Kettering University Fuel Cell Project

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Kettering University
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## Overview

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Barriers</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Start</strong> – July 2006</td>
<td><strong>Barriers</strong></td>
<td><strong>Bei-Tech</strong> – Polymer Membranes</td>
</tr>
<tr>
<td><strong>Finish</strong> - June 2008</td>
<td>➢ A. Materials and manufacturing costs</td>
<td><strong>Umicore Fuel Cells</strong></td>
</tr>
<tr>
<td><strong>40% Complete</strong></td>
<td>➢ B. Membrane performance</td>
<td>- MEA Development</td>
</tr>
<tr>
<td></td>
<td>➢ C. Water and thermal management</td>
<td></td>
</tr>
</tbody>
</table>

### Budget

- **Total project funding**
  - DOE - $600K
- **Funding received in FY06**
  - $150K
- **Funding for FY07**
  - $300K
- **Funding for FY08**
  - $150K

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# Objectives

| Overall | • Development of Novel Proton Exchange Membranes (PEM) for Fuel Cells  
|         | • Development of CFD porous flow model for PEM fuel cells for improved water and thermal management |
|         | **2006**  
|         | • Low-cost, high-performance membrane  
|         | - Design and Manufacturing Processes  
|         | - Experimental Testing and Performance Validation |
|         | **2007-2008**  
|         | • Low-cost, high-performance membrane  
|         | - Real-time membrane testing for single cell and stack  
|         | - Real-time testing for stability and materials properties  
|         | • Integrated multiphase CFD model for PEM Fuel Cell  
|         | - Complete unit fuel cell performance evaluation  
|         | - Performance evaluation for fuel cell stack |

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Approach

Plan & Approach

- **Task 1: New Fuel Cell Membrane**
  - Literature survey
  - Theoretical analysis and model development
  - Inexpensive materials search

- **Task 2: Chemical modification**
  - Modification of polymer backbone
  - Increased proton conductivity
  - Reduced resistance than peer

- **Task 3: Thermal stability and Water management**
  - Test of water uptake and thermal stability
  - Improved durability and efficiency
  - Test of stable proton conductivity

- **Task 4: CFD multiphase model for PEM fuel cell**
  - Literature survey
  - Developed CFD multiphase mathematical model
  - Developing graphical user interface

90% Completed
80% Completed
70% Completed
40% Completed

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Approach

Approach Overview

- We used novel patented polymer Chain modification process through chemical treatment onto an inexpensive robust polymer backbone

- Patented Polymer backbone modification technology
- New SAS FC Membrane
- Performance Validation

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Accomplishments/Progress/Results

- Membrane’s proton exchange capacity

- Induction time (time required to start proton transfer) is 85% less than Nafion 212
- Higher proton transfer rate than peer membrane (Nafion 212) materials
- Steady proton transfer capacity at higher rate than Nafion 212 for extended period of time
- Very inexpensive membrane materials and easy to manufacture than Nafion 212
Accomplishments/Progress/Results

- Membrane conductivity and resistance

- 80% increased in proton conductivity than peer materials
- 85% increased in induction time
- Very low resistance in per unit area than peer (Nafion 212) materials
- Ability to quickly reach equilibrium state

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Accomplishments/Progress/Results

- **Comparison of membrane quantities**

<table>
<thead>
<tr>
<th>Membrane Type</th>
<th>Maximum protons transfer capacity (moles/min.)</th>
<th>Average protons transfer capacity (moles/min.)</th>
<th>Induction time (min.) (start of proton transfer)</th>
<th>Resistance (ohm-cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nafion 212</td>
<td>1.0515</td>
<td>1.03538</td>
<td>99.931</td>
<td>0.012707</td>
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<tr>
<td>SAS type I</td>
<td>1.8140</td>
<td>1.81175</td>
<td>15.534</td>
<td>0.007261</td>
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<tr>
<td>SAS type II</td>
<td>1.7174</td>
<td>1.71080</td>
<td>30.042</td>
<td>0.007690</td>
</tr>
</tbody>
</table>

- 80% higher proton transfer rate than Nafion 212
- 50% less membrane resistance than Nafion 212
- Less induction time than peer
Accomplishments/Progress/Results

• Membrane Water Uptake

• Experimental test is in progress. We will present this result during poster presentation
Accomplishments/Progress/Results

• Membrane Swelling Measurement

• Experimental test is in progress. We will present this result during poster presentation
## Accomplishments/Progress/Results

- **Membrane Thermal Stability**

  • Experimental test is in progress. We will present this result during poster presentation
Future Work

• Future Work (FY07-FY08)

  • Performance improvement of SAS membrane

    - Apply cross-linking agent to make membrane chemically inert towards reactant gases
    - Test thermal effect and life-cycle sensitivity
    - Map membrane water history

  • Development of integrated CFD porous media multiphase model

    - FEA graphical user interface for unit PEM fuel cell and stack
    - Effect of flow, heat transfer and electrochemistry on fuel cell performance
    - Improve design of single cell and stack
    - Develop 3D surface map for effective control of fuel cell systems
Future Work

- Future Work (FY07-FY08)

  - Explore other avenues for membrane performance enhancement
    - Replace sulfate group with phosphate group for better water management
    - Real-time test of membrane performance with single cell and stack
    - Membrane properties calculations and validation with peers

  - Improve design of unit cell and stack based on CFD modeling results
    - Perform parametric study for design sensitivity analysis
    - Calculation of optimal combination of operating conditions based on CFD surface map
    - Identify water production and management precursors
    - Identify self-humidifying mechanism for effective fuel cells water management

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## Summary

### Project Summary

**Relevance:** Help to develop advanced membrane materials for fuel cell applications

**Approach:** Using patented polymer structure modification technology, develop and experimentally characterize new membrane properties and validated with peers

**Technical Accomplishments and Progress:** Advanced fuel cell membrane manufacturing procedure has been developed. Mathematical formulation for CFD multiphase porous media flow model is completed

**Technology Transfer/Collaborations:** Active partnership with Bei-Tech, Unicore fuel cell, presentations, publication and patents

**Proposed Future Research:** Seek answers by identifying factors limiting PEM fuel cell performance

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Additional Slides 1

- Rate of change of pH in water cell

![Graph showing rate of change of pH in water cell for SAS membrane type I and type II.]

- Concentration of protons (H\(^+\)): 10\(^{-\text{pH}}\)
• Rate of change of pH in water cell

• Concentration of protons (H⁺): 10⁻ᵖᴴ