New High Performance Water Vapor Membranes To Improve Fuel Cell Balance of Plant Efficiency and Lower Costs

Earl H. Wagener (PI)
Brad P. Morgan, Jeffrey R. DiMaio

Tetramer Technologies
May 15, 2012

Project ID # FC102

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Overview

Timeline
• Start: June 17, 2011
• End: March 16, 2012
• Phase I Effort Complete: 100%

Budget
• Total project funding
  – DOE share: $150,000
  – Contractor share: $0
• Phase I Funding FY11: $150K

Barriers
• Cost
• Durability
• Performance – stack water management

Partners
• General Motors (Automotive Prototype Membrane Performance Testing)
• Ballard (Non-automotive Prototype Membrane Performance Testing)
• Membrane Technology Research (Module Prototype Production)
## Relevance

Design and develop high performance, low cost water vapor membranes for cathode humidification

<table>
<thead>
<tr>
<th>DOE Barriers</th>
<th>2017 DOE Technical Targets for Cathode Humidifier Membrane</th>
<th>Tetramer 2012-2013 Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>&lt;$10/m²</td>
<td>~ $20/m²</td>
</tr>
<tr>
<td>Durability</td>
<td>5000 hours with &lt; 10% drop in performance</td>
<td>20,000 cycles in GM durability test at 90 °C with a leak rate &lt;150 GPU.</td>
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</tbody>
</table>
| Performance – stack water management | • Operate at >95 °C  
• Pressure differential <75 kPa  
• Water transfer flux =0.025 g min⁻¹ cm⁻² | 20,000 GPU with less than 20% loss projected over 2 years |
## Phase I Approach and Technical Objectives

<table>
<thead>
<tr>
<th>Progress</th>
<th>Objective</th>
<th>Status</th>
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<tbody>
<tr>
<td>100%</td>
<td>Demonstrate water vapor transport membrane with &gt;18,000 GPU</td>
<td>GM has measured membranes demonstrating 18,319 GPU</td>
</tr>
<tr>
<td>80%</td>
<td>Water vapor membrane with less the 20% loss in performance after GM stress test</td>
<td>Demonstrated 11% decrease in permeability after 500 hours of continuous operation</td>
</tr>
<tr>
<td>90%</td>
<td>Crossover leak rate: &lt;150 GPU</td>
<td>Membranes have demonstrated &lt;50 GPU in short term tests</td>
</tr>
<tr>
<td>80%</td>
<td>Temperature Durability of 90 °C to excursions to 100 °C</td>
<td>Test were run at 85 °C and membranes achieved 20,000 cycles</td>
</tr>
<tr>
<td>50%</td>
<td>Cost - &lt;$10/m² at medium volumes</td>
<td>Variable costs depending on polymer structure. Phase I membranes estimated at $20/m²</td>
</tr>
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</table>
## Approach: Technical Tasks

<table>
<thead>
<tr>
<th>% Completion</th>
<th>Tasks</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>95%</td>
<td>Ionomer Membrane Performance Optimization through Improvements in Molecular Architecture</td>
<td>Tetramer has produced over 20 new polymer structures that exceed competition</td>
</tr>
<tr>
<td>40%</td>
<td>Durability Improvement</td>
<td>Demonstrated 21% decrease in permeability after 1,800 hours of continuous operation</td>
</tr>
<tr>
<td>100%</td>
<td>Scale up of High Performance Materials</td>
<td>Multiple samples have been scaled up for testing</td>
</tr>
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Previous Accomplishments -
Improved PEM Performance vs. Nafion® 1000

- Membrane conductivity as a function of relative humidity (RH) for proprietary Generation 1 TT PEM ionomer and Nafion® 1000.
- Fuel cell polarization curve at 150% RH\textsubscript{out} for proprietary TT ionomer membrane and Nafion® 1000.
Results of Different Molecular Architectures During Phase I

- Significant improvements have been made during Phase I to improve gas permeation of water through Tetramer’s proprietary membranes.
  - New molecular architectures were vital towards success.
Phase I Technical Accomplishments -

Generation 1 Water Vapor Membranes

• Generation 1 WVT membranes showed high water vapor gas permeation. These materials exceeded current commercial materials.
Phase I Technical Accomplishments -
Durability of Current Water Vapor Membranes

- Current rate of degradation is currently below the target 2%/500hr target (shown as a red line).
- Tetrramer has identified 7 different methods to reduce the rate of degradation.
Collaborations

Partners

• General Motors (Industry) – Automotive Prototype Membrane Performance Testing

• Ballard (Industry) – Non-automotive Prototype Membrane Performance Testing

• Membrane Technology Research (Industry) – Module Prototype Production
Phase I Summary

**Relevance** – Develop water vapor membranes to enable improved cathode humidification modules.

**Approach** – Develop advanced molecular architectures to increase water vapor transport and durability while decreasing cost.

**Technical Accomplishments** – Demonstrated improved water vapor transport and durability. Improved processing yields to lower overall cost.

**Collaborations** – Partners in place to build and evaluate prototype modules with down selected materials.

**Future Work** – Using structures developed in Phase I, fabricate membranes and optimize tradeoff in performance and durability. Scale up to provide partners with membranes for prototype testing.
Contact Information

Earl Wagener, CEO
earl.wagener@tetramertechologies.com
864.650.0430

Jeffrey DiMaio, Technology Manager
dimaio@tetramertechologies.com
864.903.9009

Brad Morgan, Senior Research Scientist
brad.morgan@tetramertechnooiges.com
864.506.1263