeability
- High mechanical stability



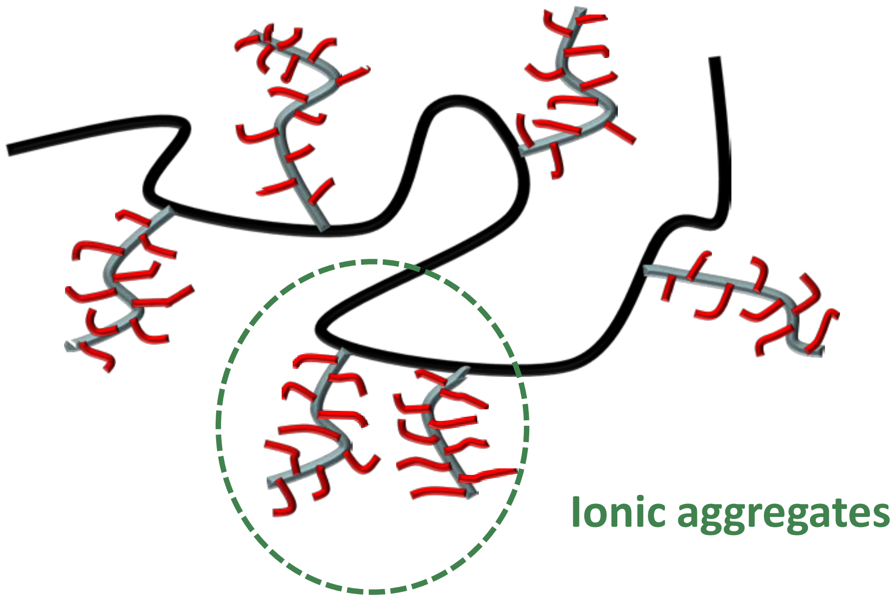
High ionic conductivity & good mechanical property

Graft copolymer

- **Graft copolymers** are segmented copolymers with a linear backbone of one composite and have structurally different branches of another composite.
- Graft co-polymerization is an attractive method to impart a variety of functional groups to a polymer.
- Graft copolymers **allow the combination of properties of two highly incompatible polymeric constituents**.

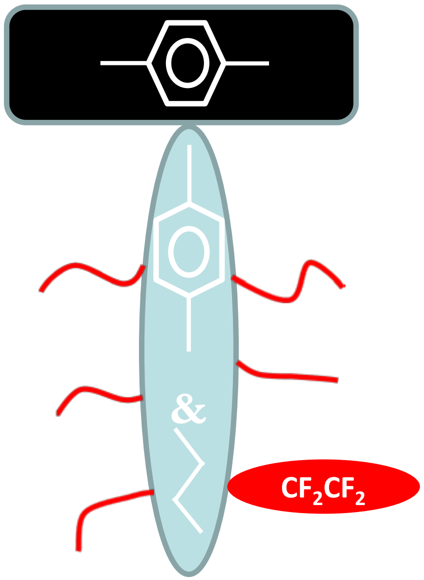


Graft Copolymer PEM for Hydrogen Fuel Cells



High molecular weight hydrophobic polymer backbone
Oligomeric graft chain
Superacidic fluoroalkyl sulfonate

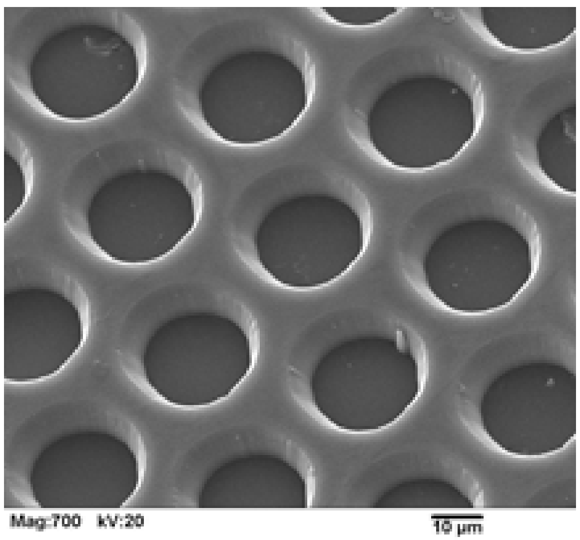
General Structure of Target PEMs



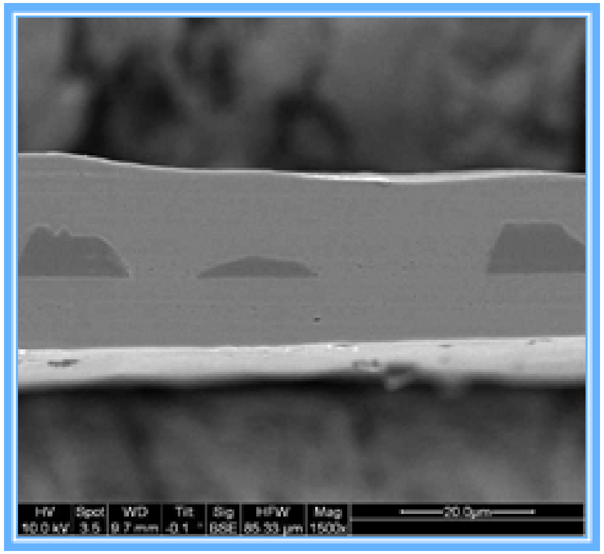
- **Fluorine-containing hydrophobic main chain:** good mechanical & chemical stabilities
  - Only C-C bond in the main chain
- **Rigid & flexible oligomeric graft chains: high ion density**
- **Superacidic fluoroalkyl sulfonate group for H^+ conductivity**

Mechanical Stability

- Giner will incorporate some of the membranes provided by Prof Bae into its DSM supporting structure to provide mechanical strength



DSM mechanical structure



Cross-section of a membrane with the incorporated structure

Objective

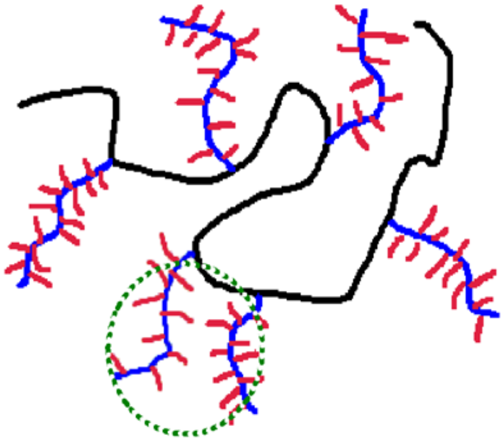
- The overall technical objective of this program is to develop a fuel cell PEM displaying
  - High conductivity
  - Good mechanical qualities
  - High chemical durability
- For use in low-RH, high temperature applications

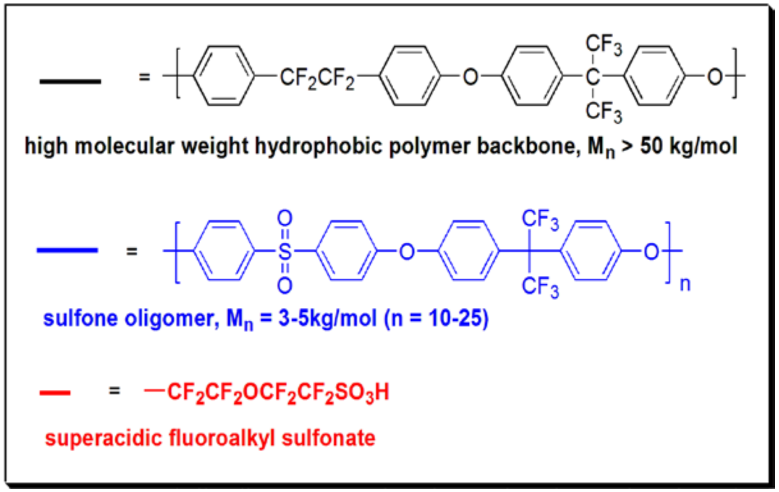
Tasks

- Prepare hydrocarbon membranes (RPI)
- Fabricate DSM using hydrocarbon membranes (Giner)
- Characterize the hydrocarbon membranes (Giner)
- Downselect membranes for Phase II

Approach: Task 1 – Prepare Hydrocarbon Membranes

- 20 graft and random copolymers will be prepared by RPI





Graphical illustration of proposed sulfonated graft polymers and representative structures of each unit

Approach:Task 2 Hydrocarbon DSM

- Each of the 20 films produced by RPI will be incorporated into the DSM substrate
  - Comparison of properties will be done for the HC DSMs against the neat ionomer
- Close consultation with RPI will be done to ensure proper hot-pressing parameters
- Giner's SEM will be used to validate membrane adherance after pressing

Approach – Task 3 Membrane Characterization

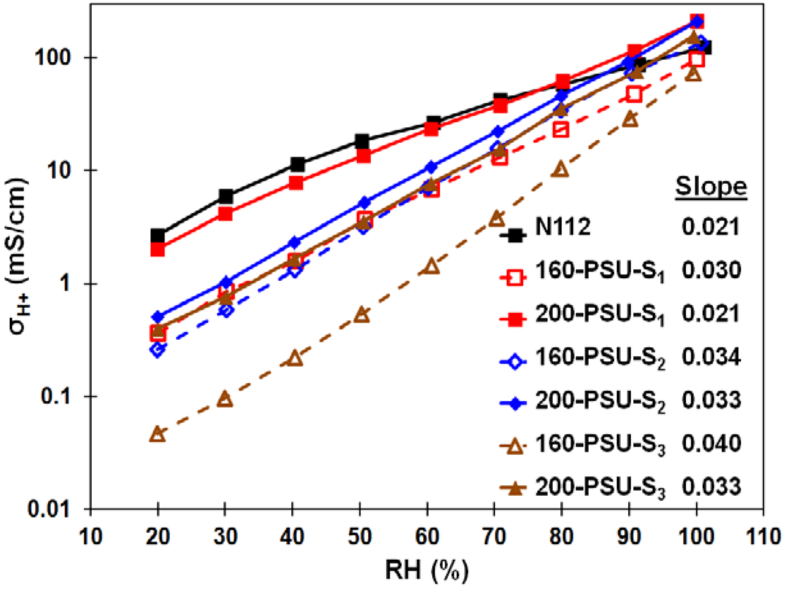
- Conductivity
  - Giner will test membrane conductivity at varying temperatures and RH levels (to 95%)
  - Five membranes can be tested at a time up to 140°C
- Gas Permeability
  - H_2, O_2 and N_2 permeability will measured
  - Temperature up to 130°C
  - RH from 0 to 95%
- Water uptake
  - Using Giner's novel Sievert-type water uptake apparatus
  - RH levels from 0 to 100%
  - Temperatures from 25 to 95°C
- Physical Properties
  - Giner's DMAs will be used to measure stress-strain curves at various temeprature and RH levels

Approach: Task 4
Down select Membranes

- The membranes showing the best combination of properties will be selected for use in the Phase II
- The Phase II will consist of
  - Membrane optimization
  - MEA fabrication
  - Short- and long-term MEA operation in a high-temperature, low-RH fuel cell system

Achievements: ($1333 Spent to Date)

- Task 1: Baseline Hydrocarbons Prepared
- Task 3: Baseline Membrane Measured



Future Work: Scheduling

Task	Month								
	1	2	3	4	5	6	7	8	9
1. Prepare hydrocarbon membranes (RPI)									
2.Fabricate DSM using hydrocarbon membranes (Giner)									
3.Characterize the hydrocarbon membranes (Giner)									
4. Downselect membranes for Phase II									
Report					X				X

Milestones	Month
Mid-program Report	5
Downselected membrane choices	9
Final Report	9

Collaborations

- Rensselaer Polytechnic Institute