Dimensionally Stable High Performance Membrane

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5/16/2006

Project ID # FCP 12

This presentation does not contain any proprietary or confidential information
Overview

Timeline
- Start – June 2005
- End – March 2006
- 100% Complete

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

Budget
- Total Project Funding: $100 K
- Funding Received: $100 K in FY05
Objectives

- Develop MEAs based on dimensionally stable membrane (DSM) with high freeze/thaw durability
- Enhance MEA X-Y (in-plane) dimensional stability
- Develop MEAs with high ionic conductivity and excellent mechanical properties
- Demonstrate concept feasibility for membranes based on patterned support
Approach

Task 1: Polymer Support Development
- Pattern Design
- Method Validation

Task 2: Membrane Fabrication
- Direct Insertion
- Ionomer Dispersion Coating
  - Automated Spraying
  - Blade Coating

Task 3: Membrane Characterization
- Water Uptake
- Mechanical Properties

Task 4: Freeze/Thaw and Performance
- Freeze/Thaw Durability
- Performance Evaluation
- MEA Configuration
- Diffusion Media Type
Supported membranes demonstrate drastically improved freeze/thaw stability compared to Nafion® in *ex-situ* tests.

Supported membranes show 10X better in-plane swelling stability than Nafion®.

Supported membranes show more than one order of magnitude less creep rate compared to Nafion®.

Supported MEA with EW700 ionomer demonstrates superior mechanical properties and 40% performance gain over Nafion®.
Various support patterns have been successfully fabricated based on Eximer laser technology.

Figures in the top row are schematic illustrations. Figures in the second row are micrographs of the samples.
Based on technology developed at GES, DSMs can be readily fabricated with uniformity better than 5%.
Compared to Nafion, DSMs demonstrate >10X swelling stability at elevated temperatures when submerged in water.
DSM demonstrates extraordinary dimensional stability compared to non-supported EW700 membranes.
Compared to Nafion, DSMs show more than one order of magnitude improvement on creep rate (percentage elongation / hour).
After 10 thermal cycles from -40°C to 50°C unconstrained, DSM show no observable degradation while Nafion membrane sustained severe damage.
Impact of MEA Configuration

Reactant Gas: H₂ and air, Pressure: 25 Psi balanced, Temperature: 80°C cell, 64°C (50% RH) air, 80°C (100% RH), Gas Stoic: 4*, Mode: Constant current (* Under OCV conditions, the gases supplied at 200 mA/cm² equivalent flow.)

MEA with catalyst on diffusion media performed significantly worse than catalyst on membrane.
Wide flow channels (2 mm) pose water management problems compared to narrow channels (0.9 mm), given the same gas flow rate.

Reactant Gas: H₂ and air, Pressure: 25 Psi balanced, Temperature: 80°C cell, 64°C (50% RH) air, 80°C (100% RH), Gas Stoic: 4*, Mode: Constant current (* Under OCV conditions, the gases supplied at 200 mA/cm² equivalent flow.)
Freeze/Thaw Impact on Performance

Reactant Gas: \( \text{H}_2 \) and air, Pressure: 25 Psi balanced, Temperature: 80°C cell, 64°C (50% RH) air, 80°C (100% RH), Gas Stoic: 4*, Mode: Constant current (* Under OCV conditions, the gases supplied at 200 mA/cm² equivalent flow.)

After 40 thermal cycles from -40°C to 50°C, all MEAs demonstrate excellent stability.
## Electrochemical Surface Area (ECSA) Test

After 40 thermal cycles from -40°C to 50°C, there is no significant drop of ECSA for all MEAs.

<table>
<thead>
<tr>
<th>Sample Designation</th>
<th>ECSA Before Freeze/Thaw (m²/g)</th>
<th>ECSA After Freeze/Thaw (m²/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N112</td>
<td>48</td>
<td>46</td>
</tr>
<tr>
<td>H70W7</td>
<td>51</td>
<td>48</td>
</tr>
<tr>
<td>H25W7</td>
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<td>47</td>
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<tr>
<td>H6W7</td>
<td>47</td>
<td>49</td>
</tr>
</tbody>
</table>
EW700 based DSMs show comparable mechanical properties to Nafion while providing a 40% performance increase. Unsupported EW700 membrane shows unacceptable poor mechanical properties.
Future Work – Phase II Work Plan

- **Freeze/Thaw Test Protocol Development**
  - Number of Cycles
  - Temperature Range

- **Better Patterning Method**
  - Improve Current Technology
  - Alternative Fabrication Method
  - Alternative Support Material

- **Local Reinforcement**
  - Identification of Problematic Areas
  - Design and Test Locally Reinforced DSMs

- **Identify Best MEA Configuration for Freeze/Thaw Durability**

- **DSM Based Stack Performance Evaluation**
Summary

- DSM with high freeze/thaw durability successfully demonstrated in ex-situ tests.
- Highly uniform DSM successfully developed with projected cost of the patterned support < $0.02/cm².
- DSMs show >10X X-Y (in-plane) dimensional stability compared to Nafion membranes.
- EW700 Based DSM shows a 40% improvement in performance while maintaining comparable/better mechanical properties.