Light-weight, Low Cost PEM Fuel Cell Stacks

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Project ID# FCP19

May 2007

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Project Overview

DOE Hydrogen Program

Timeline

Start Date: April 2007

End Date: April 2009

% Complete: <5%

DOE Barriers Addressed

Stack Cost:
Substantially different stack design, materials and assembly

Performance:
Lower W/cm^2, but higher kW/kg through minimization of stack weight and BOP requirements

Budget

Total Funding: $1.06 M
DOE: $846K
Cost Share: $212K
FY07 funding: $300K (est)

Collaborators

Endura Plastics, Inc.

Lead Investigators

DOE Hydrogen Program

- <u>Case Western Reserve University</u>
- Jesse Wainright, Assoc. Res. Prof., ChemE
- Gary Wnek, Professor, Macrom. Sci.
- C. C. Liu, Professor, ChemE
- Vladimir Gurau, Sr. Research Assoc., ChemE
- Tom Zawodzinski, Professor, ChemE

- <u>Endura Plastics Inc.</u>
- Mark DiLillo, President
- Martin Klammer, Engineering Manager

Endura Plastics Inc.

DOE Hydrogen Program

Sub-contractor under CWRU

- Located in Kirtland OH
- specializes in the design, manufacture and assembly of critical safety products such as low pressure air sensing switches for the HVAC industry, automotive brake reservoir assemblies and precision medical components.

Role in this project:

- materials selection for the molded components
- mechanical and manufacturing analyses of the molded components
- design and selection of the tooling and molds, and molding processes required
- manufacturing and assembly of the molded components

Project Objectives

DOE Hydrogen Program

- 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
- Develop direct humidification scheme based on printed 2D microfluidics
- Develop optimized printable current collectors for edge collection
- Accelerate stack development by incorporation of multiple cell level sensors within the stack coupled with CFD modeling

DOE Technical Barriers Addressed

DOE Hydrogen Program

Cost:
- Known manufacturing processes – printing, injection molding
- Low parts count, easier assembly
- Eliminate costly bipolar plates, GDLs
-

Durability/Reliability:
- Parallelled 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

Performance:
- Light weight stack components
- Minimal balance of plant – lower parasitic losses
- Lower W/cm^2, but higher kW/kg

Air Management:
- Ambient pressure operation – eliminate compressor/expander

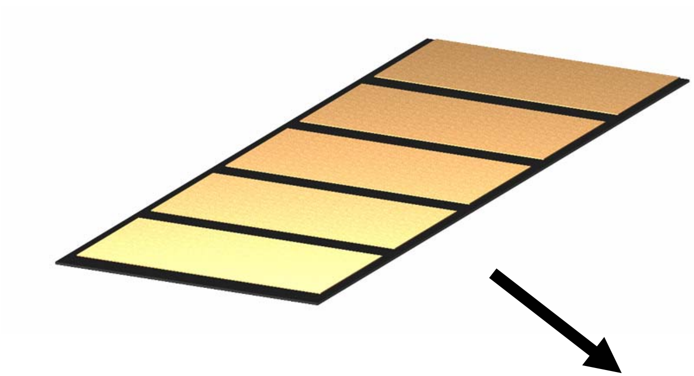
Approach

- **Edge Collection of Current – no bipolar plates**
- **Current collector/GDL deposited directly on CCM**
- **Molded housings for sub-stack**
  - Series electrical connection between cells
  - Reactant manifolds and seals
  - STCM humidification paths printed on housing
- **Molded housings to join sub-stacks into stacks**
  - Parallel electrical connection of sub-stacks
  - Manifolds
- **Adiabatic Operation**
  - Low pressure – no compressor/expander
  - Direct humidification of CCM (anode side)
  - No cooling plates or radiator, but requires a condenser

Approach

DOE Hydrogen Program

Printed current collectors for edge collection



- Highly conductive
- Porous for reactant transport
- Tailored hydrophobicity/hydrophilicity
- Thinner than conventional GDL (ca. 20 um vs 300 um)

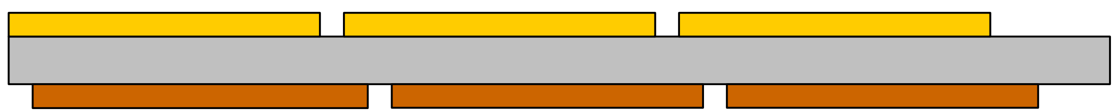
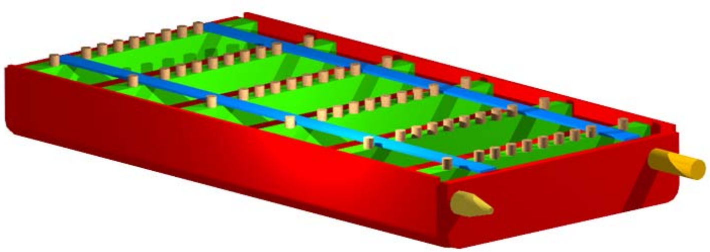


Figure 2 – side view of membrane with top and bottom current collectors visible. Note that the current collectors are staggered to allow for subsequent series connection of the cells. Catalyst layers not shown.

Approach

Conceptual drawing of ½ of a molded substack housing



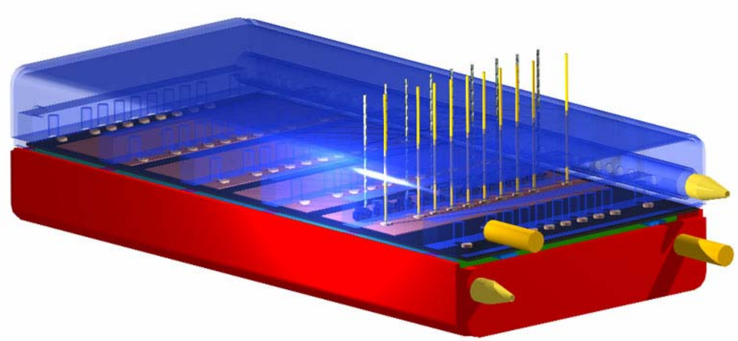
Drawing not to scale

Key Components:

- microfluidic pathways
- intercell electrical connections
- reactant manifolds
- molded as one piece, with subsequent printing of gaskets and microfluidic pathways

Approach

Sensor Integration for Rapid Design Evaluation

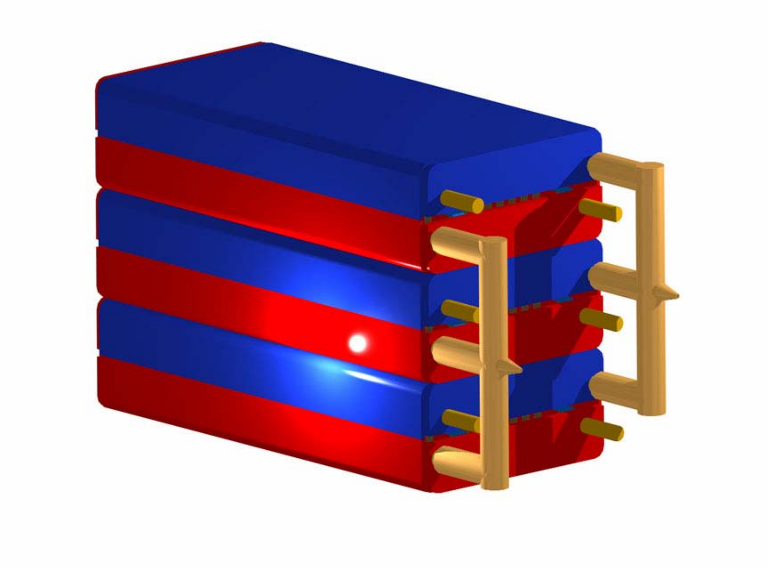


- Sub-stack design permits access to gas space above each cell
- Temperature, humidity, gas composition can be monitored
- Current collector can also be segmented to allow for measurement of local potentials
- Results used to evaluate/enhance CFD models

Approach

DOE Hydrogen Program

Sub-stacks are grouped into stacks with additional molded components

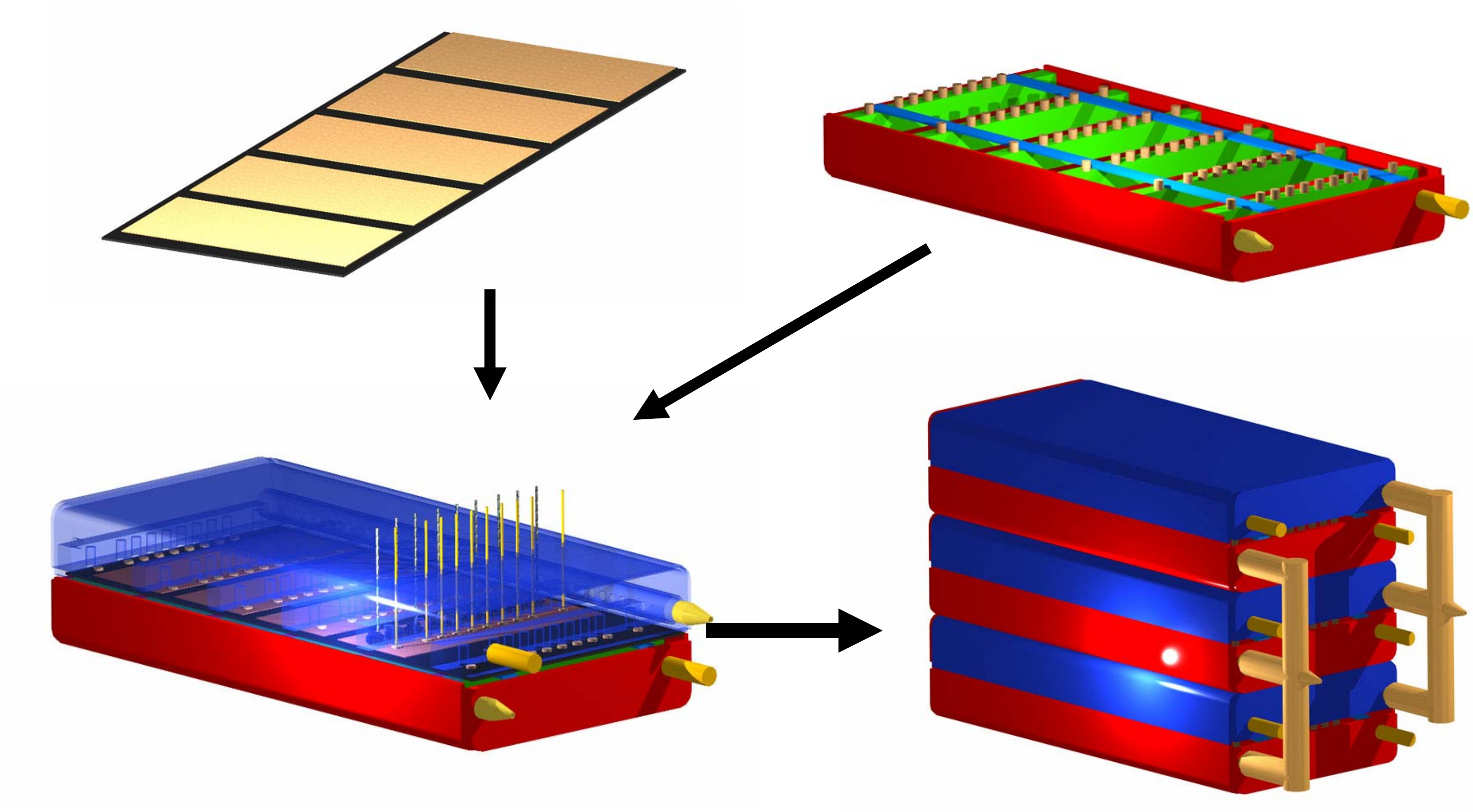


End-cap housings provide:

- Parallel or series connection between sub-stacks – reconfigurable to meet power requirements
- Reactant manifolding

Approach

DOE Hydrogen Program



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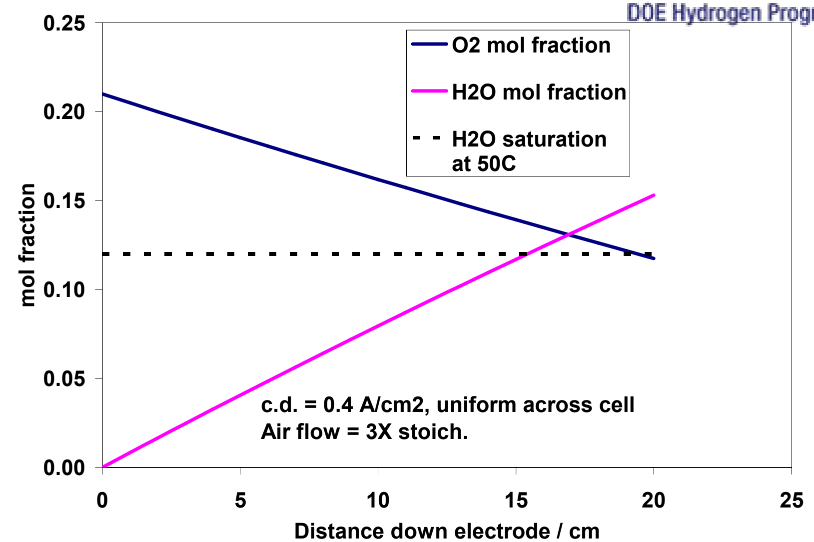
Technical Results

DOE Hydrogen Program

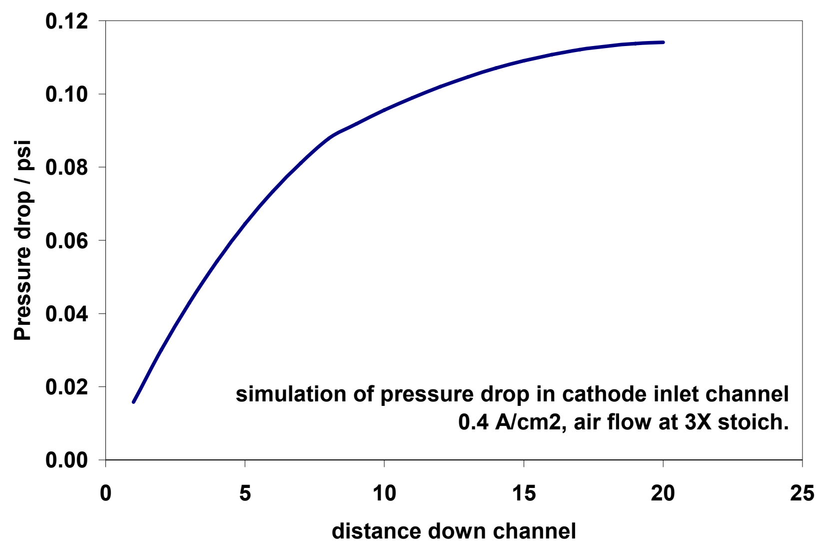
Modeling of the Air Plenum

Sub-stack size can be limited by:

- Pressure drop
- H_2O build up and condensation
- O_2 depletion



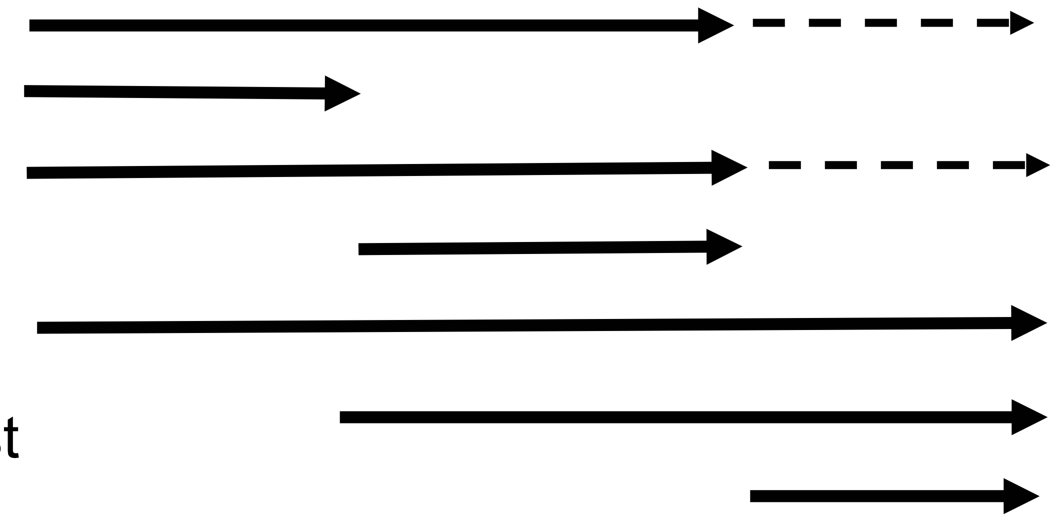
- Results to date suggest that H_2O build-up and pressure drop are the dominant concerns. This result is:
  - independent of boundary layer thickness
  - strongly dependent on temperature



Timeline – Phase I – Materials/Process Development and Sub-stack Prototype

DOE Hydrogen Program

- Task 1 2/3 4/5 6/7 8/9 mo.
- Collectors
- Gaskets
- STCM
- Interconnects
- CFD Model
- Molded Parts
- Sub-stack test

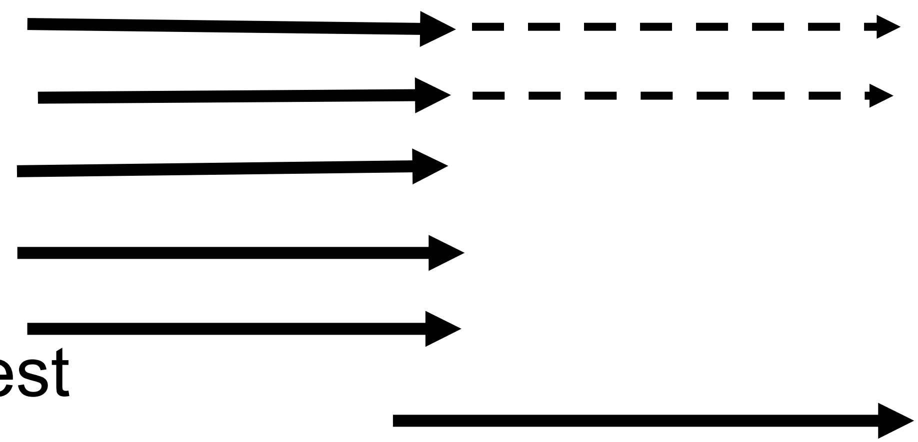


- Each of the first 6 tasks has an associated milestone at month 6 for recommended materials/processes/designs for fabrication of the 1st Generation sub-stack.

Timeline – Phase II
Sub-stacks into Stacks

DOE Hydrogen Program

- Task 10/11 12/13 14/15 16/17 18 mo.
- Collectors
- STCM
- CFD Models
- Stack Design
- Sub-stack fab/test
- Stack fab/test



- Each of the first 3 tasks has milestones for recommendations for the 2nd Gen. sub-stack (mo. 11) and for the 1 kW stack (mo. 18)

Timeline – Phase III – 1 kW stack

DOE Hydrogen Program

- Task 19 20 21 22 23 24
- Design (months 19–20)
- Fab/
- Assembly (months 20–23)
- Testing (months 23–24)
- Milestone: 1kW stack to be delivered to DOE at 24 mo.

Go / No-Go Decisions

- G1 – sub-stack to prototype stack
- at 14 months
- basis: sub-stack performance >500 W/kg

- G2 – 1 kW stack fabrication
- at 18 months
- basis: do prototype stack results predict
- system level specific power >500 W/kg?

Project Summary

DOE Hydrogen Program

- 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: Project started 4/07
  - Modeling of the sub-stack has begun
- Collaborators: CWRU and Endura Plastics, a custom molding company
- Future Work: within the next 4 months, develop material and size specifications for the first generation sub-stack