Light-weight, Low Cost PEM Fuel Cell Stacks

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June 2008

Project ID # FCP1

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# Project Overview

## Timeline

<table>
<thead>
<tr>
<th>Start Date</th>
<th>April 2007</th>
</tr>
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<tbody>
<tr>
<td>End Date</td>
<td>October 2009</td>
</tr>
<tr>
<td>% Complete</td>
<td>35%</td>
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## DOE Barriers Addressed

- **B. Stack Cost:**
  Substantially different stack design, materials and assembly

- **C. Performance:**
  Lower W/cm², but higher kW/kg through minimization of stack weight and BOP requirements

## Budget

<table>
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<tr>
<th>Total Funding</th>
<th>$1.06 M</th>
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<tbody>
<tr>
<td>DOE</td>
<td>$846K</td>
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<td>Cost Share</td>
<td>$212K</td>
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<td>FY07 funding</td>
<td>$400K</td>
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<tr>
<td>FY08 funding</td>
<td>$350K (est)</td>
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## Collaborators

Endura Plastics, Inc.
Project Objectives

- Demonstrate edge collected stack design capable of >1 kW/kg (system level)
  - DOE 2010 targets: 2 kW/kg (stack), 650 W/kg (system)

- Develop low cost, injection molded stack components
  - DOE 2010 targets: $25/kW (stack), $45/kW (system)

- Verify stack performance under adiabatic conditions
  - DOE 2010 target: 55% stack efficiency at rated power

- Accelerate stack development by incorporation of multiple cell level sensors within the stack coupled with CFD modeling
B. Cost:
- Known manufacturing processes – printing, injection molding
- Low parts count, easier assembly
- Eliminate costly bipolar plates, GDLs

C. Performance:
- Light weight stack components
- Minimal balance of plant – lower parasitic losses
- Lower W/cm², but higher kW/kg

A. Durability/Reliability:
- Series/Parallel Sub-stacks for higher reliability
- Design allows for membrane expansion with lower stress
- Minimal balance of plant
- No impact on durability issues related to impurities
**Project Summary**

- **Relevance:** Our stack design is intended to significantly reduce materials cost and to promote ease of manufacturing and assembly.

- **Approach:** A combination of molded plastic components and direct fabrication via printing to yield a stack with a very low parts count.

- **Progress:**
  - Single cell testing looks reasonable – could be better
  - Molds being re-worked – sub-stack testing delayed

- **Future Work:**
  - within the next 3 months, fabricate first generation sub-stack
Future Work:

- Continue Single Cell testing
  - Optimize Collector properties
  - Correlate test results with CFD predictions

- Refine CFD model – anode assumptions

- Fabricate first generation sub-stack
  - Combining single cell results with initial molded part weights suggests sub-stack could achieve 1500 W/kg
Go / No-Go Decisions

- G1 – sub-stack to prototype stack
  - at 18 months
  - basis: sub-stack performance >500 W/kg

- G2 – 1 kW stack fabrication
  - at 24 months
  - basis: do prototype stack results predict system level specific power >500 W/kg?
Conventional Bipolar Stacks vs Edge Collected Stacks

**Bipolar**
- minimal iR loss in bipolar plates
- more seals required – gasketing at the cell level
- higher parts count - CCM, GDL, gaskets, plus bipolar plate, plus endplates/tie-rods
- Substantial weight in in-active components
- Thick GDL required to obtained reactant distribution over ribs, significant transport losses in GDL
- significant Compressive force needed to obtain good seals, low resistance interfaces

**Edge Collected**
- iR loss can be significant
- Lower pressure drop possible
- Fewer seals, one gasket can envelop multiple cells
- lower parts count
- Avoids ribbed flow field, much thinner GDL possible
Task 1 and 4
Current collectors and Interconnects

Status:
- Acceptable conductivity, porosity demonstrated
- Hydrophobicity needs improvement (?)
- Long term stability with humidity cycling to be evaluated (summer undergrad project)
- Have not evaluated spray/electro-spray to date – only screen printed inks
Task 1 and 4
Approach

Printed current collectors for edge collection

- Highly conductive
- Strongly adherent
- Porous for reactant transport
- Tailored hydrophobicity/hydrophilicity
- Thinner than conventional GDL (ca. 20 um vs 300 um)
Task 1: Limit On Electrode Length For Edge Collection

\[ L = \left\{ \frac{2\Delta V (t^* \sigma)}{i_{avg}} \right\}^{1/2} \]

- \( \sigma \): conductivity
- \( \Delta V \): voltage loss
- \( t \): collector thickness
- \( L \): collector length

Allowable Current Collector Length for 10 mV loss

- \( I_{avg} = 0.1 \text{ A/cm}^2 \)
- \( I_{avg} = 0.2 \text{ A/cm}^2 \)
- \( I_{avg} = 0.4 \text{ A/cm}^2 \)

Target for this project:
- 40 um thick, 25,000 S/cm
Task 1: Technical Results

Printed Current Collectors / Interconnects

- Silver based ink – 27,000 S/cm
- Vias laser drilled – 1 mm dia., 6 vias spaced evenly over 1 cm width
- Resistance = 0.009 ohm

![Graph showing the relationship between current (I) and voltage (E)(Volts).]
Task 2
Gaskets

Status:

- Seal problems have been an issue in single cell tests, and sub-stack flow testing
- Intent for some sub-stack and stack fuel cell tests is to ultrasonically weld the assembly – eliminating the need for tie-bolts and gaskets – but this will prevent convenient disassembly
Task 3
Surface Tension Controlled Microfluidics

Status:

- Task set aside early in project
  - Student not available
  - Performance of early trials too far off projections to be viable for first generation tests
Task 5
CFD modeling

Status:

- Single cell simulations
  - Cathode kinetics, water transport, membrane conductivity included
  - Anode kinetics ignored
- Predict current density variations for
  - Different inlet humidities
  - Different inlet flow rates
  - As a function of overall current density
- Single Cell Fuel Cell testing on-going using similar conditions
Task 5
CFD modeling

Example Results:

Dry Air at 2.5X stoich
100%RH H₂
Avg. c.d. = 0.47 A/cm²
Bottom half of cell is saturated, constant current density
Task 5

CFD modeling

Issues:

- Anode side is averaged over inlet/outlet conditions ala Springer – cannot currently evaluate co- vs counter-flow effects
- Water transport through printed current collectors has not been well characterized.
Approach

Sensor Integration for Rapid Design Evaluation

• Sub-stack design permits access to gas space above each cell
• Temperature, humidity, gas composition can be monitored
• Current collector can also be segmented to allow for measurement of local potentials
• Results used to evaluate/enhance CFD models
1. Task 6
Design and Fab of Molded Parts

- 1st run – 11/16/07. High levels of stress – significant warpage when raised to operating temperature
- 2nd run – 12/7/08. Lower residual stress. Annealing at 88C relieves stress, part remains flat at operating temperature
  - inlet/outlet ports still not acceptable
  - Incorrect placement of through hole
- Production with re-designed mold originally scheduled for mid-Feb has been delayed until May
Approach

Generation 1a design with modified bolt hole location and inset molded inlet/outlet tubes

Light Weight, Low-Cost PEM Fuel Cell Stacks
DOE Review June 2008
Approach

Exploded View of Short stack consisting of 3 sub-stacks
Approach

Conceptual View of Short Stack with Molded Manifold End Cap
Approach

View w/o End Cap showing contact tabs and reactant ports
Task 7
Fuel Cell Testing

- Single cell testing in progress
  - Effects of temperature, reactant flow rates and humidities
  - Evaluation of current collector inks in fuel cell environment
  - Evaluation of metallization options at the ends of a sub-stack
  - New graduate student was added to take over this area in mid-Jan
Task 7
Fuel Cell Testing

Single Cell Test
Gore CCM with CWRU GDL
50°C,
H₂ / Air
atmospheric pressure
Constant reactant flow
5 mV/s sweep
Power Density
= 0.3 W/cm²

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