Light-weight, Low Cost PEM Fuel Cell Stacks

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Project Overview

DOE Hydrogen Program

Timeline

Start Date: April 2007

End Date: October 2009

% Complete: 35%

DOE Barriers Addressed

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

C. 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: $400K
FY08 funding: $350K (est)

Collaborators

Endura Plastics, Inc.

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
  - 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

DOE Technical Barriers Addressed

DOE Hydrogen Program

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/cm^2, 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

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:
  - 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:

DOE Hydrogen Program

- 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

DOE Hydrogen Program

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

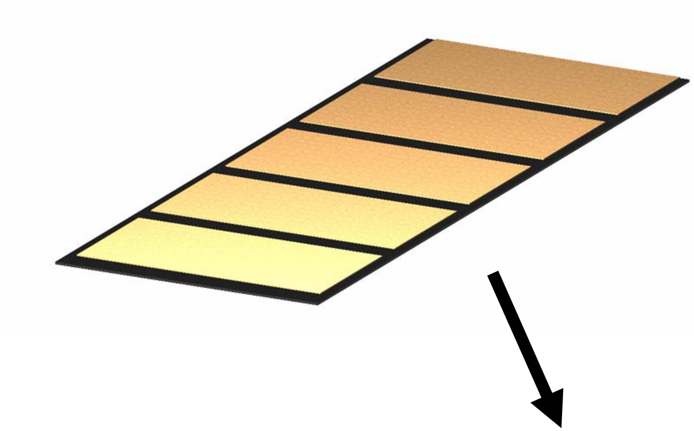
Status:

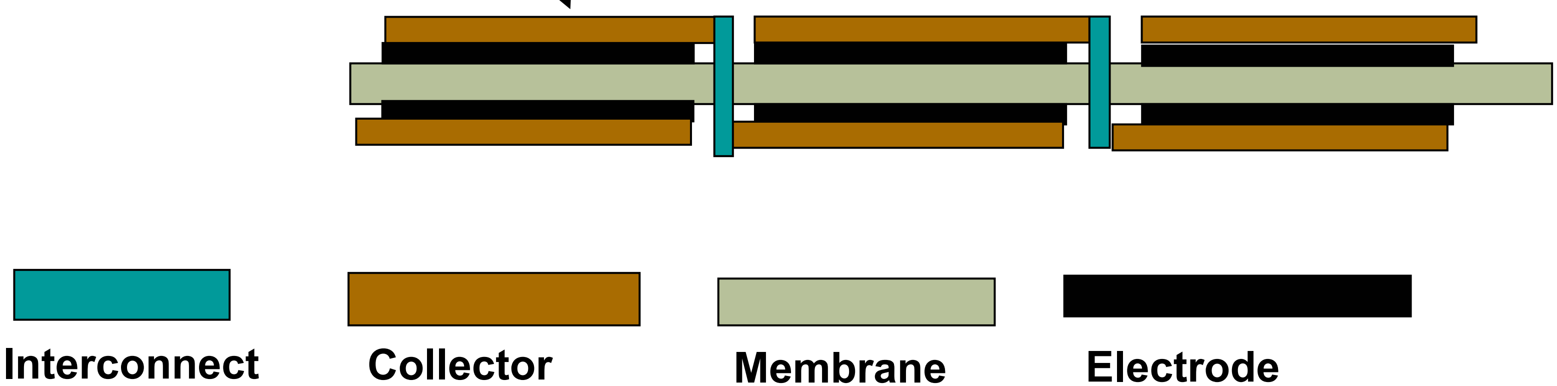
- Acceptable conductivity, porosity demonstrated
- Hydrophobicity needs improvement (?)
- Long term stability with humidity cycling to be evaluated (summer undergrad project)
- Have not evaluated spray/electro-spray to date – only screen printed inks

Task 1 and 4 Approach

Printed current collectors for edge collection

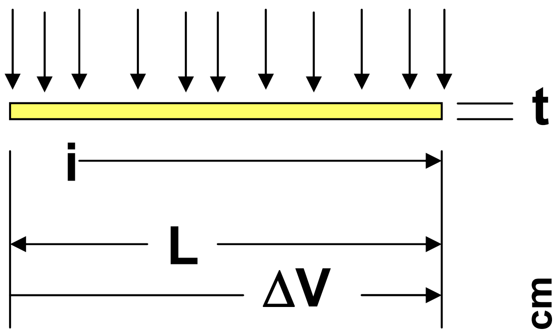
- Highly conductive
- Strongly adherent
- Porous for reactant transport
- Tailored hydrophobicity/hydrophilicity
- Thinner than conventional GDL (ca. 20 um vs 300 um)





Task 1: Limit On Electrode Length For Edge Collection

DOE Hydrogen Program



$$L=\{2\Delta V(t^*\sigma)/i_{avg}\}^{1/2}$$

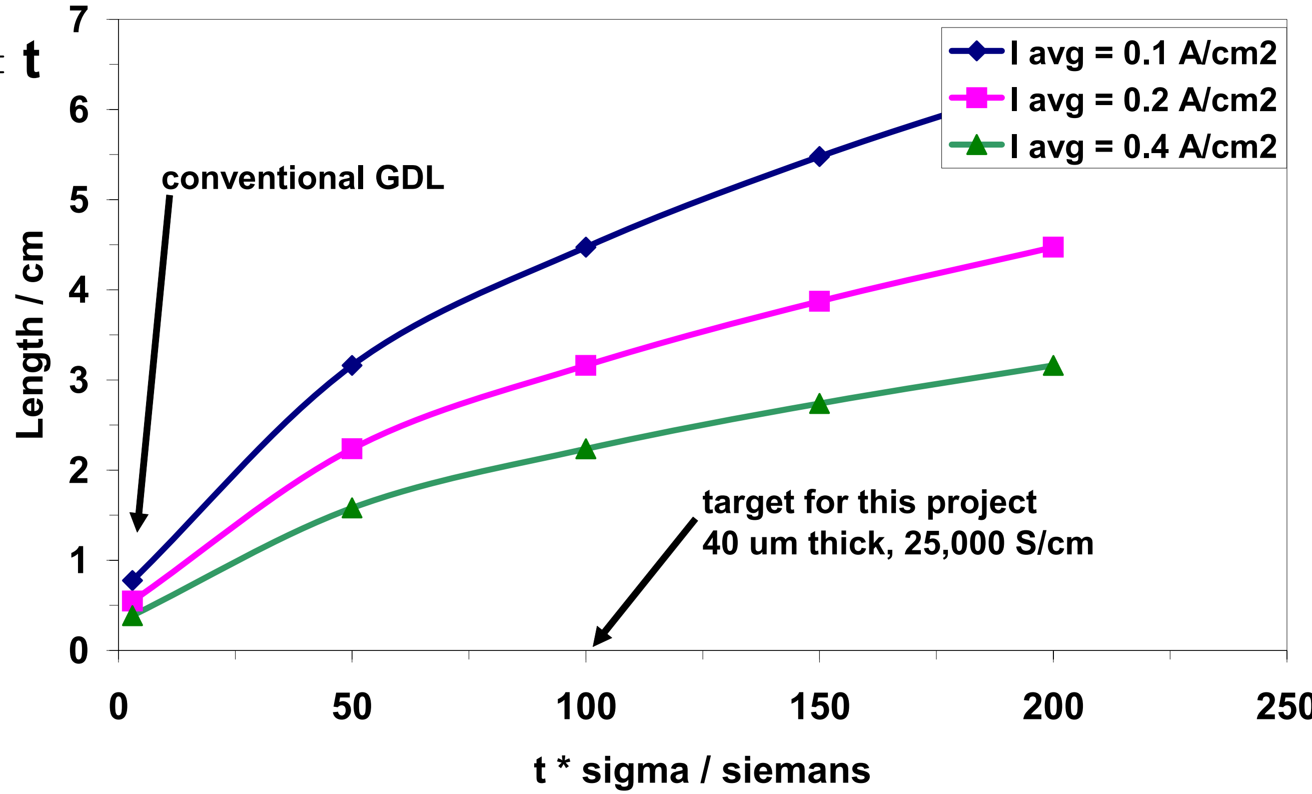
σ - conductivity

ΔV – voltage loss

t – collector thickness

L – collector length

Allowable Current Collector Length for 10 mV loss

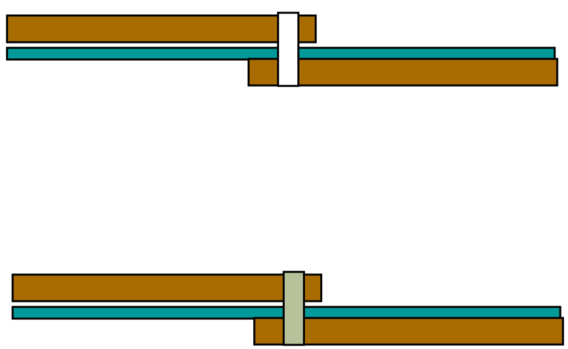


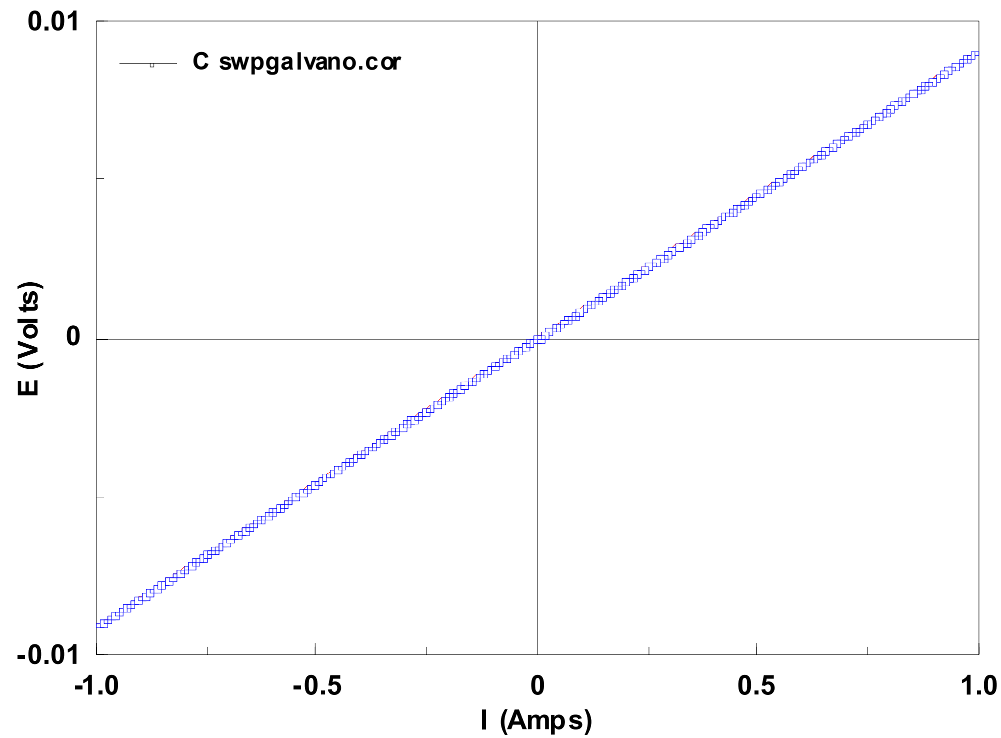
Task 1: Technical Results

DOE Hydrogen Program

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





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

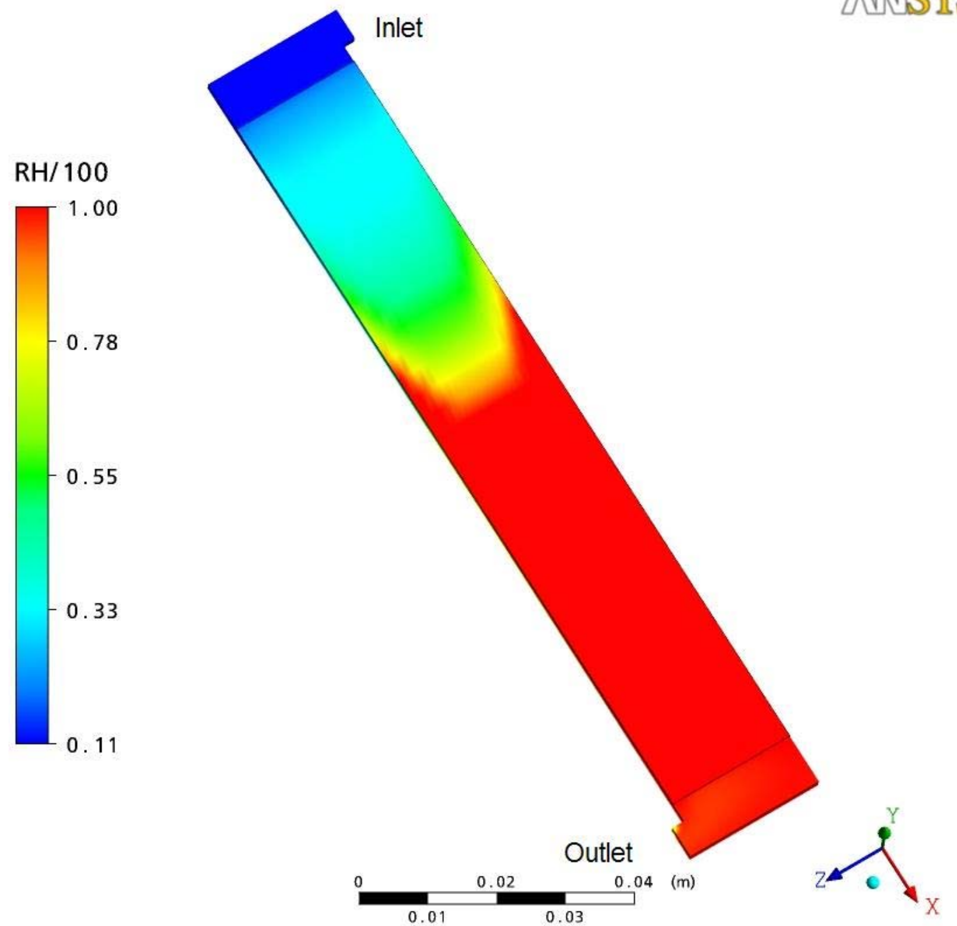
Example Results:

Dry Air at 2.5X stoich

100%RH H_2

Avg. c.d. = 0.47 A/cm^2

Bottom half of cell is saturated, constant current density



Task 5
CFD modeling

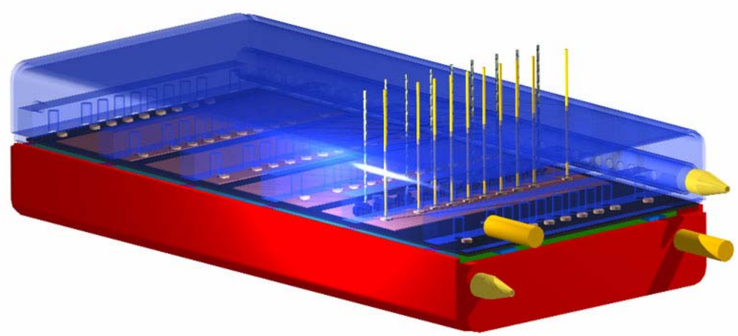
Issues:

- 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

DOE Hydrogen Program

Sensor Integration for Rapid Design Evaluation

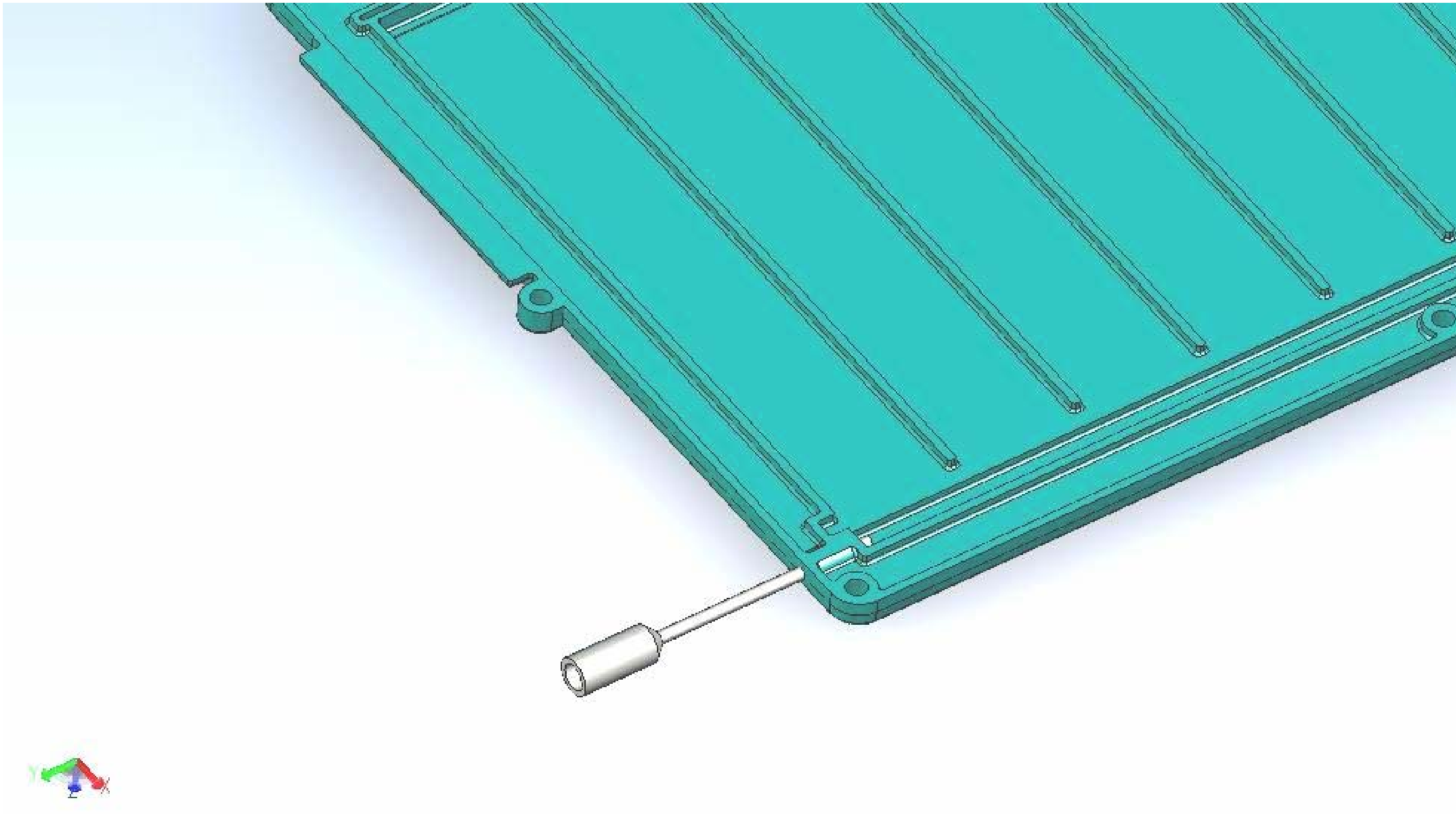


- Sub-stack design permits access to gas space above each cell
- Temperature, humidity, gas composition can be monitored
- Current collector can also be segmented to allow for measurement of local potentials
- Results used to evaluate/enhance CFD models

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

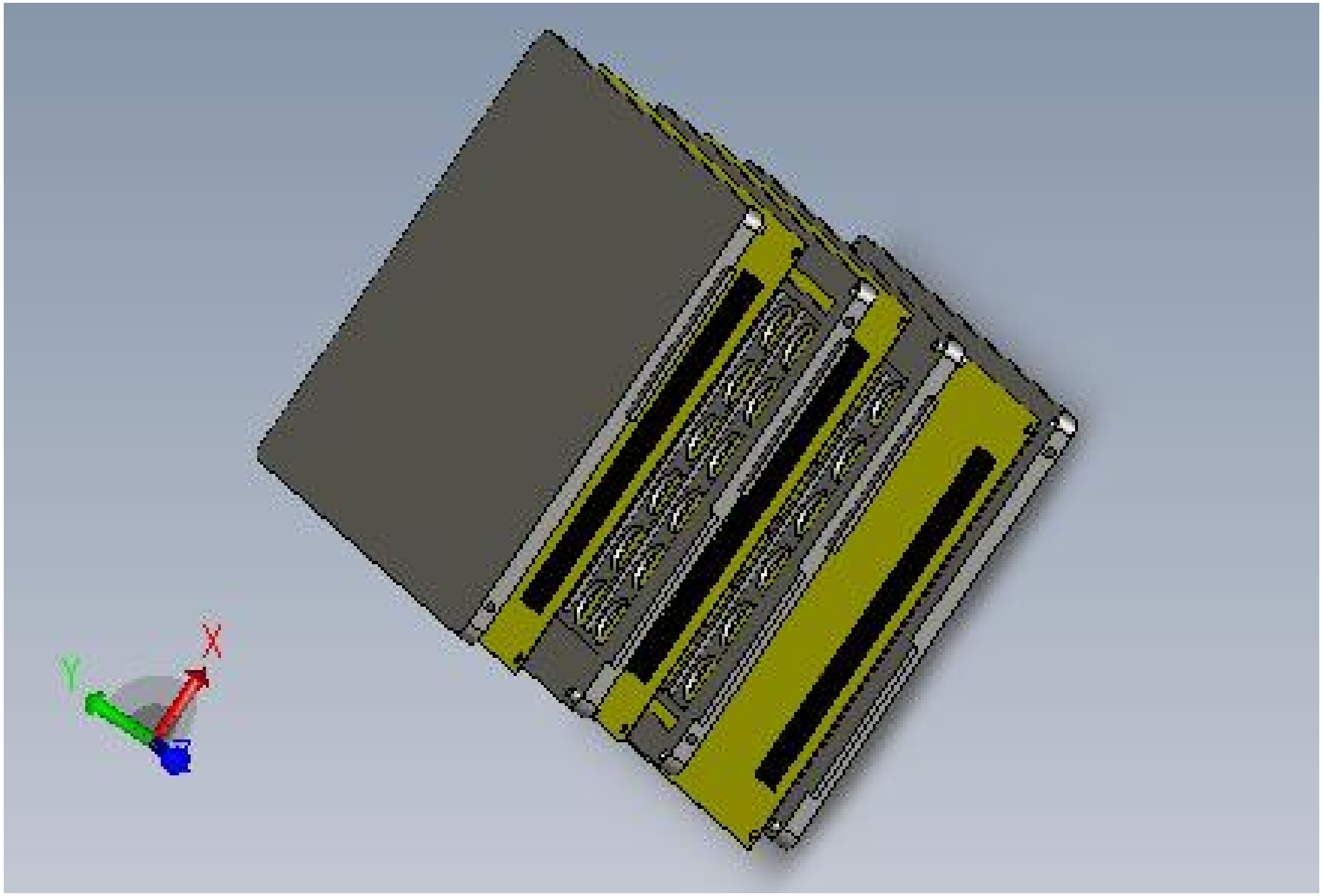
Approach



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

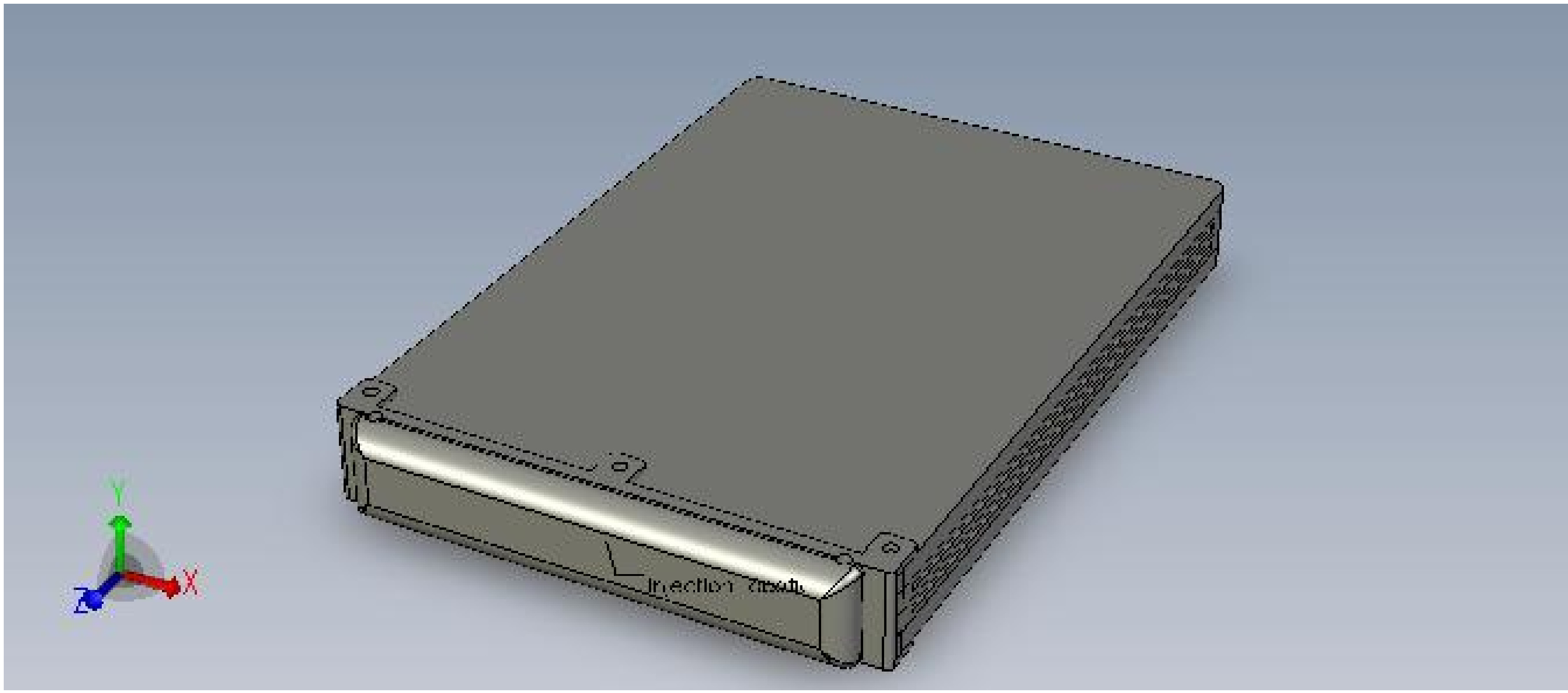
Approach

Exploded View of Short stack consisting of 3 sub-stacks



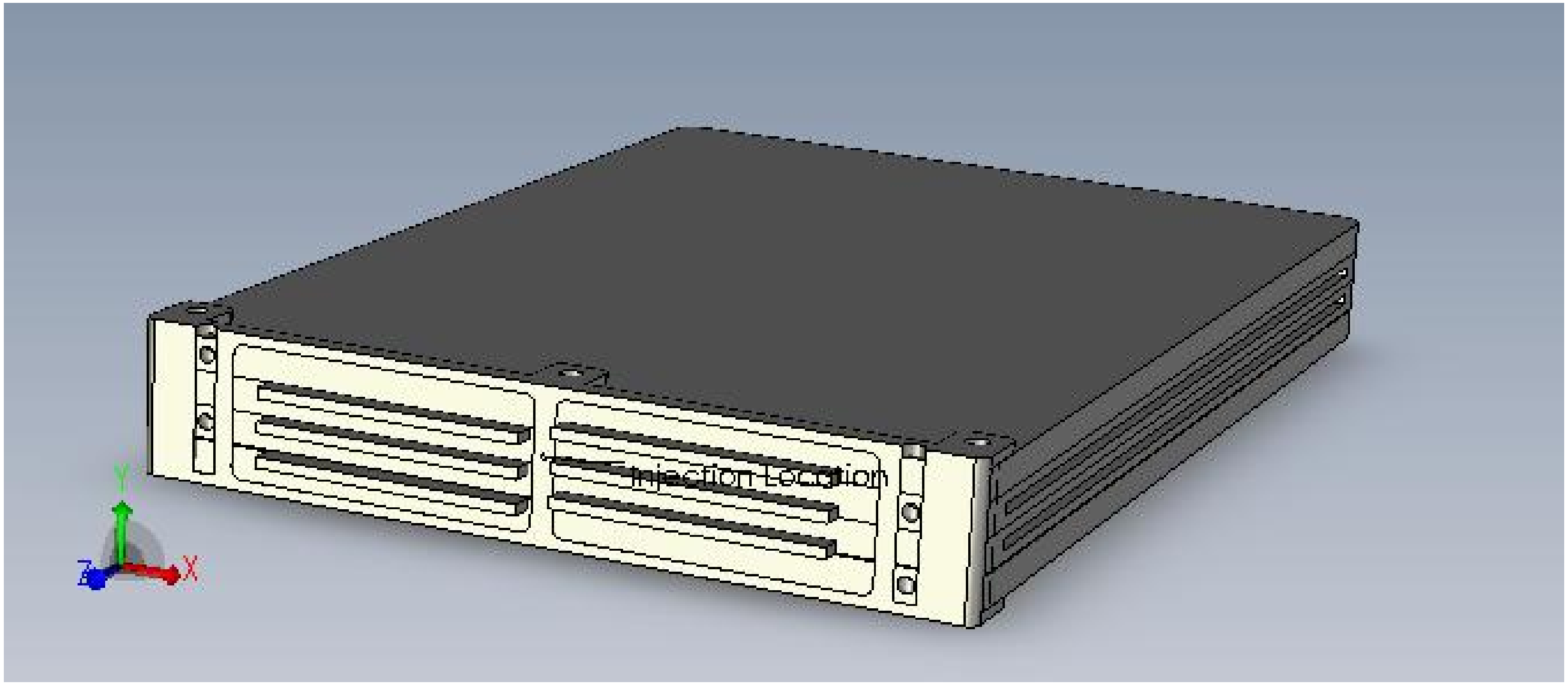
Approach

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

50C,

H_2 / Air

atmospheric pressure

Constant reactant flow

5 mV/s sweep

Power Density

= 0.3 W/cm^2