Dimensionally Stable High Performance Membrane

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FCP-013

Overview

Timeline

- Start – August 2006
- End – August 2008
- 85% Complete

Barriers

- Freeze/Thaw Durability
- Low RH Operation
- Ionic Conductivity

Budget

- Total Project Funding: $750 K
- Funding Received: $375 K in FY08

Objectives

- Develop Membrane-Electrode Assemblies (MEAs) based on dimensionally stable membrane (DSM™) with high freeze/thaw durability
- Enhance MEA RH cycling durability
- Develop/improve fabrication technology for support structure
- Develop/evaluate localized reinforcement strategy
- Evaluate the effect of MEA configuration

Approach

Task 1: F/T Protocol Development

- Longer, Wider Range
- In-situ Monitoring

Task 3: Selective Reinforcement

- Identify Weak Area
- Develop Reinforcement Strategy

Task 2: Enhanced Patterning

- Micromolding
- Micromachining
- Material Screening

Task 4: MEA Configuration

- Channel Width
- Compression
- Catalyst Layer Configuration

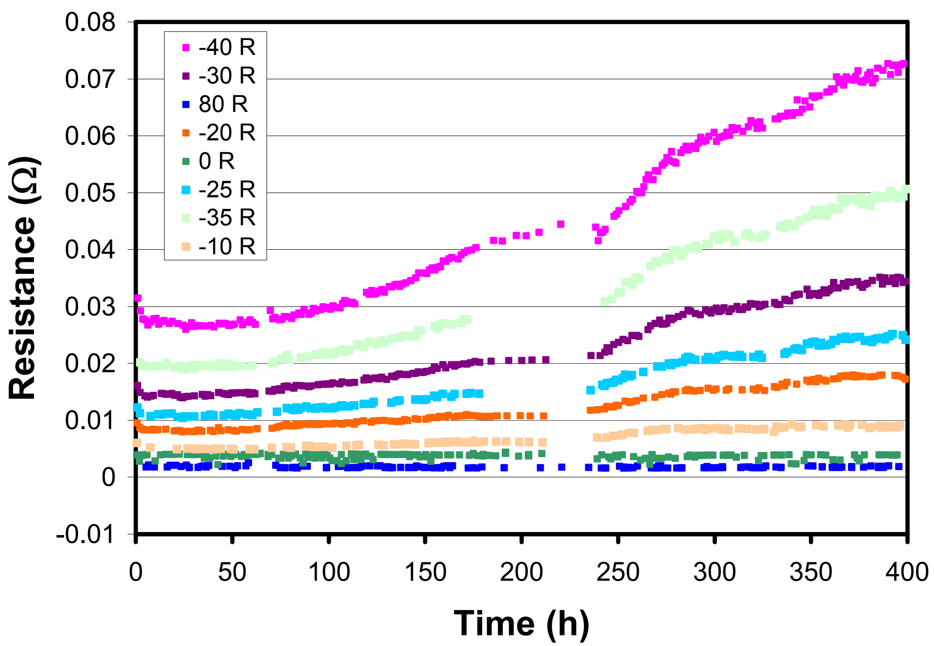
Task 5: Stack Test

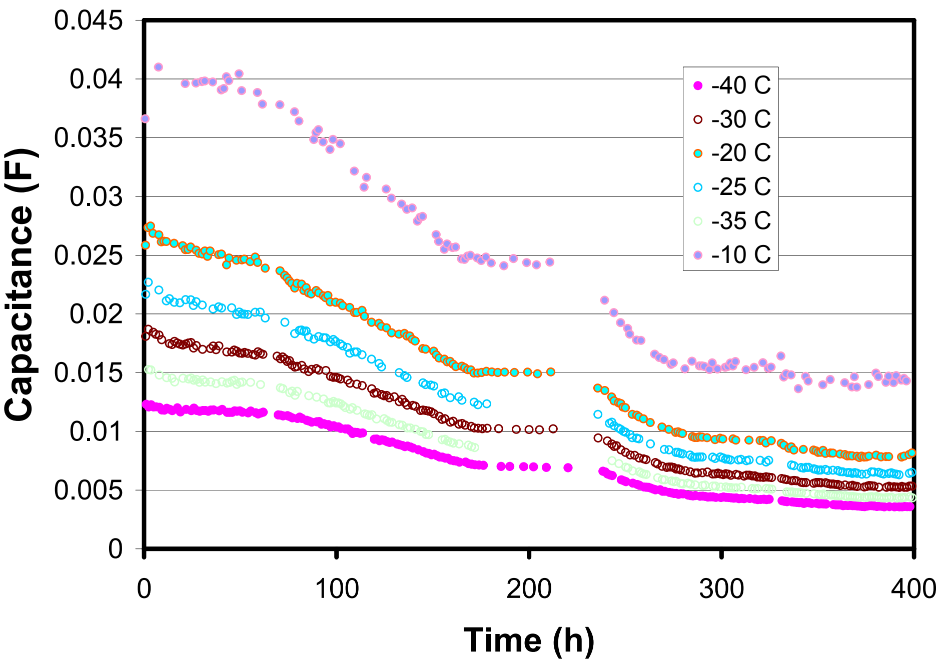
Technical Accomplishments/ Progress/Results

- Successfully developed new membrane support fabrication process that can be readily scaled up for continuous low cost mass production of DSM™.
- The DSM™ show 10X better in-plane swelling stability and more than one order of magnitude less creep rate than Nafion® 112.
- Localized mitigation for the DSM™ completely eliminates edge failures.

DOE Hydrogen Program

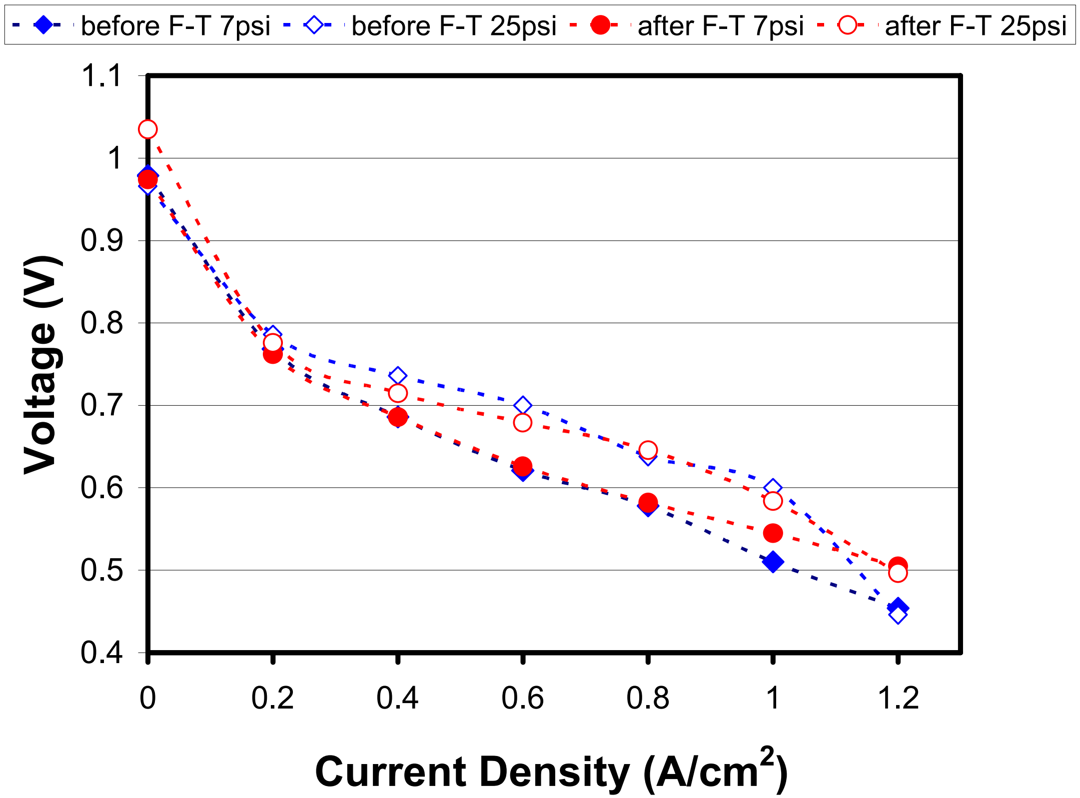
Freeze/Thaw Cycling (Nafion 112)





Resistance @ -40°C increases with number of cycling while impedance @ 80°C remains constant. Capacitance decreases with time.

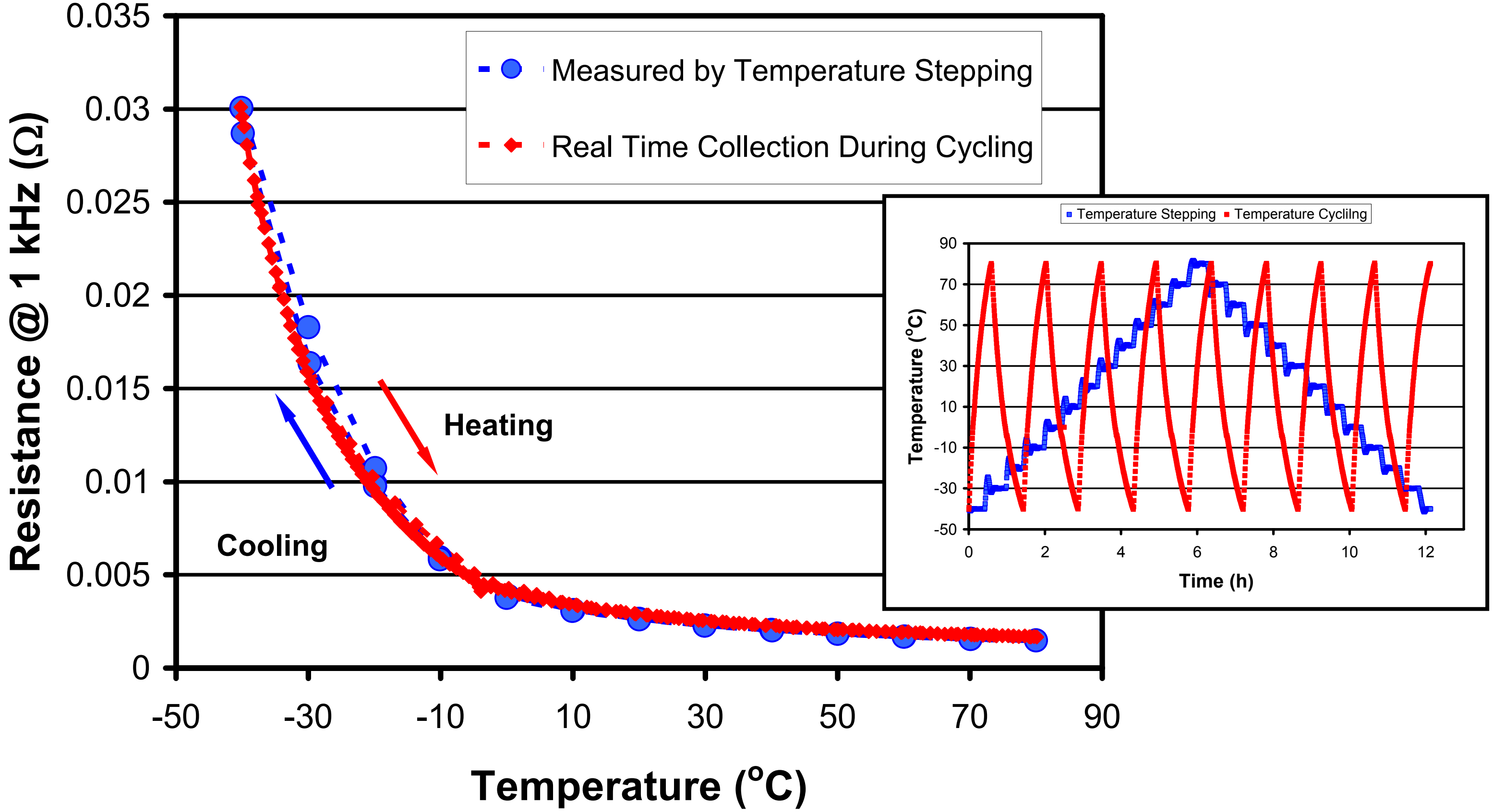
Freeze/Thaw Cycling (Nafion 112)



Reactant Gas: H_2 and air, Pressure: balanced, Temperature: 80°C cell, 64°C (50% RH) air, 80°C (100% RH), Gas Stoic: 2*, Mode: Constant current (* Under OCV conditions, the gases supplied at 200 mA/cm^2 equivalent flow.)

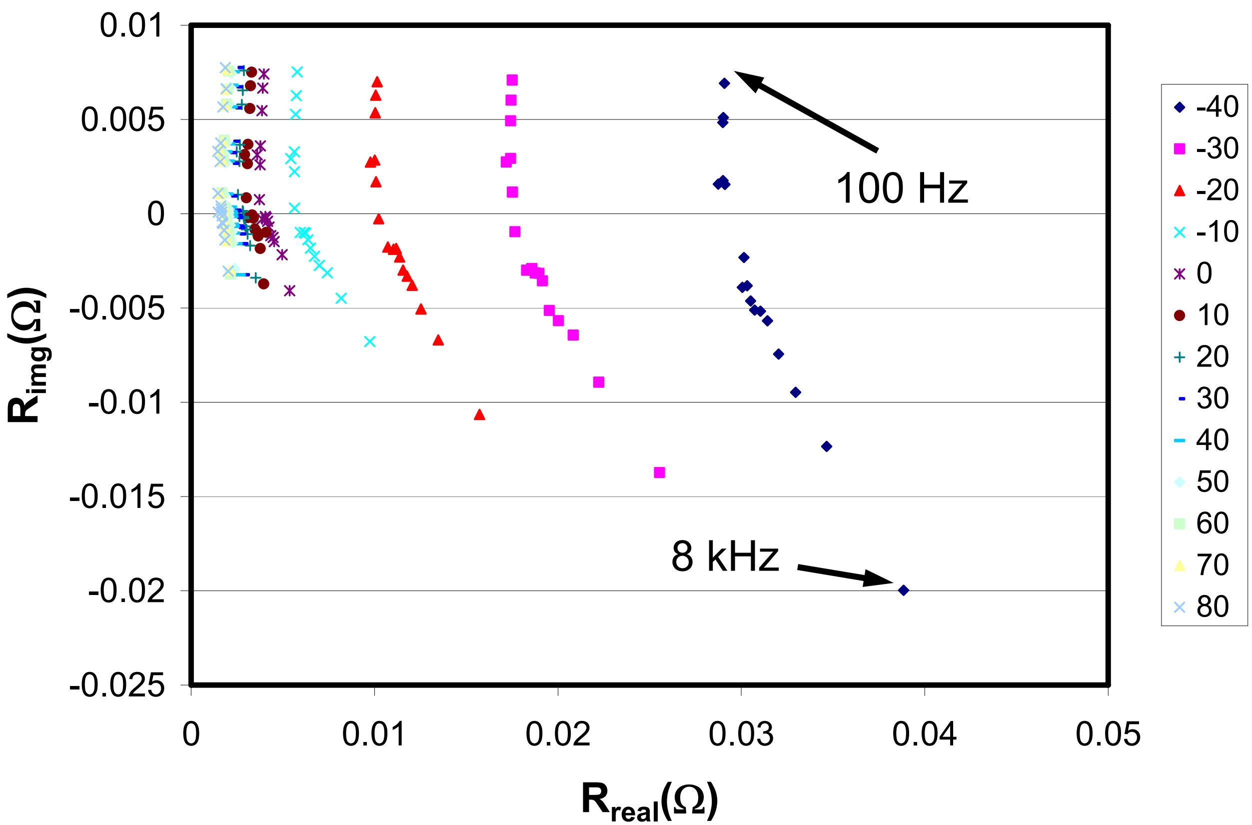
The resistance increase at low temperature does not lead to any detectable performance loss after the F/T cyclings.

Freeze/Thaw Cycling (Nafion 112)



Results from the new temperature stepping protocol indicate that the measured resistance is not an artifact of delayed heat transfer.

Freeze/Thaw Cycling (Nafion 112)



More detailed impedance data can be obtained from the new temperature stepping protocol.

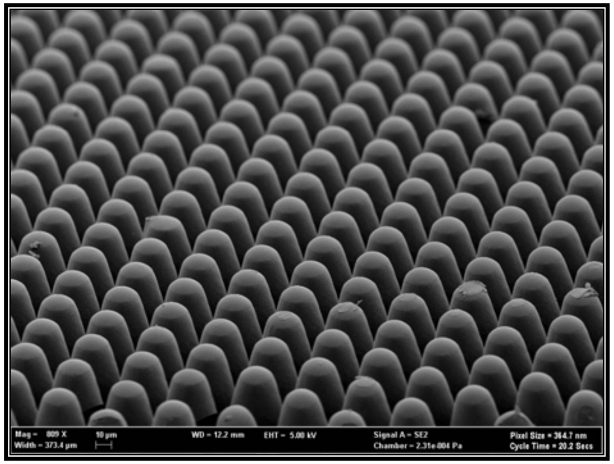
DOE Hydrogen Program

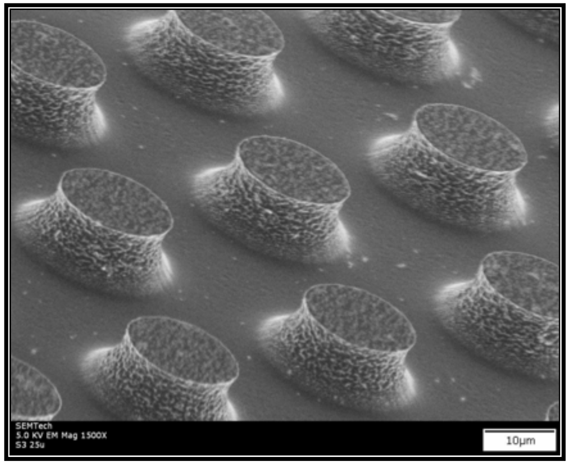
Freeze/Thaw Cycling (Nafion 112)

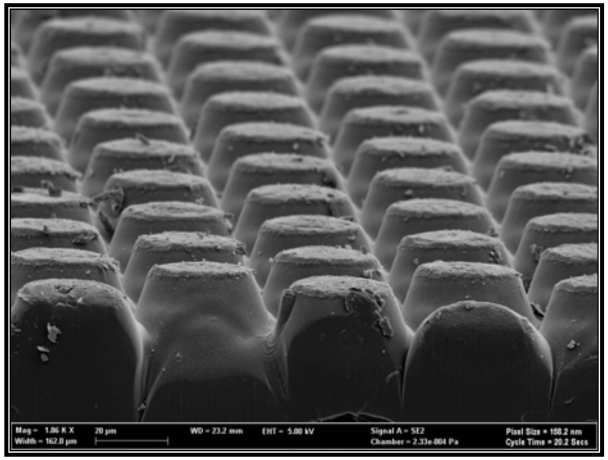
Material	% elongation at break	
	Before Cycling	**After 385 F/T Cycles (Dry)**
Membrane (machine direction)	1290	40
Membrane (cross direction)	320	25
MEA (machine direction)	960	52
MEA (cross direction)	510	37
	Before Cycling	**After 200 F/T Cycles (Wet)**
Membrane (machine direction)	> 300	> 300
Membrane (cross direction)	> 300	> 300

Previous data from GES show N112 becomes brittle after F/T cycling under dry conditions. There is no detectable difference after similar experiments under wet conditions.

Low Cost Fabrication of DSM™ Support

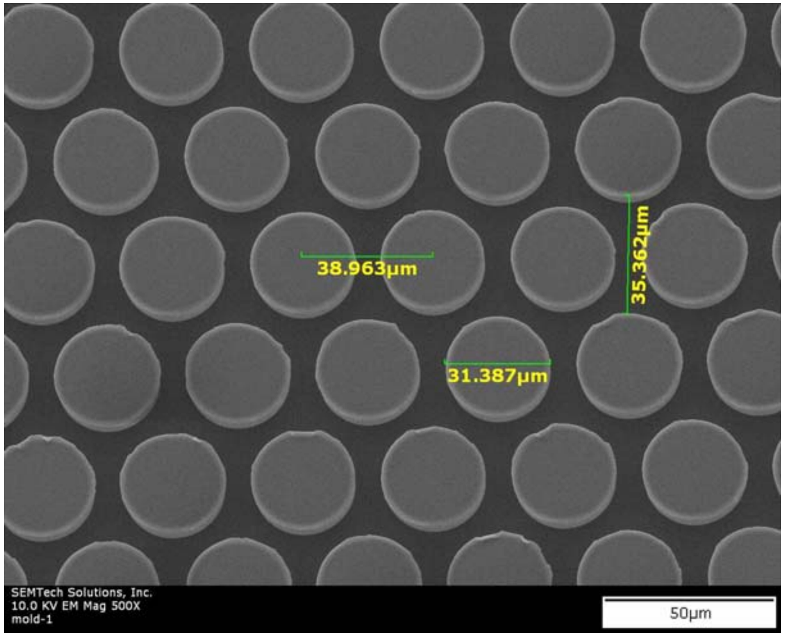


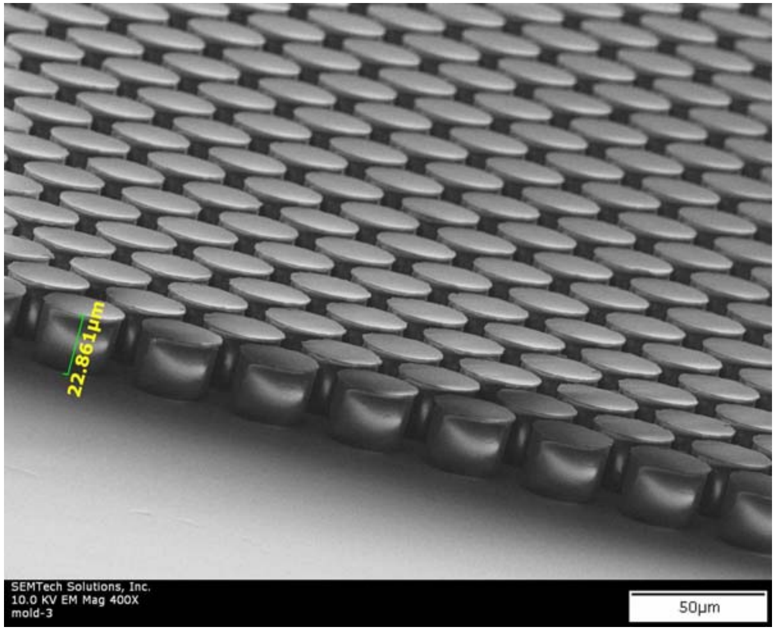




Various technologies have been used to develop micromolds for DSM™ support fabrication.

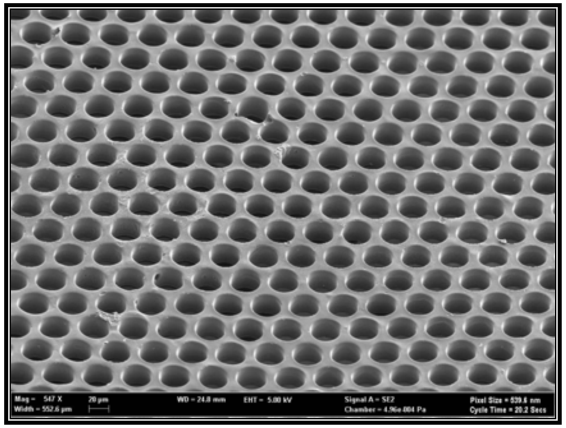
Low Cost Fabrication of DSM™ Support

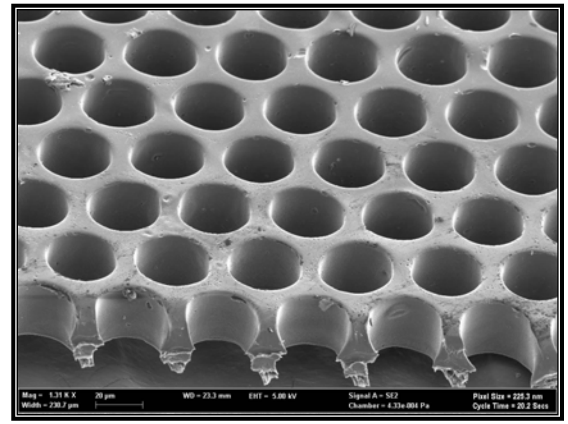


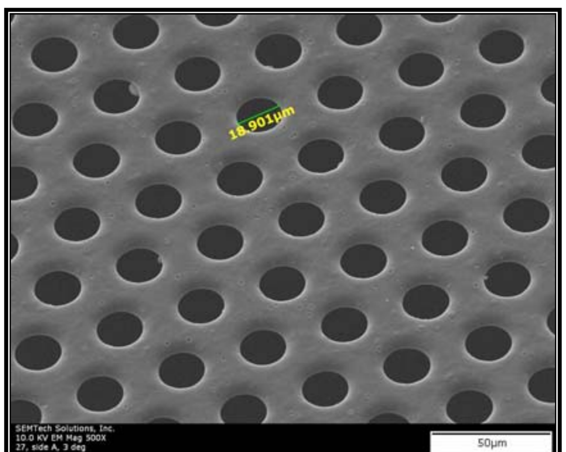


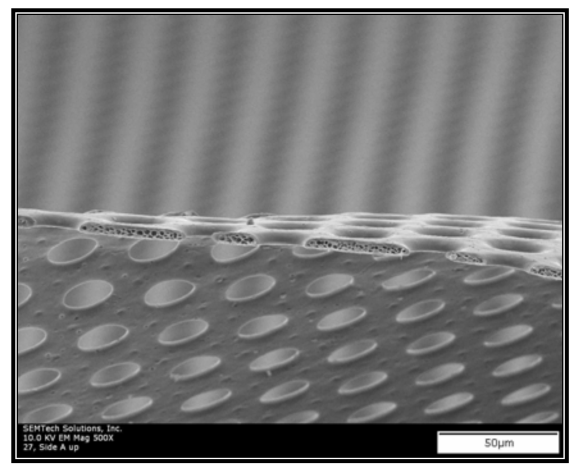
New micromolds can replicate the dimensions of the laser drilled support structure.

Low Cost Fabrication of DSM™ Support



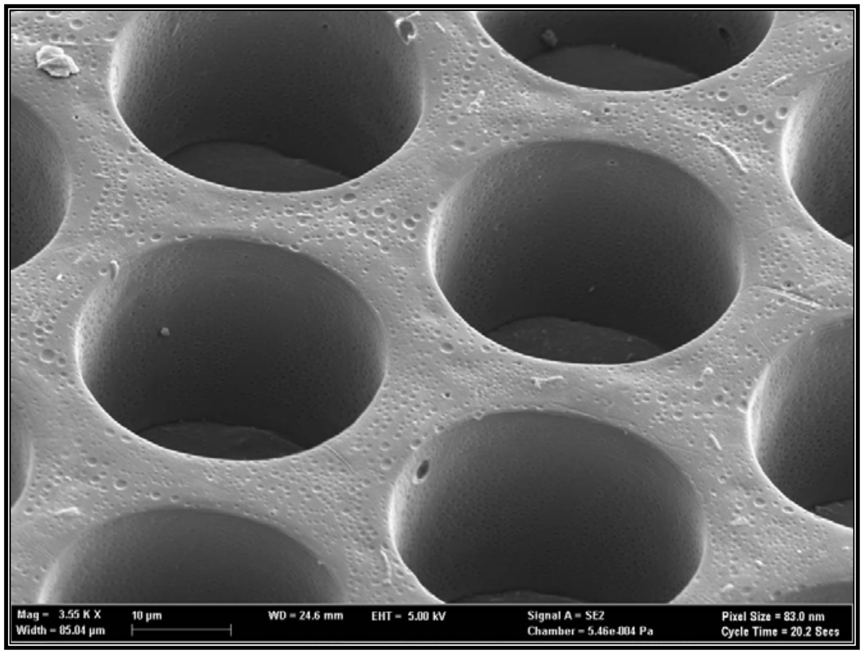


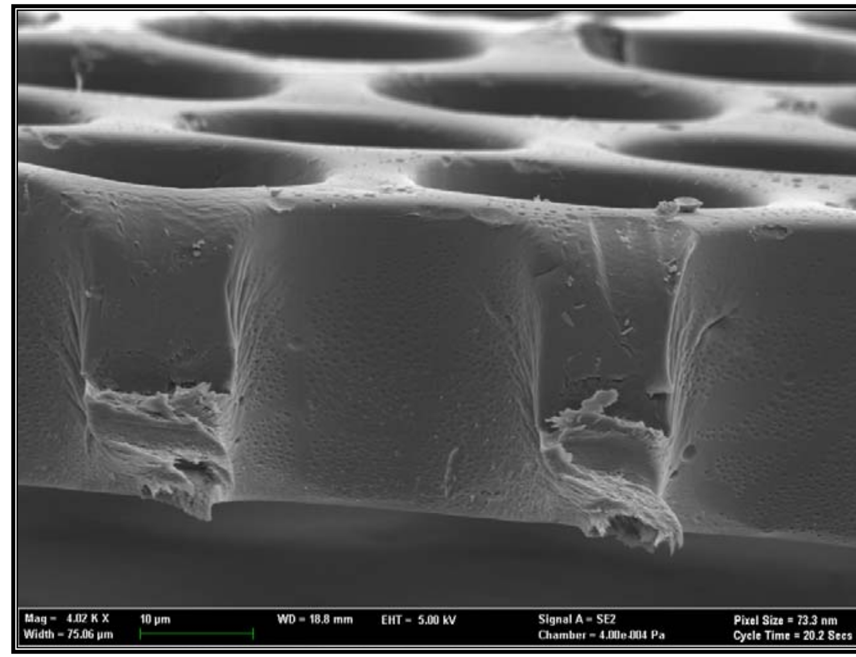




Support structure with difference thicknesses can be readily prepared.

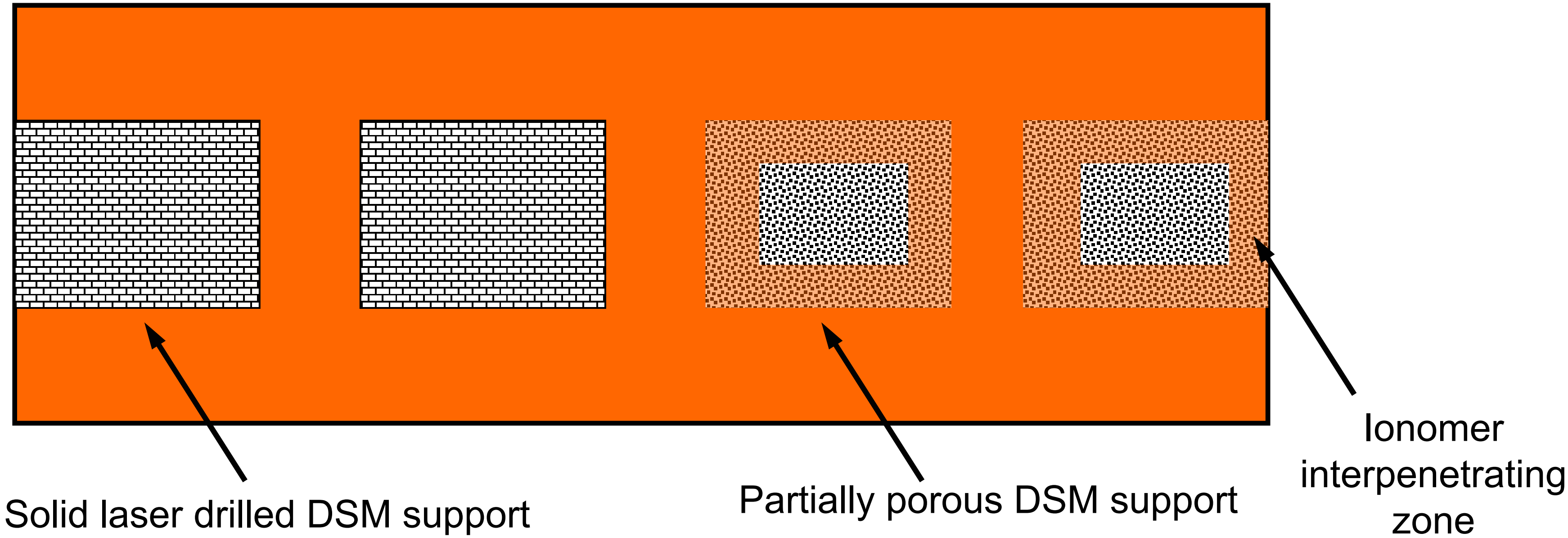
Low Cost Fabrication of DSM™ Support





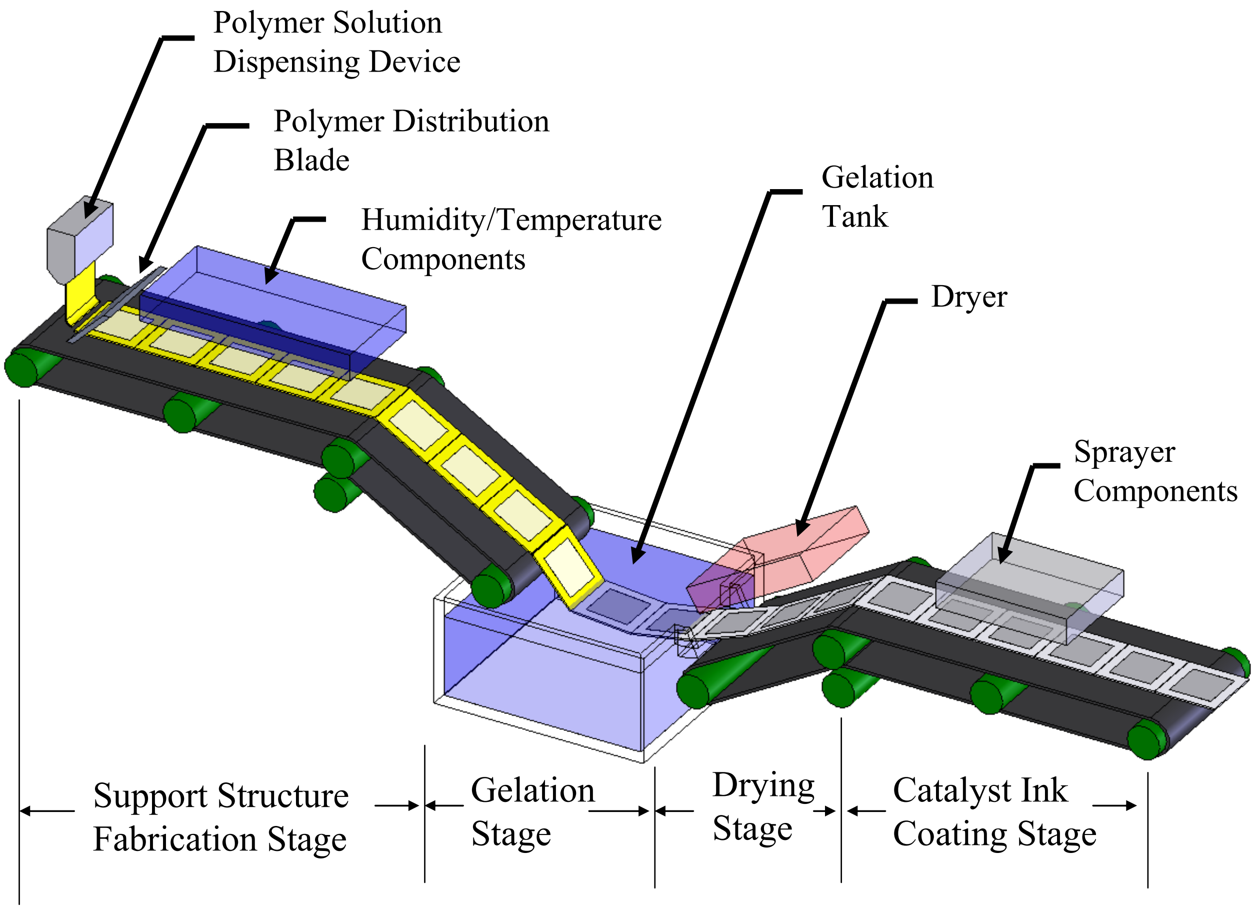
The support structure can be prepared with controlled surface/bulk porosity, which can further enhance ionomer adhesion, although adhesion has never been an observed problem for DSM™ based on laser drilled support.

Low Cost Fabrication of DSM™ Support



Since the support structure can be prepared with controlled porosity, an ionomer interpenetrating zone can be formed, which enhances conductivity without sacrificing mechanical properties.

Low Cost Fabrication of DSM™ Support

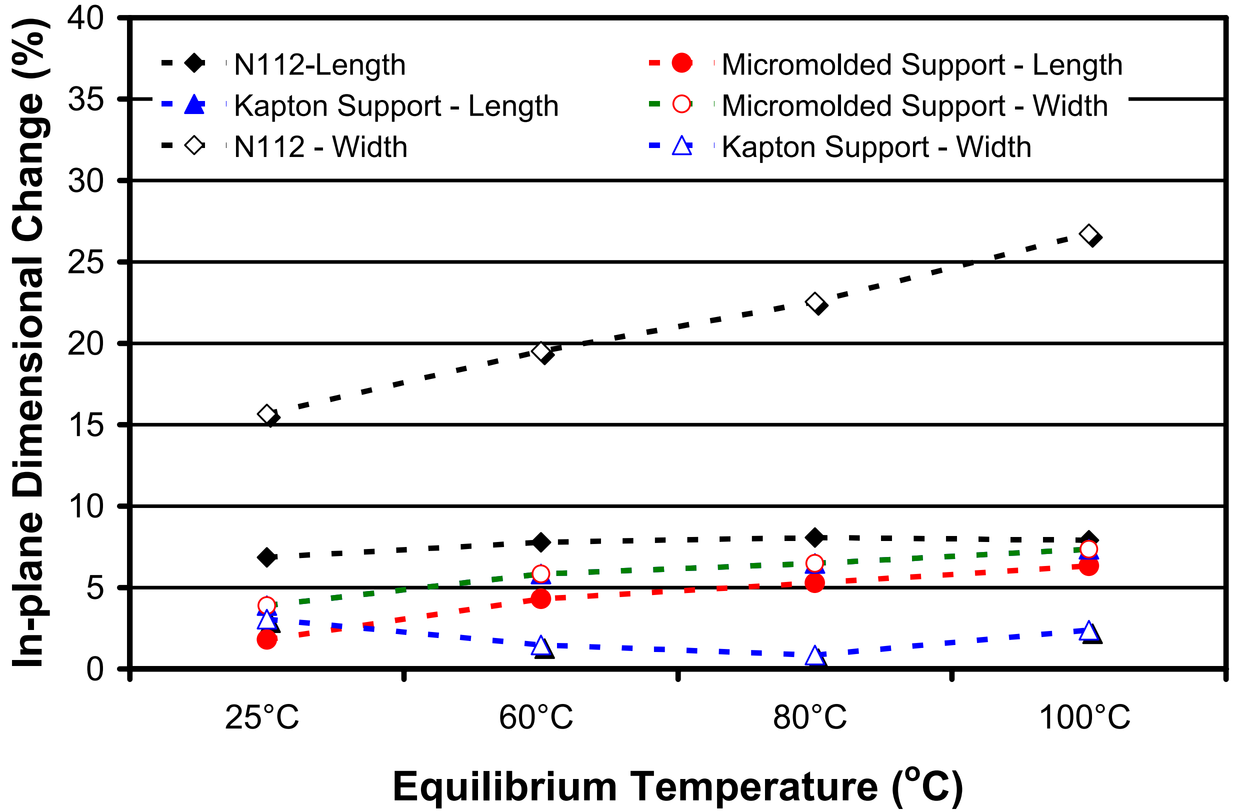


Schematic illustration of full DSM™ MEA fabrication line. Direct catalyst inking, instead of decal transfer, can be used due to high mechanical stability of DSM™.

Low Cost Fabrication of DSM™ Support

A section of prototype DSM™ fabrication belt for continuous manufacturing of DSM™ support.

Low Cost Fabrication of DSM™ Support

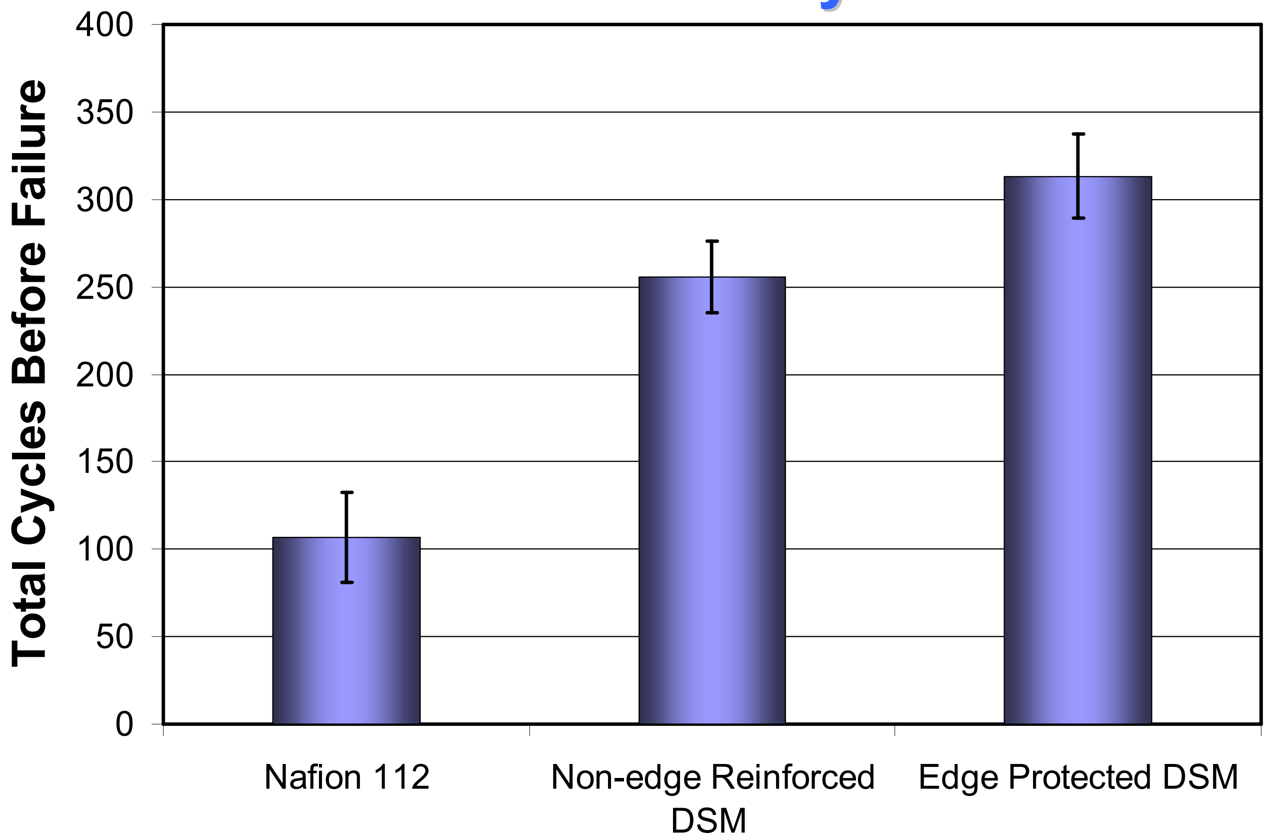


The DSM with micromolded support structure shows similar dimensionally stability compared to laser drilled samples.

RH Cycling Experimental

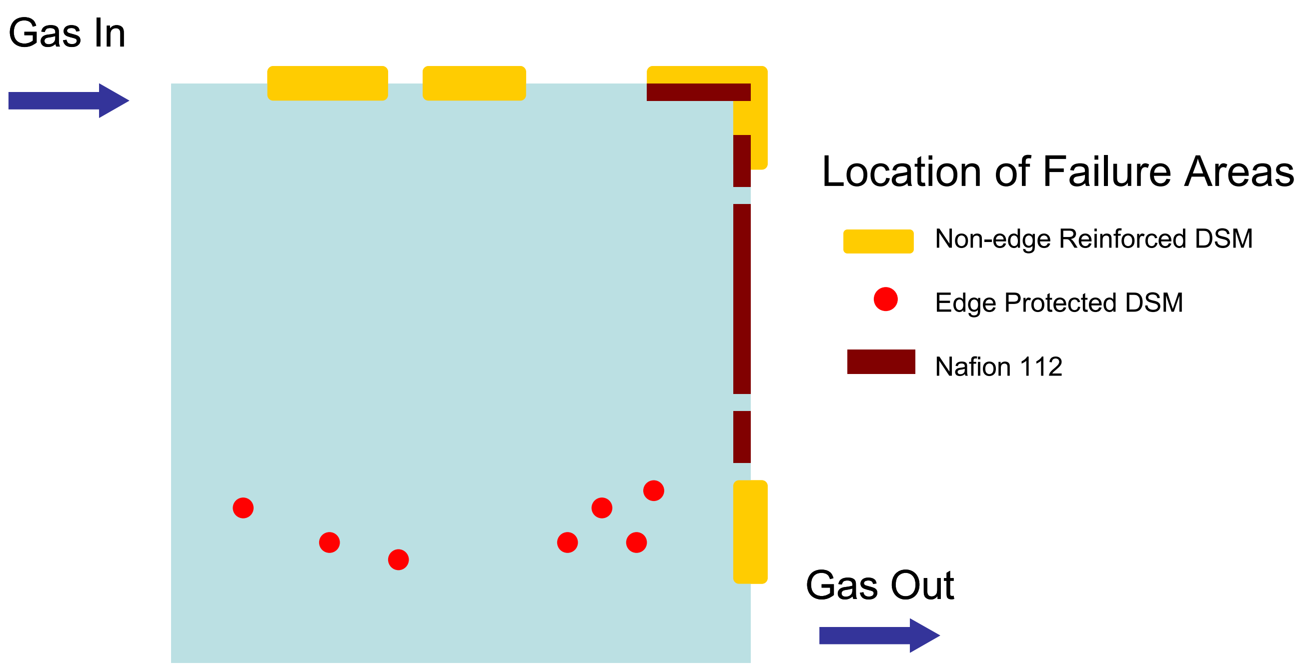
- Based on accelerated RH cycling protocol developed by GM.
- All tests were conducted at 95^{o}C, ~ 5 cycles per hour.
- All cells were tested to failure (0.8A/cm^{2}, <0.1V).

Effect of Localized Reinforcement on RH Cycling Durability



DSM™ with edge protection enhances the durability to > 3X compared N112 membranes.

Effect of Localized Reinforcement



DSM^{TM} with edge protection completely eliminate edge failures.

Future Work

- Demonstrate the feasibility of continuous fabrication.
- Investigate alternative polymer support materials.
- Study the effect of interpenetrating zone and porosity of the support structure.
- Evaluate the effect of MEA structure on freeze/thaw durability.

Summary

- New fabrication method offers unique DSM^{TM} support with controlled porosity, pattern configuration and feasibility for continuous MEA manufacturing.
- DSM^{TM} show 10X better in-plane swelling stability and more than one order of magnitude less creep rate compared to Nafion.
- Edge protected DSM^{TM} completely eliminates edge failures and enhances the durability to > 3X better than the N112 membranes.