Fuel Cell Research at the University of South Carolina

John W. Van Zee
University of South Carolina
Columbia, SC

Project ID # FCP8

This presentation does not contain any proprietary, confidential, or otherwise restricted information
Overview

Timeline

• Start - Feb 2007
• Finish – Oct 2008
• Percent complete - 5%

Barriers

• Barriers addressed
  • A - Durability
  • B - Cost
  • C - Performance

Budget

• Total project funding -$2,068,750
  • DOE - $1,655,000
  • Contractor - $ 413,750
• Funding received in FY06 - $0
• Funding for FY07 - $886,607

Partners

• Interactions/ collaborations
  • 14 Companies of NSF I/UCRC Center for Fuel Cells
• DOE H2 Quality Team
• Plug Power
OBJECTIVES

Project 1- Non Carbon Supported Catalysts
- Develop novel materials (e.g., Nb doped) for
  - improved corrosion resistance
  - improved fuel cell components

Project 2 - Hydrogen Quality
- Develop a fundamental understanding of
  - performance loss induced by fuel contaminants
  - durability loss fuel induced by contaminants

Project 3 - Gaskets for PEMFCs
- Develop a fundamental understanding of
  - the degradation mechanisms of existing gaskets
  - the performance of improved materials

Project 4 - Acid Loss in PBI-type High Temperature Membranes
- Develop a fundamental understanding of
  - acid loss and acid transport mechanisms
- Predict performance and lifetime as a function of load cycle
Approach: Project 1: Non Carbon Supported Catalysts

Task 1. Development of Titania-based Non-carbon Supports
   Subtask 1.1 Synthesis of high surface area Nb doped TiO₂
   Subtask 1.2 Synthesis of high surface area Ti₄O₇ supports
   Subtask 1.3 Deposit catalysts – Form electrodes

Task 2. Characterization of the Developed Supports & Catalysts
   Surface and Spectroscopy Methods:
      (BET, Porosimetry, SEM, TEM, XRD, TGA, XPS, XAS)

Task 3. Electrochemical Characterization

Task 4. Corrosion Studies on Developed Supports & Catalysts

Task 5. Stability Analysis of the Loaded Catalysts with ADT
   (ADT = accelerated durability test)

Task 6. Industrial Interaction and Presentations
Approach: Project 2: Hydrogen Quality

Task 1. Group Contaminants by Probable Mechanism
   (Adsorption/Desorption, Reactive, Transport Through MEA)

Task 2. Study Effect of Temperature Distributions (75%)
   Subtask 1.1 Predict temperatures in common cells
   Subtask 1.2 Design new laboratory cells
   Subtask 1.3 Measure temperature distributions

Task 3. Design & Perform Experiments by Mechanism
   Sub Task 3.1 Determine independent adsorption isotherms and rate constants
      (for CO, a marker compound, as agreed by H2 quality team)
   Sub Task 3.2 Extend the methodology to other species

Task 4. Predict Long-term Effects
Task 5. Exploratory Study with ORNL: Intra-PEMFC Sensors
Task 6. Interact with H2 Quality Team
Task 7. Presentations of Results
Approach: Project 3- Gaskets for PEMFCs

Task 1. Selection of Commercially Available Seal Materials. (95 % complete)

Task 2. Aging of Seal Materials
   In simulated and accelerated FC environment
   With and without stress/deformation

Task 3. Characterization of Chemical Stability
   Perform both constant stress & constant displacement tests
   Assess the effect of applied stress/deformation on the rate of degradation
   Measure chemical/thermal stability will be assessed by various

Task 4. Characterization of Mechanical Stability

Task 5. Development of Accelerated Life Testing Procedures

Task 6. Industrial Interaction and Presentations
Approach: Project 4-Acid Loss in PBI-type High Temperature Membranes

Task 1. Exercise Existing Computer Code
(a) over a range of operating conditions
(b) to determine model limitations
(c) to compare predictions/behavior with existing data.
(d) propose experiments required to improve the model

Task 2. Additional Experiments and Model Modification
Subtask 2.1 - transient experiments
Subtask 2.2 - experiments to understand anode phenomena
Subtask 2.3 - experiments designed from model predictions

Task 3. Presentations and Publication
Technical Accomplishments/Progress/Results

Project 1: Supports synthesized – characterization in progress

Project 2: Distributions predicted for lab. cell designs
  • See below
  • Design proposed to minimize temperature gradients

Project 3: Materials selected & companies engaged

Project 4: Experiments designed with Plug Power
  • Start during June 2007
Results: Project 2: Hydrogen Quality- Task 2

Geometry of 50cm$^2$ straight parallel PEMFC

Conventional cell

Ideal cell
Current density distributions of 50cm² straight parallel PEMFCs
(Automotive conditions at 0.6 A/cm²)

Conventional cell

Ideal cell
Conventional cell

Membrane water contents distribution

Hydrogen mole fraction distribution

Oxygen mole fraction distribution

Temperature distribution

Results: Project 2: Hydrogen Quality- Task 2 cont
Fuel flow at anode channel: conventional cell
The effect of manifold width ($l_M$)

Results: Project 2: Hydrogen Quality - Task 2 cont
Current density distributions with variations of manifold width ($l_M$)

$l_M = 4\text{mm}$  $l_M = 8\text{mm}$  $l_M = 12\text{mm}$
The effect of flow direction on current density distribution
Summary- Analysis of Conventional Cell

• The conventional cell showed low performance and severely non-uniform current density distributions.

• The performance was increased and current density distribution became more uniform with an increase of $l_M$ until 8 mm. However, longer $l_M$ did not show increased performance and only slightly increased the uniformity.

• $l_M$ = 8 mm and semi co-flow are proposed for an improved cell. The improved cell shows better performance than the conventional cell and less local current density differences. However, this cell still has non-uniform current density distributions due to non-uniform flow profiles.

• Note: the flow profiles are changed with the electrochemical reactions. Thus, optimization should be performed with simulations that consider electrochemical reactions (i.e., use reactive flow conditions rather than cold flow calculations).
Additional Calculations: Geometry of Optimum Cell

Cathode bipolar plate

Anode bipolar plate
Results: Project 2: Hydrogen Quality- Task 2 cont

Current density distributions at $i=0.6 \text{ A/cm}^2$

Optimum cell

Ideal cell

![Diagram showing current density distributions](image)
Current density distributions at $i=0.2$ A/cm$^2$

Optimum cell

Ideal cell
Current density distributions at $i=1.0\ \text{A/cm}^2$

Optimum cell

Ideal cell
Current density distributions (0.6 A/cm$^2$)

Conventional cell

Improved cell

Optimum cell

Ideal cell
Comparison of Improved & Optimized Cells at 0.6 A/cm²

<table>
<thead>
<tr>
<th></th>
<th>C1(mm)</th>
<th>C2(mm)</th>
<th>l_M(mm)</th>
<th>A1(mm)</th>
<th>V_{cell}(V)</th>
<th>Δi(Acm⁻²)</th>
<th>λ_{avg}</th>
<th>T_{avg}(K)</th>
<th>ΔT(K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Cell</td>
<td>0</td>
<td>0</td>
<td>0.8</td>
<td>0</td>
<td>0.405</td>
<td>1.602</td>
<td>9.57</td>
<td>357.44</td>
<td>12.62</td>
</tr>
<tr>
<td>Improved Cell</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>0.563</td>
<td>0.324</td>
<td>5.065</td>
<td>356.45</td>
<td>4.08</td>
</tr>
<tr>
<td>Ideal Cell</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>0.566</td>
<td>0.304</td>
<td>5.151</td>
<td>356.47</td>
<td>4</td>
</tr>
<tr>
<td>Optimum Cell</td>
<td>8</td>
<td>16</td>
<td>8</td>
<td>8</td>
<td>0.563</td>
<td>0.322</td>
<td>4.969</td>
<td>356.48</td>
<td>4.06</td>
</tr>
</tbody>
</table>

Results: Project 2: Hydrogen Quality- Task 2 cont
Project 2, Task 2 Conclusions

- The optimum cell showed uniform flow profiles and symmetric current density distributions similar to ideal cell, at 0.6 A/cm². However, non-uniform flow profiles which lead to un-symmetric current density distributions were observed at lower and higher current densities. These were mainly caused by different inlet velocities.

- The optimum cell showed similar current density distributions and slightly lower performance than the ideal cell. It showed more uniform flow profiles than improved cell. Also, the optimum cell had significantly higher performance and more uniform current density distributions than conventional cell because optimization of the geometry leads to more uniform flow profiles.
Summary

• Projects just started

• All Projects involve interaction with industry

• Results from Project 2: H2 Quality
  • has implications for existing data and experimental procedures
  • results to be assessed with H2 quality team