Dimensionally Stable Membranes

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Project ID #FC 24

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Dimensionally Stable Membranes for High Temperature Applications

Timeline

- Begin 4/3/2006
- Review 4/2/2009
- 50% Complete

Budget

- Total project funding (to 2009)
  - \$899K DOE Funding
  - \$529K Recipient
  - 37% Cost Share
  - \$300K received FY 2007
  - \$300K for FY 2008
  - \$590K DOE funds spent to date

Barriers addressed

A. Durability
B. Cost

Technical Targets (DOE 2010 Targets)

- 0.10 S/cm at 1.5 kPa H_2O Air inlet
- <\$40/m^2
- > 5000 h lifetime
- Stability in Condensing conditions

Partners

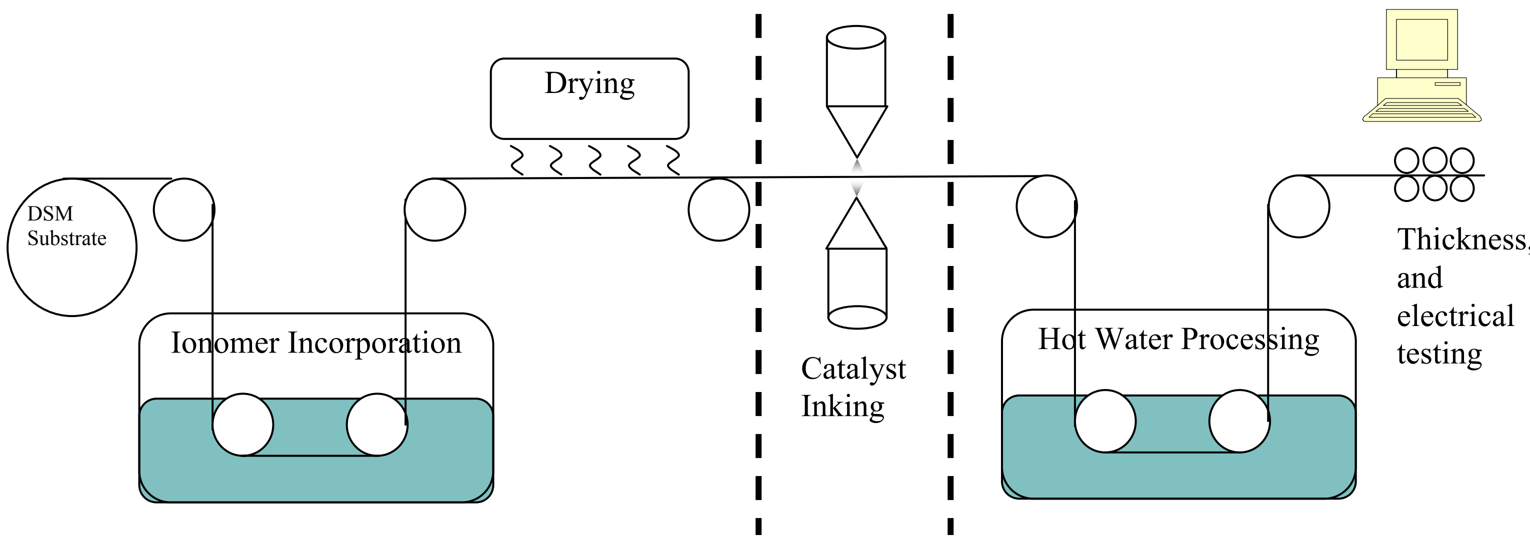
- General Motors
- SUNY-ESF

OVERVIEW

- OBJECTIVES/MILESTONES
- APPROACH and ACCOMPLISHMENTS
  - Rationale
  - Two Dimensionally Stable Membranes™
  - Three Dimensionally Stable Membranes™
- OTHER OPPORTUNITIES
- CHALLENGES

OBJECTIVES: Ultimate Goal

Meet performance targets with film that can be generated in roll at DOE cost targets

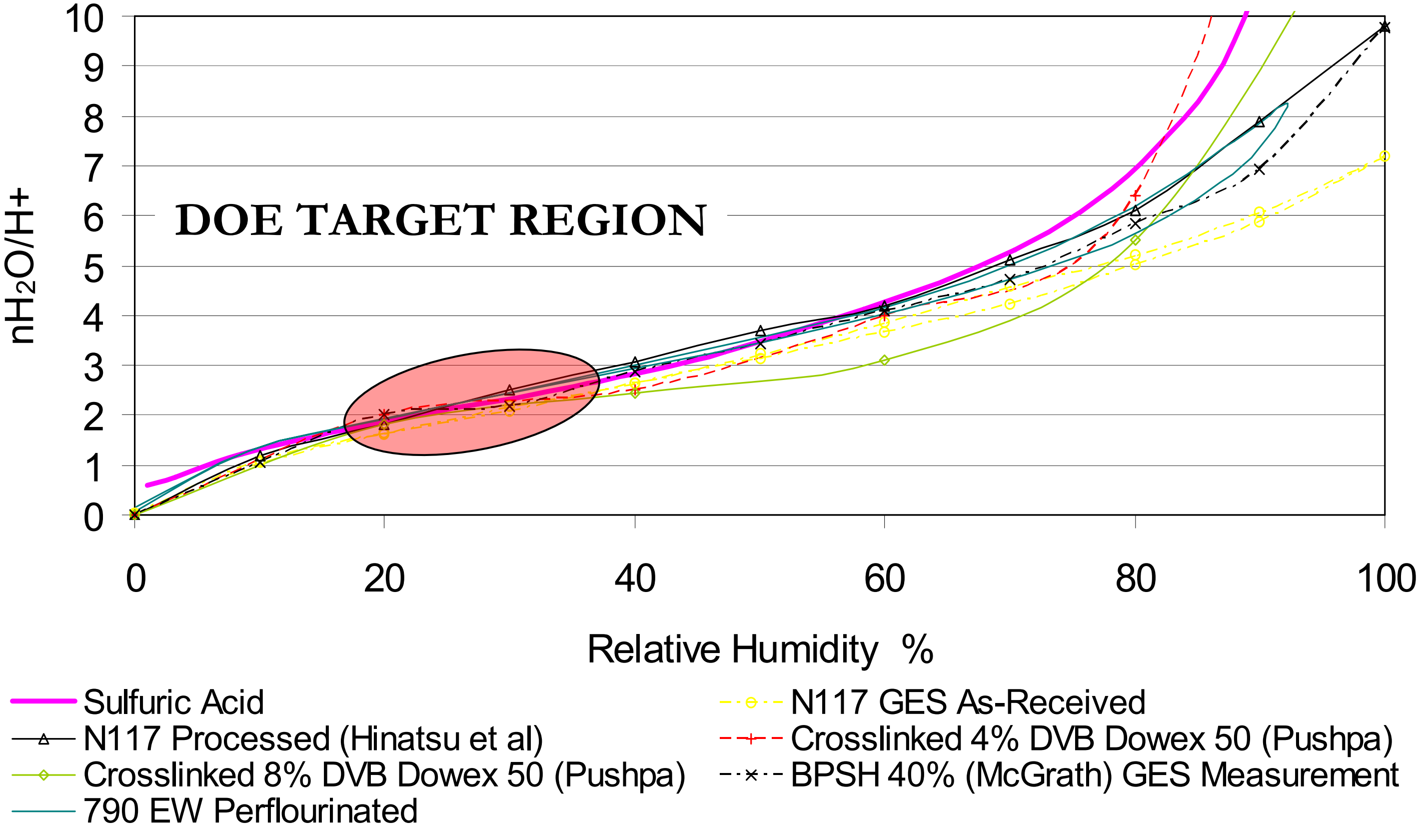


MILESTONES

YEAR	OBJECTIVE
2006	Determine the effect of pore size and substrate thickness on conductivity and water uptake. Demonstrate polymerization conditions suitable for bulk polymerization of the PFSA.
2007	Demonstrate, by the 3rd Quarter, membrane conductivity of 0.07 S/cm at 80% relative humidity at room temperature using non-Nafion materials. Samples will be prepared and delivered to the Topic 2 Awardee.
2008	**Go/No-Go Decision:** Demonstrate, by the 3rd Quarter, membrane conductivity > 0.1 S/cm at 25% relative humidity at 120°C using non-Nafion materials. Samples will be prepared and delivered to the Topic 2 Awardee.

APPROACH: Rationale

Water Uptake of Ionomers based on $-SO_3H$ Moiety

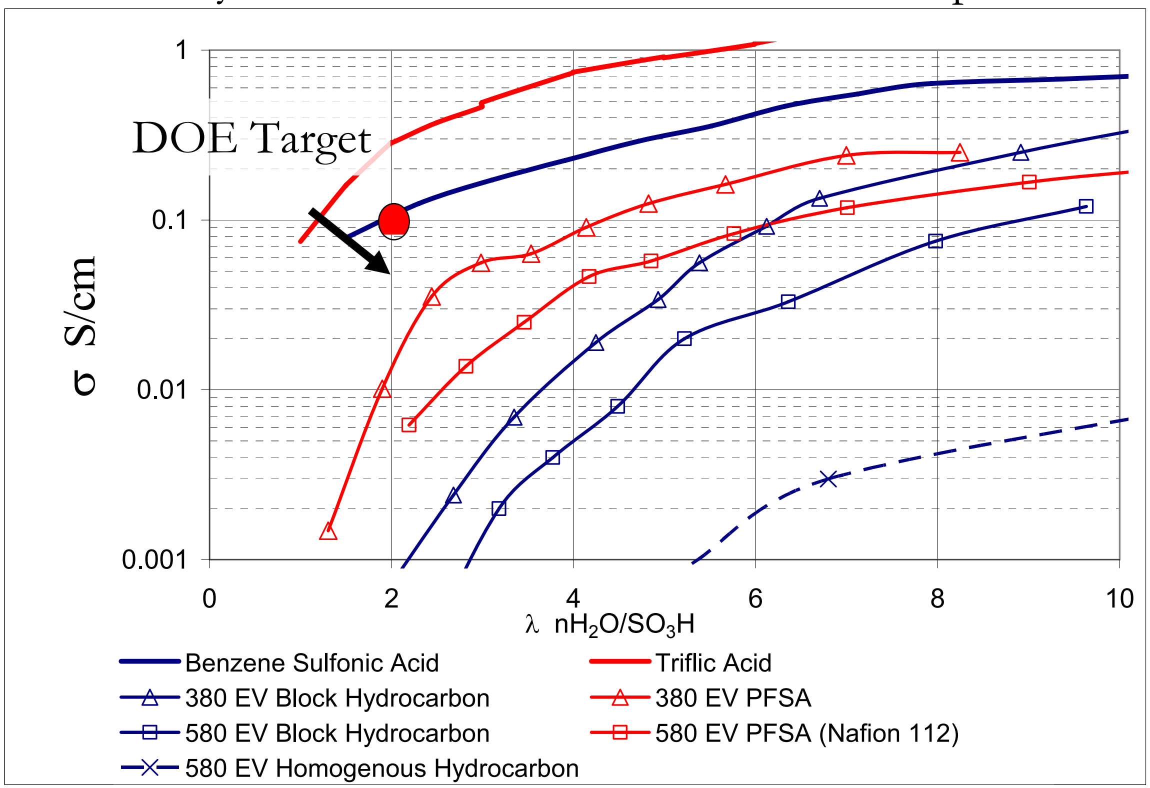


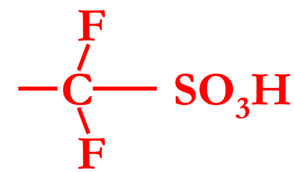
Water Content is the same regardless of pendant group

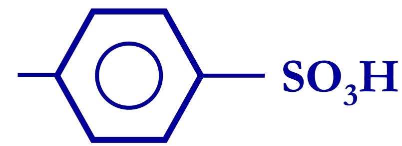
APPROACH: Rationale

Importance Of Ionic Functional Group, Morphology

Conductivity of Various Ionomers and Model Compounds at 80°C







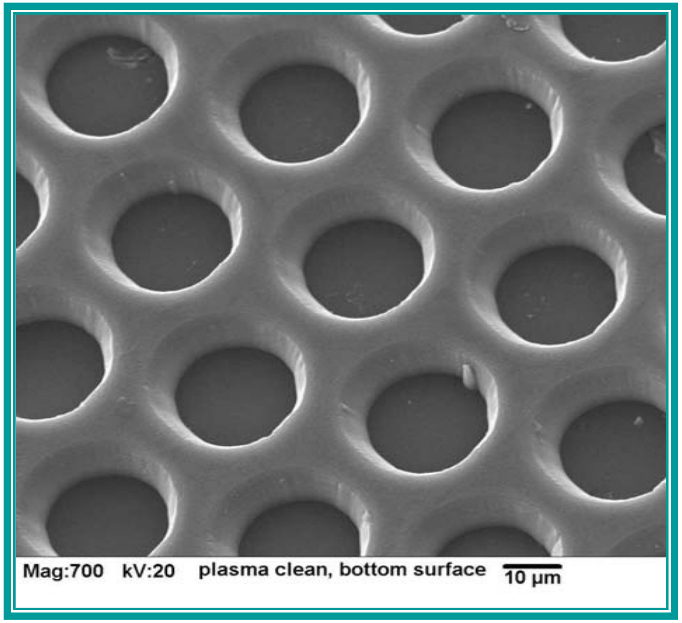
EV = EW/Density

To meet DOE targets membranes should be perfluorinated and very low EW

APPROACH: 2DSM™

Dimensionally Stable Membrane Support Structures Used to Date

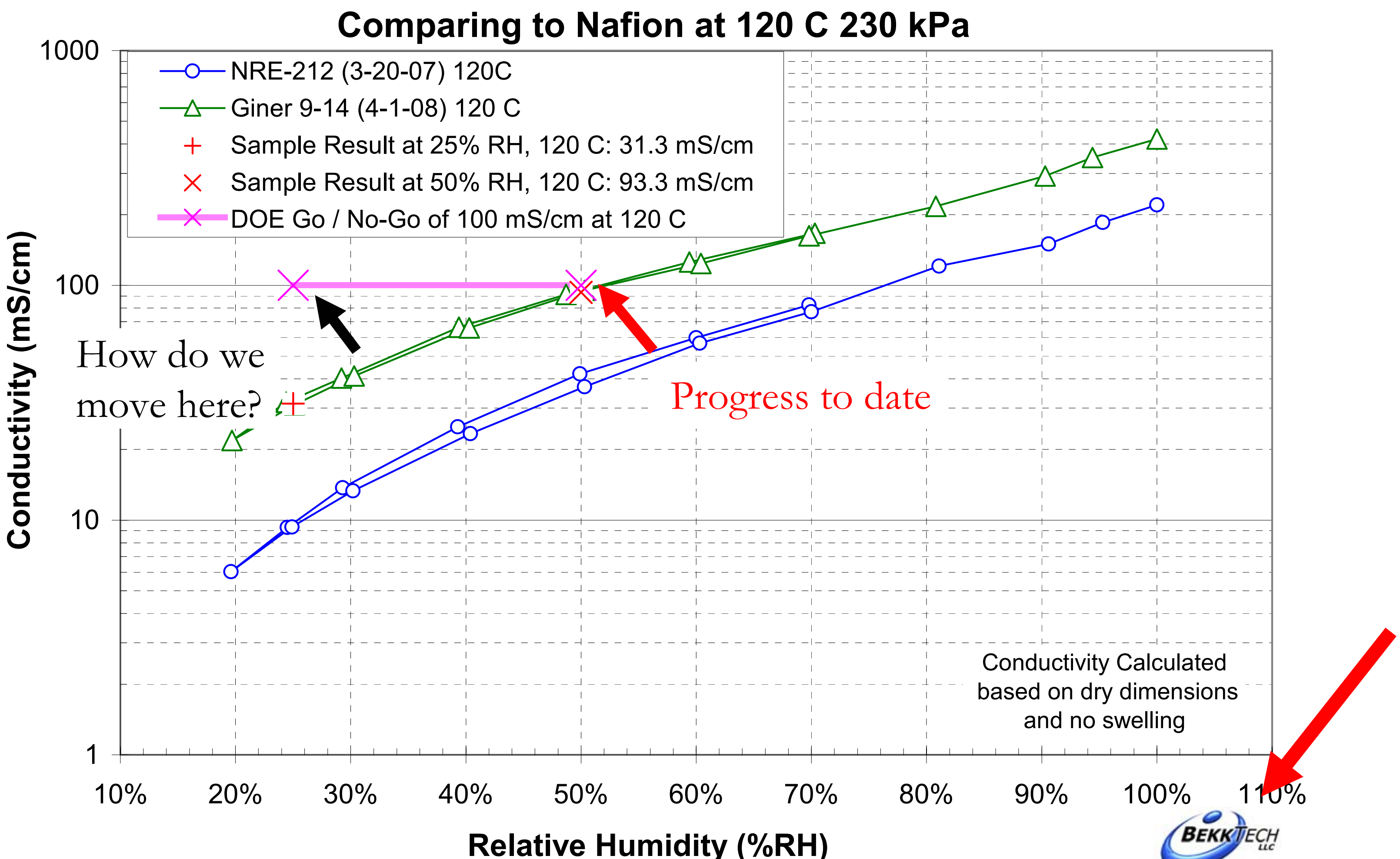
Material, condition	**Young's Modulus** (Mpa)
Nafion 112 Dry 20°C	300
Nafion 112 Wet 80°C	70
Poly(tetrafluoroethylene) (PTFE)	400
Polysulfone	2600
Polyimide (PI), e.g., Kapton®	2900



In 2007 Demonstrated no x-y swelling over large matrix of Geometries and compositions, Additionally conductivity was ~ 2.5x Nafion over the entire RH range

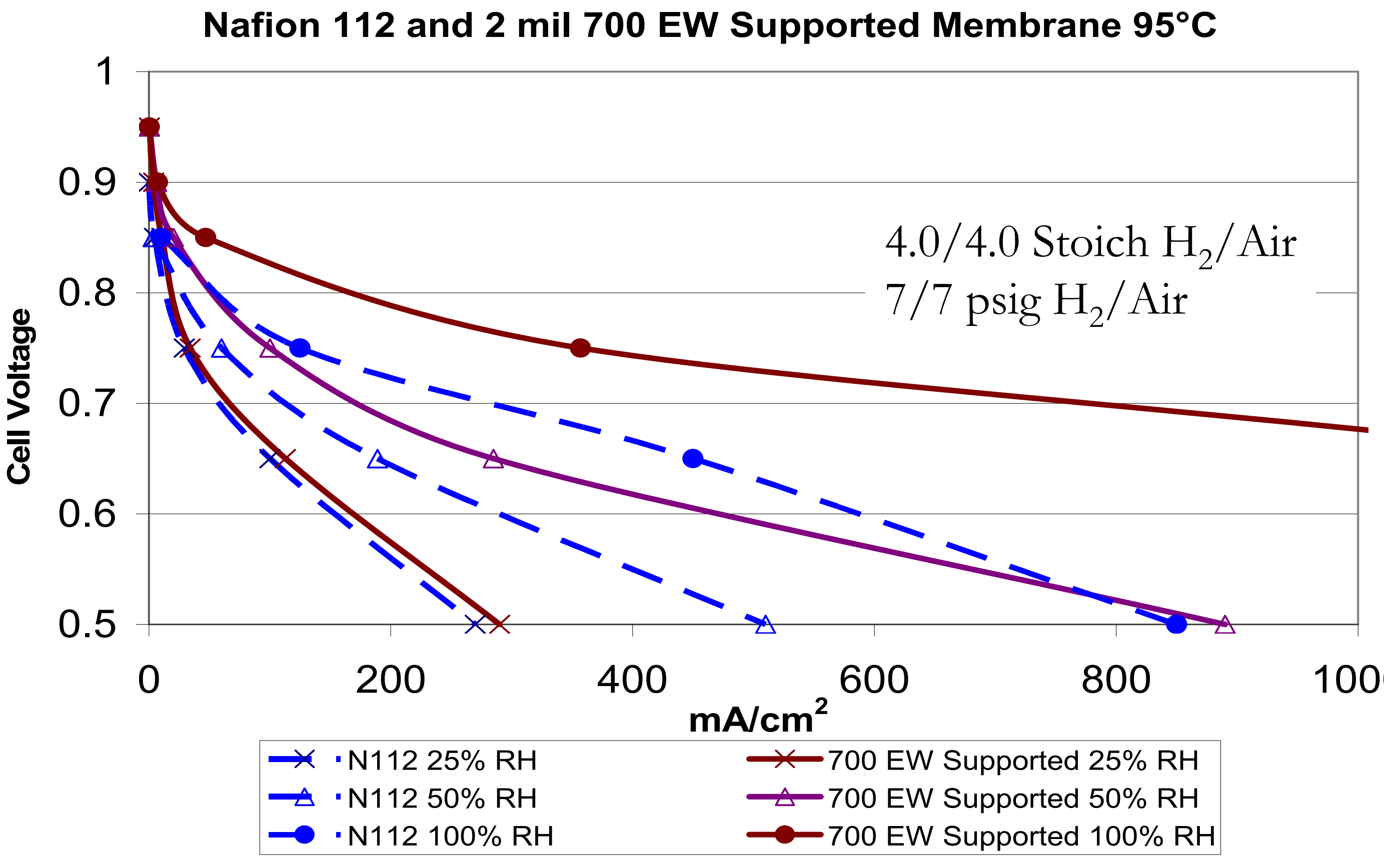
ACCOMPLISHMENTS: 2DSM™

700 EW Membrane with DSM™ Support, Conductivity as a function of RH



ACCOMPLISHMENTS: 2DSM™

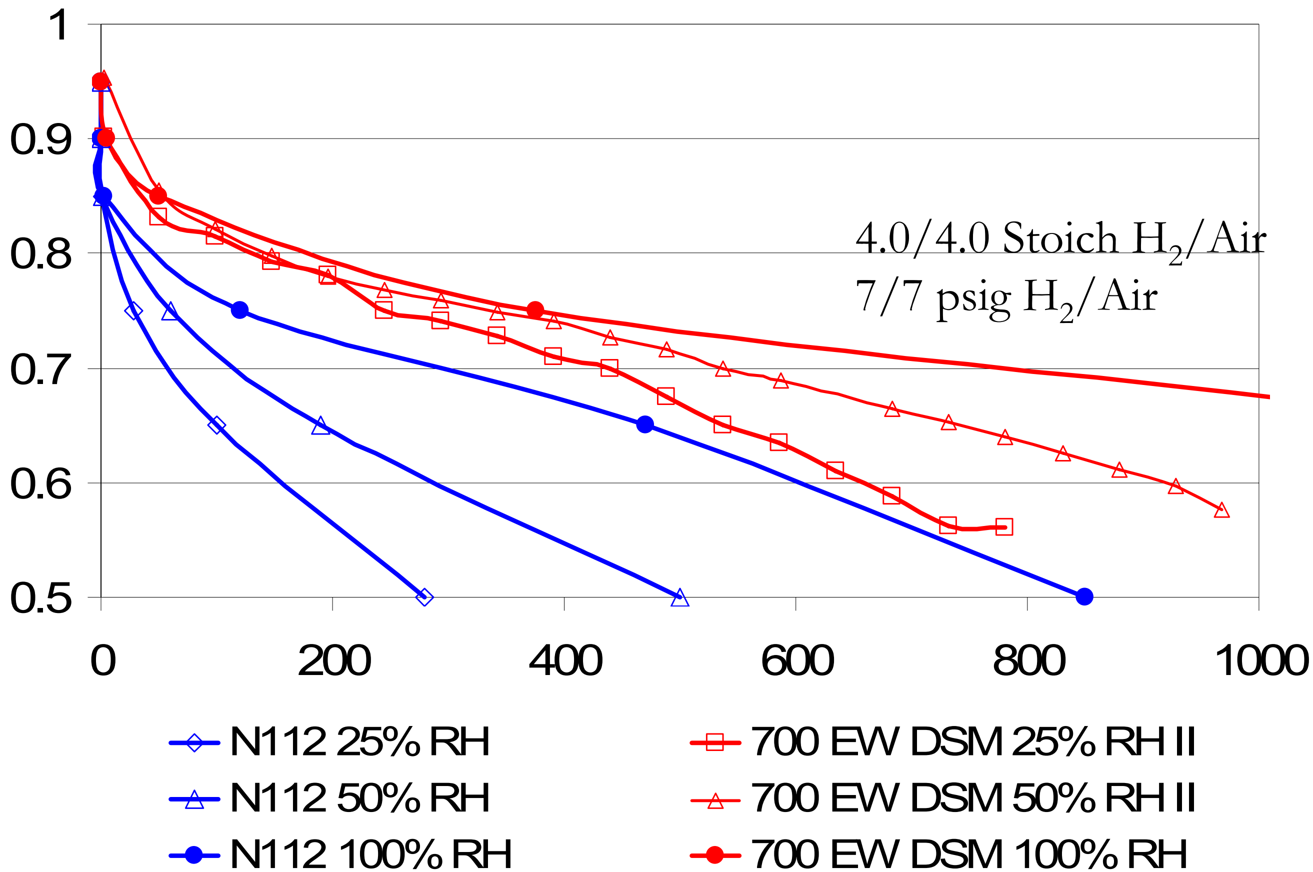
Fuel Cell Performance (2007 presentation)



25% RH data much worse than predicted based on DSM conductivity and high-frequency resistance: Work to do on the catalyst layer

ACCOMPLISHMENTS: 2DSM™

95°C

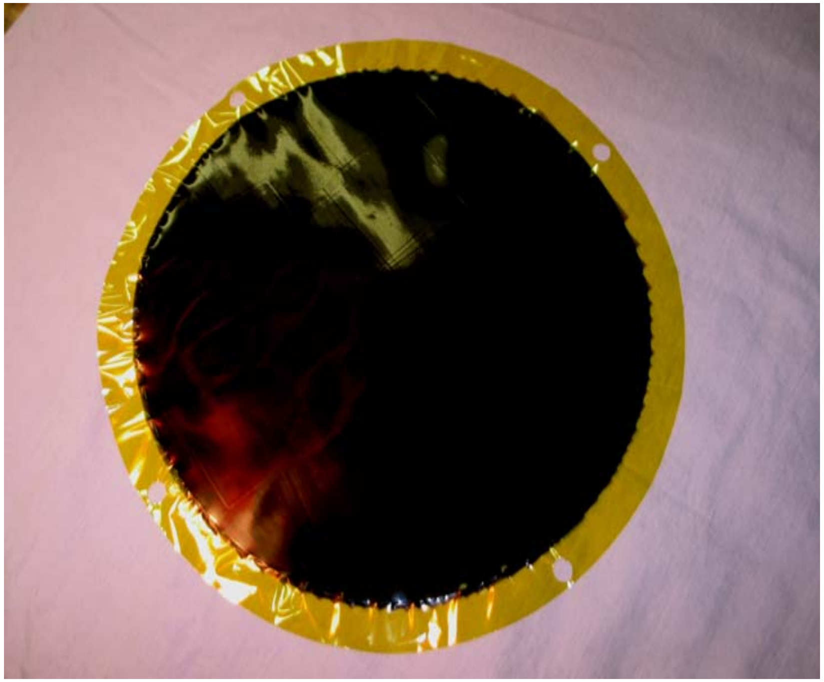


Superior conductivity of DSM membrane is manifest with improved catalyst layer

ACCOMPLISHMENTS: 2DSM™

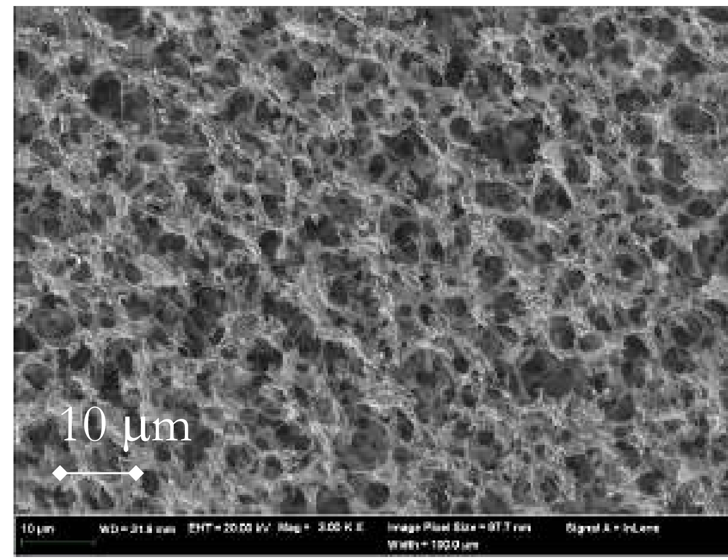
MEA Fabrication

- Generated 200 cm^2 MEA
- Catalyst Applied Directly To Membrane
- No Decal Transfer



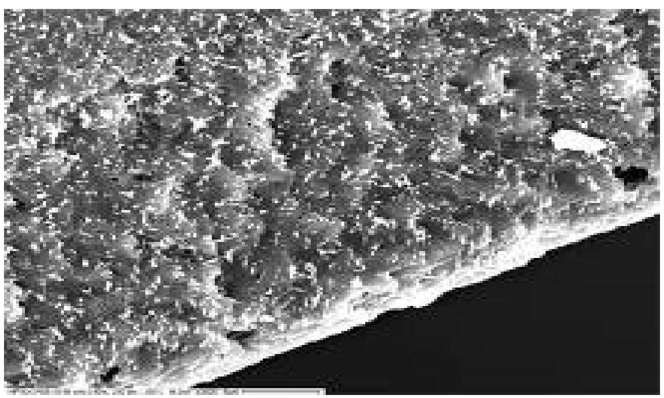
APPROACH: 3DSM™

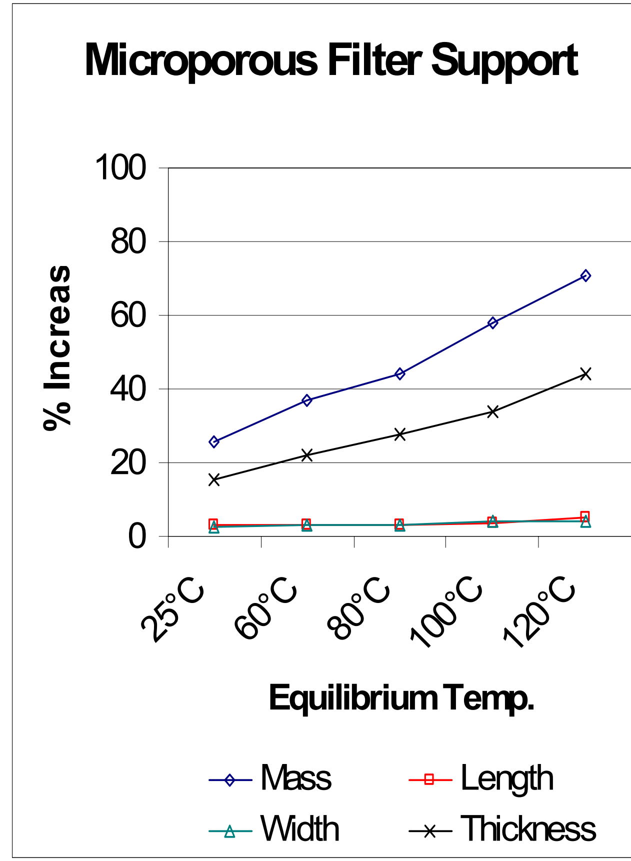
- Cost of Laser Drilling Prohibitively High
- Three-Dimensional Supports Commercially Available
- Using Conventional PFSA Ionomers to Meet Cost Targets
- Synthesizing New Low EW Ionomers to Meet Performance Targets
  - *Work being done by Israel Cabasso's Group at SUNY Syracuse Polymer Research Institute*



ACCOMPLISHMENTS: 3DSM™ -Commercial PFSA

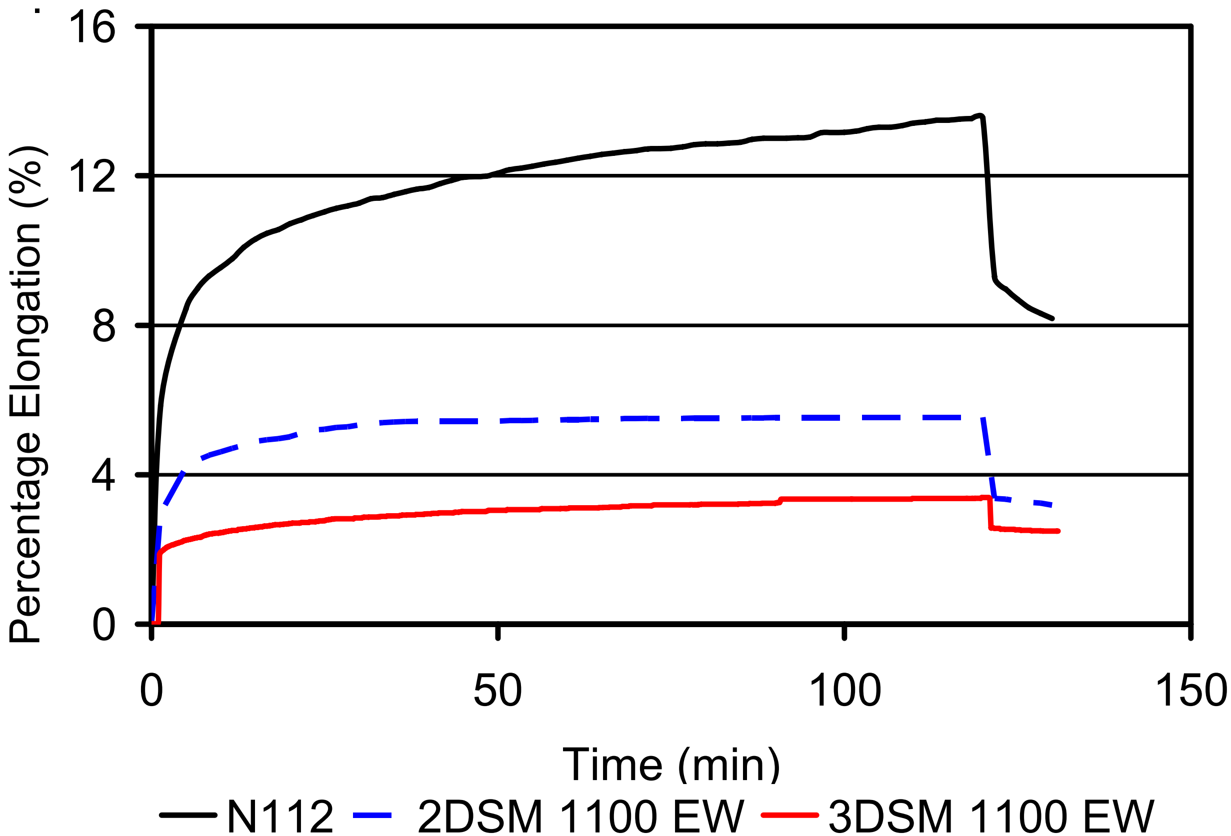
- Filled Supports With Commercial PFSA Material
- Swelling is Comparable to 2DSM
- Completely Filling Support was a Major Challenge
- ~33% Conductivity Penalty





Three-dimensional supports have same ability to limit in-plane swelling as 2DSM

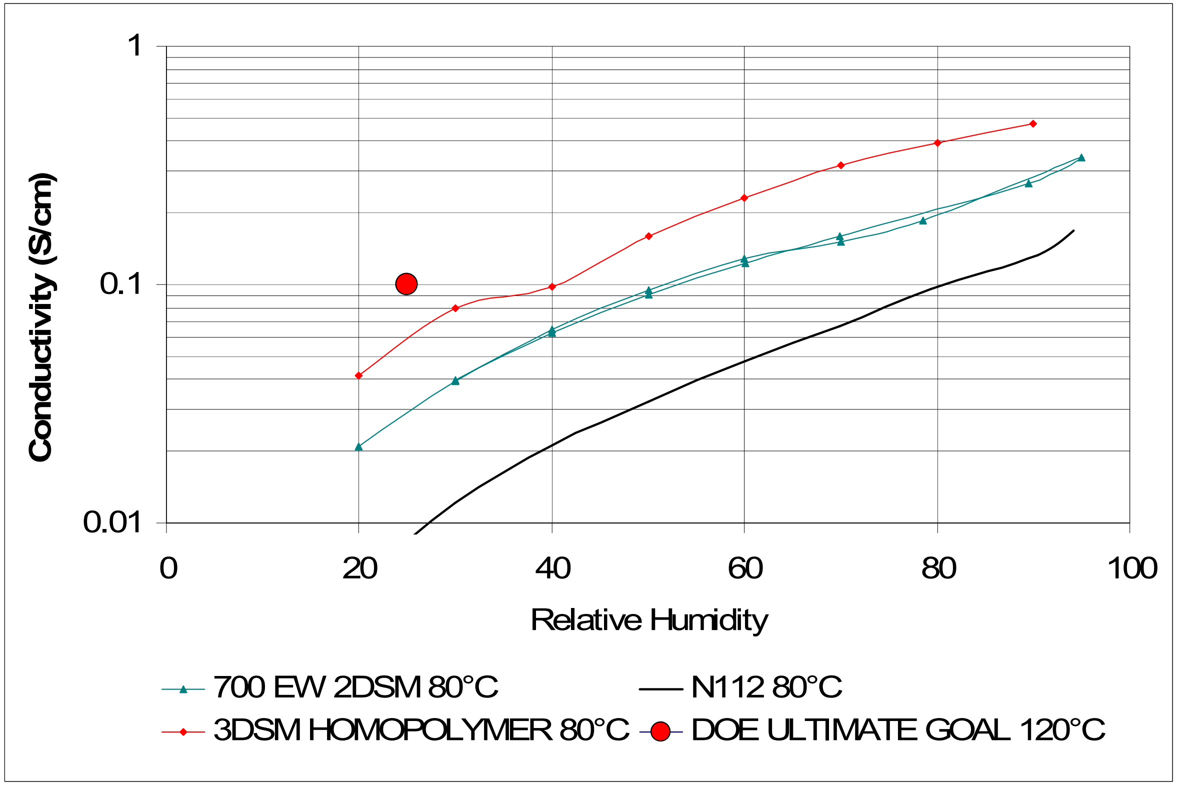
ACCOMPLISHMENTS: 3DSM™ -Creep Behavior Submerged at 80°C



Both 2DSM™ and 3DSM™ Supports greatly limit tension creep rates

ACCOMPLISHMENTS: 3DSM™

Alternative Synthesis: Homopolymer



Synthesis of new PFSA Monomers
Working with SUNY-ESF to make new copolymers and homopolymer

CF_2CF
$OCF_2CF(CF_3)OCF_2CF_2SO_2F$

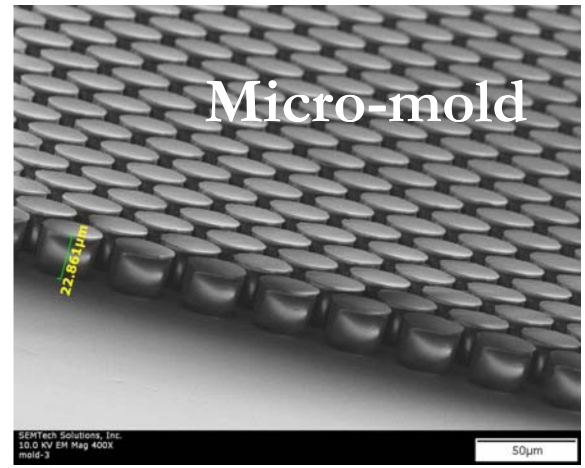
+ ?

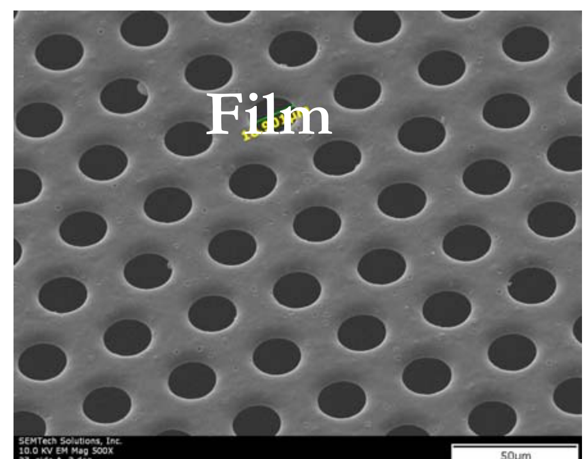
Three non-PTFE copolymers successfully synthesized. EW from 500-1300.

Getting closer to DOE target!

Challenges: 2DSM™

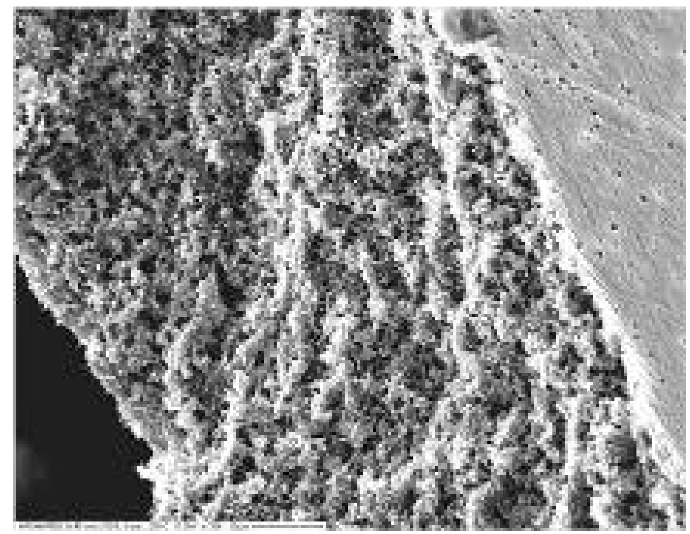
- Biggest Challenge is Cost
  - Laser Drilling
    - Currently ~ $1/cm^2$
    - Projected ~$0.02/cm^2$
      - $200/m^2$
  - In Separate DOE Project Developing Low-Cost Casting Technique
  - SEE HAN LIU POSTER FCP-013
    - (**DE-FG02-05ER84322**)





Challenges: 3DSM™

- Commercial Supports are too Thick
  - ~100 µm
  - Need ~ 10-25 µm
  - Can be made thinner, need the application
  - Trying to make our own
- Excessive Swelling
  - Working on Cross-linking syntheses



In-situ bulk polymerization in three-dimensional support

Future Work: 2DSM™

- Characterize RH cycling stability
    - MEA fabrication and catalyst uniformity are big questions
- Characterize thin membrane for fuel cell performance and durability
    - First Comparisons were with 2 mil film to compare to N112
    - Big advantage of these systems is ability to go very thin, so we will

Future Work: 3DSM™

- Characterize Fuel Cell Performance
  - Developing a thin membrane is a challenge
- Characterize RH Cycling durability
- Working with toll coater to produce large continuous film
  - Needed to any real durability data as hand-made films lack consistency
- Use cross-linking and other strategies to limit swelling of new low EW ionomers

SUMMARY

- Year 2 Milestones Achieved
  - Interim Conductivity targets have been met
    - Demonstrated by Becktech
      - .0852 S/cm at 30°C and 80% RH vs Goal of 0.07
      - .031 S/cm at 25% RH and 120°C is below DOE target
      - 0.10 S/cm achieve at 120°C and 50% RH
    - *NEARING ULTIMATE GO/NO-GO TARGET*
      - *0.08 S/cm Demonstrated at 80°C and 50% RH*
  - Fuel Cell Performance Improvements Shown
    - Electrode Improvements
- Realistic Pathways for Meeting Cost Targets Seen for both Paths
- To reach ultimate DOE Goals we will need to incorporate the low EW materials that have been developed at SUNY, Syracuse