High Performance, Low Cost Hydrogen Generation from Renewable Energy

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Project ID #PD071

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Overview

Timeline
- Project Start: Oct 2009
- Project End: March 2011
- Percent complete: 50%

Budget
- Total project funding
  - DOE share: $951,500
  - Contractor share: $237,875
- Funding for FY10
  - DOE share: $634,333

Partners
- Entegris, Inc. (Industry)
- Penn State (Academic)

Barriers
- Barriers addressed
  G: Capital Cost
  H: System Efficiency
  J: Renewable Electricity Generation Integration

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- Penn State (Academic)

Table 3.1.4: Technical Targets: Distributed Water Electrolysis Hydrogen Production

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
<th>2003 Status</th>
<th>2006 Status</th>
<th>2012 Target</th>
<th>2017 Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Cost</td>
<td>$/gge</td>
<td>5.15</td>
<td>4.80</td>
<td>3.70</td>
<td>&lt;3.00</td>
</tr>
<tr>
<td>Electrolyzer Capital Cost</td>
<td>$/gge</td>
<td>N/A</td>
<td>1.20</td>
<td>0.70</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>$/kW</td>
<td>N/A</td>
<td>665</td>
<td>400</td>
<td>125</td>
</tr>
<tr>
<td>Electrolyzer Energy Efficiency</td>
<td>% (LHV)</td>
<td>N/A</td>
<td>62</td>
<td>69</td>
<td>74</td>
</tr>
</tbody>
</table>

Table 3.1.4 Source:
DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program Multi-Year Research, Development, and Demonstration Plan, Updated April 2009
Relevance

Overall Cost of Hydrogen

• Cell stack largest contributor to system cost
  – Flowfields, separators and MEAs drive stack cost
Relevance

Project Objectives

• Improve electrolyzer cell stack manufacturability
  – Consolidation of components
  – Incorporation of alternative materials
  – Improved electrical efficiency

• Reduce cost in electrode fabrication
  – Reduction in precious metal content
  – Alternative catalyst application methods
Top Level Approach

- **Task 1.0: Catalyst Optimization**
  - Control catalyst loading
  - Improve application

- **Task 2.1: Computational Cell Model**
  - Develop full model
  - Flex parameters, observe impact on performance

- **Task 2.2: Implement New, Lower Cost Cell Design**
  - Design and verify parts
  - Production release

- **Task 2.3: Alternative Bipolar Plates**
  - Test material compatibility
  - Fabricate test parts

- **Task 3.0: Evaluation of Flowfield Prototypes**
  - Operate in electrolyzer
  - Compare performance

- **Task 4.0: H2A Model Cost Analysis**
  - Input design parameters
  - Assess impact of changes
## Progress on Milestones

<table>
<thead>
<tr>
<th>Task</th>
<th>Milestone</th>
<th>Progress Notes</th>
<th>Completion</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Demonstrate a Reduced Loading Anode Electrode</td>
<td>Concept design completed</td>
<td>100%</td>
<td>Mar-10</td>
</tr>
<tr>
<td>2.1</td>
<td>Develop a Computational Electrolyzer Cell Model</td>
<td>Model being validated against experimental data</td>
<td>50%</td>
<td>Jan-11</td>
</tr>
<tr>
<td>2.2</td>
<td>Prototype New Cell Design for Production Release</td>
<td>Prototype cell stacks assembled and on test</td>
<td>100%</td>
<td>May-10</td>
</tr>
<tr>
<td>2.3</td>
<td>Design and Prototype Alternative Flowfields</td>
<td>Prototype cell stacks assembled and on test</td>
<td>100%</td>
<td>May-10</td>
</tr>
<tr>
<td>3.0</td>
<td>Use Operational Data to Select Best Candidate</td>
<td>Preparing decision matrix</td>
<td>10%</td>
<td>Jan-11</td>
</tr>
<tr>
<td>4.0</td>
<td>Determine Gas Gallon Equivalency with H2A Model</td>
<td>Compiling cost and efficiency data</td>
<td>10%</td>
<td>Jan-11</td>
</tr>
<tr>
<td>5.0</td>
<td>Final Report to DOE</td>
<td>Composing task level reports after each test</td>
<td>10%</td>
<td>Feb-11</td>
</tr>
</tbody>
</table>
Technical Accomplishments
Task 1.0: Catalyst Optimization

- Demonstrated new alternative application techniques
- Successfully operated prototype MEAs with new catalyst formulation in electrolyzer cells
Relevance

Task 1.0: Catalyst Electrode Performance

• Achieved 55% reduction in loading with no performance loss

![Graph showing catalyst loading test results for 1800 mA/cm², 80°C. The graph includes data points for baseline, 20% loading reduction, and 55% loading reduction, with cell potential on the y-axis and run time on the x-axis.]
Relevance

Task 1.0: MEA Cost Evaluation

- Present program work impact on MEA costs
Technical Accomplishments
Subtask 2.1: Computational Model

- Computational model being validated against test data
Relevance

Task 2.1: Performance Prediction

• Cell component architecture can be refined in light of model predictions for:
  – Current density distribution
  – Electrical potential distributions
  – Volume fraction of water and gases
  – Heat distribution
Technical Accomplishments
Subtask 2.2: Cell Improvements

- New design successfully reduces part count and assembly time while improving cell robustness
- New frames with integrated features qualified and used for prototype cell build
- Prototype flowfields fabricated using production tooling and techniques
Technical Accomplishments
Subtask 2.3: Alternative Materials

• Test wafers imbedded within modified cell parts
• Preliminary results show favorable performance
• Coating is protective when present and continuous
  – Some defects observed before operation
  – Evidence of corrosion observed post operation
  – Corrosion rate not yet fully quantified, microscopic levels
Relevance

Task 2.3: In-Cell Coating Performance

• Maintained stable potential of above 2 Volts for 500 hr test
Relevance
Tasks 2.2 and 2.3: Cell Cost Reductions

- Present program work impact on cell cost
Collaboration

• Partners
  – Entegris (Industry): Demonstrating alternative materials and coating techniques for reduced cost flowfields
  – Penn State (Academic): Developing a full computational model of a functioning electrolyzer cell
  – Oak Ridge National Laboratory: (Federal) Investigating advanced coating materials and deposition techniques (Phase 2)
Future Work

• Task 2.1 Optimize catalyst application process
• Task 2.2 Monitor operational prototype stack
• Task 2.3 Continue long term materials compatibility screening and evaluation of alternative designs
• Task 3.0 Operate various flowfield designs
• Task 4.0 Perform H2A analysis for end design
Future Cell Stack Cost Reduction

- A pathway has been identified to significantly lower cell cost
Resulting Hydrogen Cost Progression

Based on $0.05/kWh electricity

$/kg H₂, H₂A model

- FuelGen65, current stack
- 150 kg/day system, next generation stack
- 150 kg/day system, advanced stack*

*Assumes volumes of 500 units/year
Summary

- **Relevance:** Cost savings at the electrolyzer cell level directly impacts hydrogen production costs
- **Approach:** Reduce cost of largest contributors first
- **Technical Accomplishments:**
  - Catalyst: Demonstrated reduced catalyst loading while maintaining desired electrical performance
  - Flowfield: Reduced part count through integration and elimination of complex subassemblies
- **Collaborations:**
  - Cell Model: Will allow for optimization of components
  - Entegris/ORNL materials: Can provide alternatives to costly metals
- **Proposed Future Work:**
  - Continue development and verification of unitized flowfield architectures