DOE Hydrogen Program

2013 DOE Hydrogen and Fuel Cells Program Review

Corrugated Membrane Fuel Cell Structures

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Ion Power, Inc (Prime)

GM & GrafTech (Sub-Contractors)

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This presentation does not contain any proprietary or confidential information

Project ID # FC090

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Overview

DOE Hydrogen Program

Timeline

- Start: Sept 1, 2010
- End: Feb 28, 2014
- 60% Complete

Budget

- Total project funding
  - DOE share $1,651,616
  - Contractor share $507,096
- DOE Funding received in FY12: $300,000
- DOE Funding planned in FY13: $130,873

Barriers

A: Costs

- Lower Metal GDL cost
- Lower Plate/GDL manufacturing costs

B: Performance

- High power density with low Pt loaded MEAs

Partners

- Interactions/ collaborations
  - ➢ General Motors
    Testing and Modeling
  - ➢ GrafTech
    Graphite components
  - ➢ GKD/Dexmet
    Metal screens
- Project lead
  - ➢ Ion Power

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Objectives

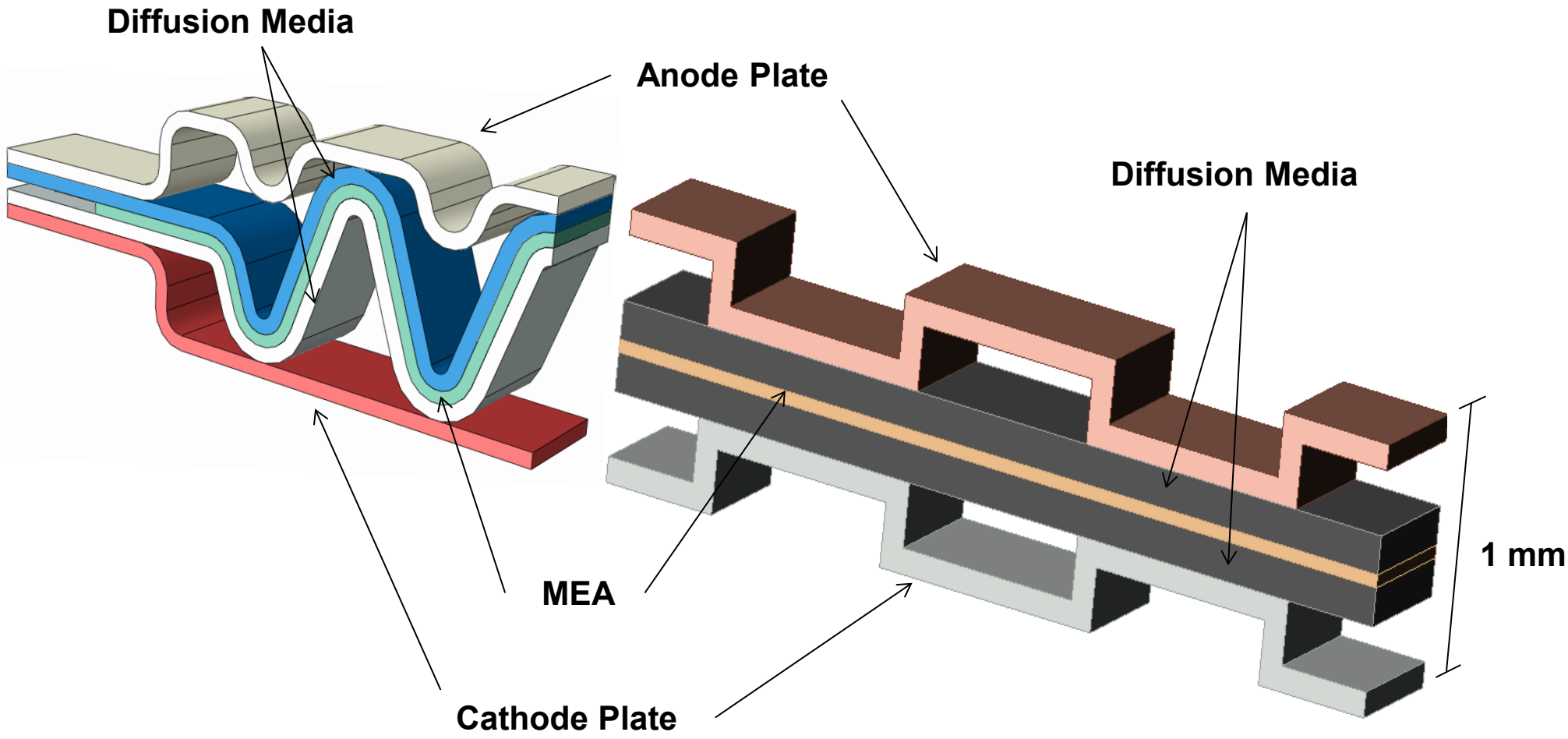
To pack more membrane active area into a given geometric plate area, thereby allowing both targets of power density and platinum utilization to be achieved

- To demonstrate a fuel cell single cell (50 cm^2) with a 2-fold increase in the membrane active area over the geometric area of the cell by corrugating the MEA structure
- Incorporation of an ultra-low Pt loaded corrugated MEA structure in a 50 cm^2 single cell that achieves the DOE 2015 target of 0.2 gram Pt/kW, while simultaneously reaching the power density targets:
  - 1 W/cm^2 at full power
  - 0.25 W/cm^2 at ¼ power

Objectives

Comparison of Convoluted Cell and Conventional Cell

The thickness of each cell is 1 mm, but the convoluted cell has twice the membrane area of the conventional cell



Objectives: Tasks and Milestones

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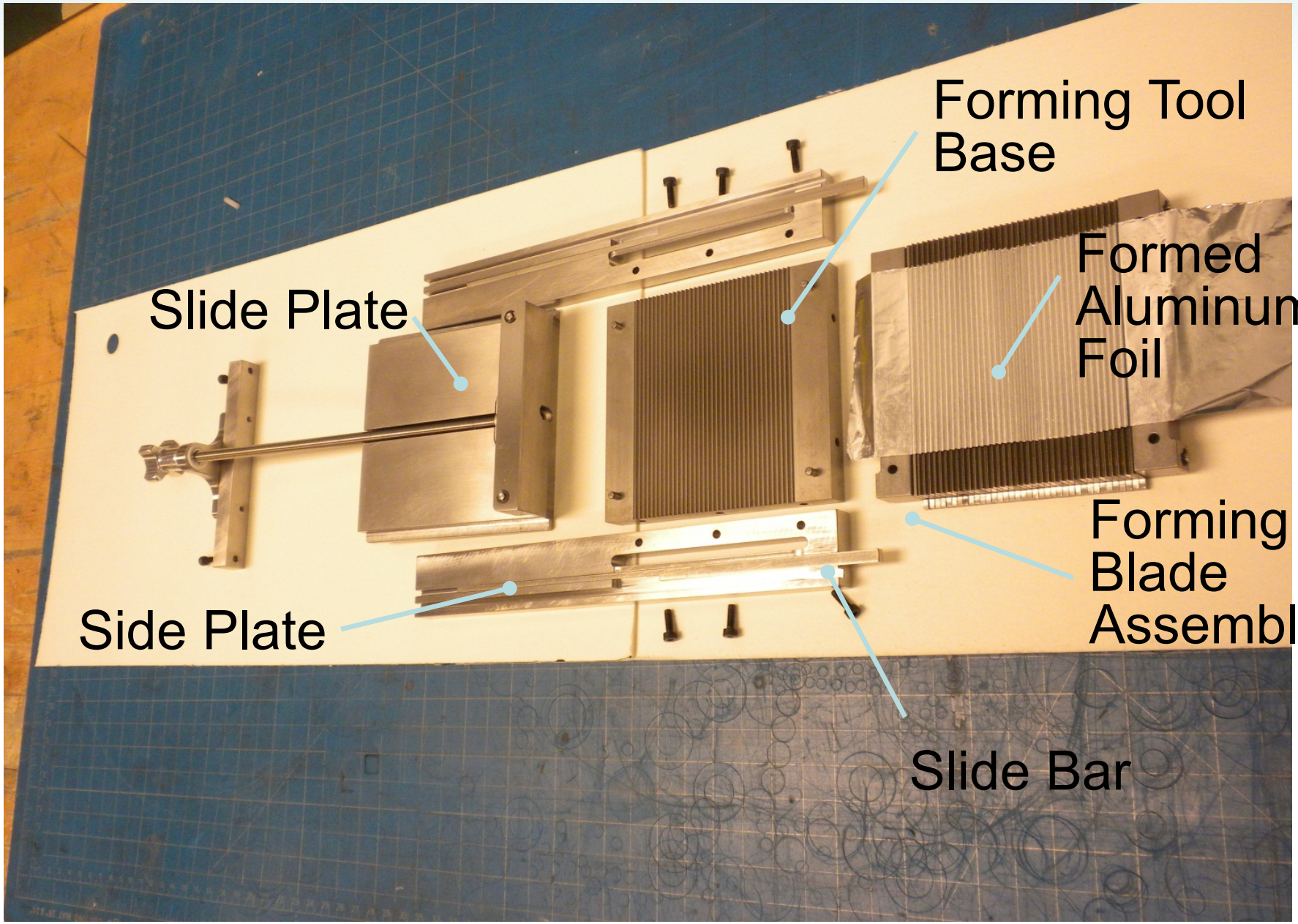
Task Number	Deliverable	Due Date	Percentage Complete	Progress Notes
GM 1.1	50 cm^2 jig designed and built	11/30/2011	100%	Completed
1.2	Both flat and corrugated seals for 50 cm^2 jig	2/28/2013	80%	Ion Power is working with GM to secure this.
1.3	**MILESTONE Year 1:** Test jig baseline equal or exceeding GM cell performance	1/31/2013	80%	Test has been run, further tests needed for confirmation
GrafTech 2	Grafoil® corrugated GDL plate subassembly, with resistance <10 mOhm-cm^2 at any compressive force >20 psi	12/21/2012	50%	Ion Power is having challenges with this material.
Ion Power 3	Provide method for making metal corrugated GDL plate sub-assemblies, with resistance <10 mOhm-cm^2 at any compressive force >20 psi	2/28/2013	90%	High degree of screen strength-welding may not be necessary.
3.1	Down-select most promising metal corrugated GDL plate sub-assembly	5/30/2013	100%	Completed
4	Membrane incorporation into the corrugated GDL plate sub-assembly	5/31/2013	60%	This is Ion Power's primary focus
4.1	Flat MEA Spray or Coating	7/30/2013	60%	On Hold
2, 3 & 5	**Go/No-Go Decision:** Successful test of a corrugated fuel cell single cell; meeting a minimum power density of 70 mW/cm^2 at 0.8V	8/31/2013	70%	

Technical Accomplishments

Forming Fixtures

Completed Membrane Forming Tool



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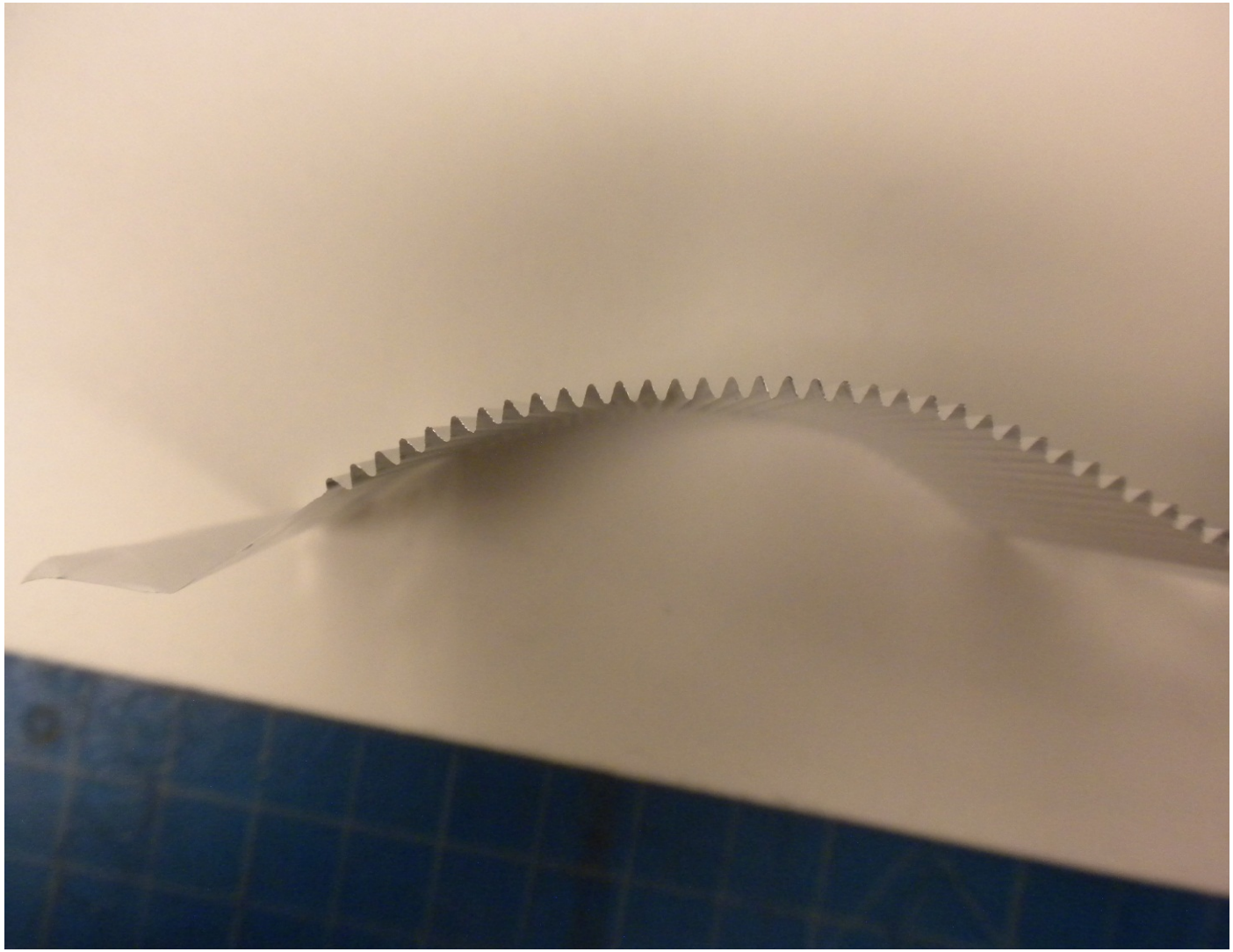
Side View of Convolutions in Formed Aluminum Foil



Technical Accomplishments

3D Finite Element Analysis (FEA)

Thermal, Structural, and Electrical Analyses of the Corrugated Structure were performed to ensure feasibility of the design

FEA Structural & Thermal Analysis

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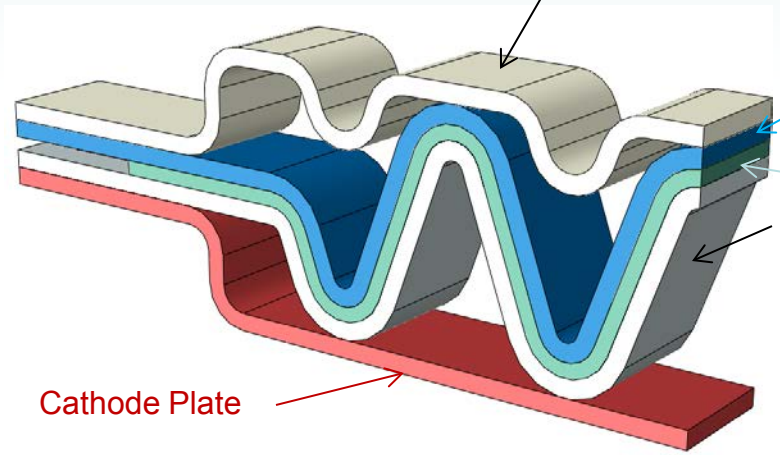
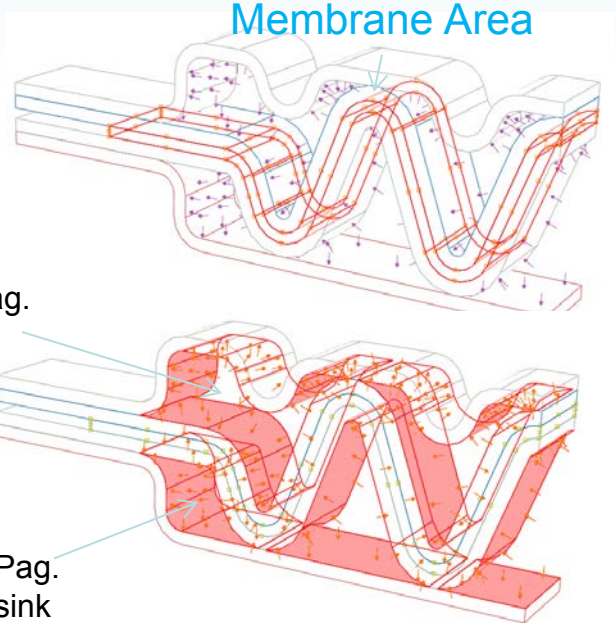
Geometry



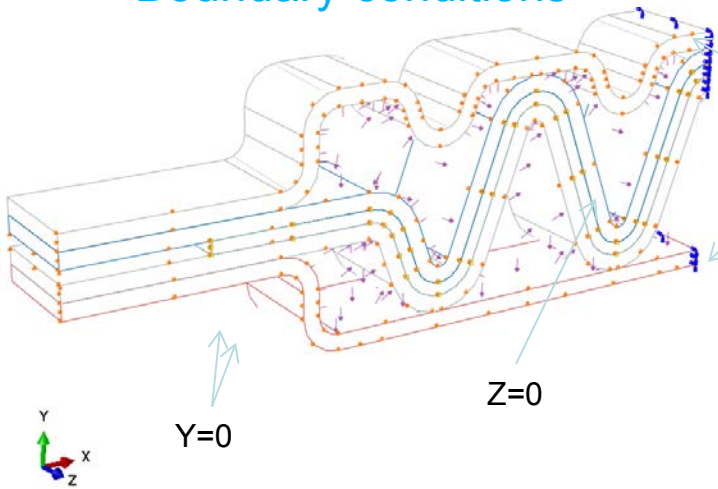
Heat generation = 0.69 W/cm^2 Membrane Area



Anode pressure = 200 kPag.
Convection h=10 W/m^2 C,
sink temperature = 80C

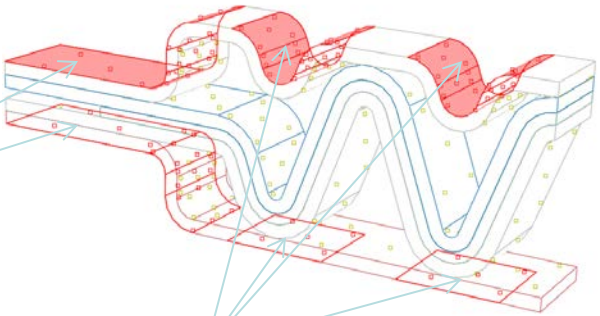
Cathode pressure = 200 kPag.
Convection h=50 W/m^2 C, sink
temperature = 80C

Boundary conditions



Symmetry
YZ plane

Ambient :
Convection h=5 W/m^2 C,
sink temperature = 30C



Coolant :
Convection h=2000 W/m^2
C, sink temperature = 80C

This geometry was used for the analysis.

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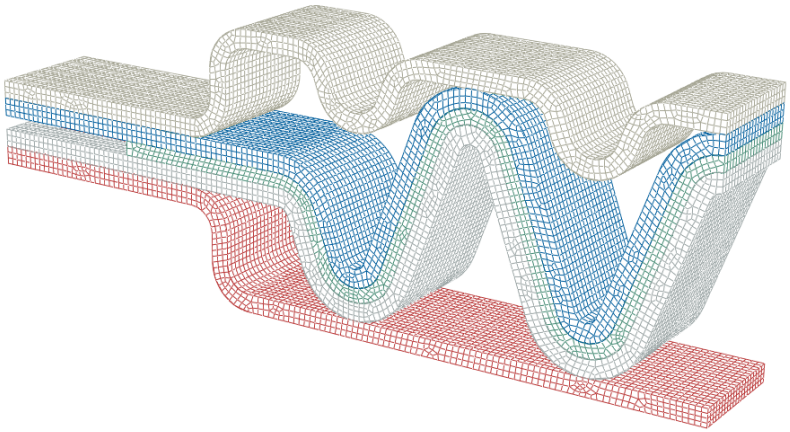
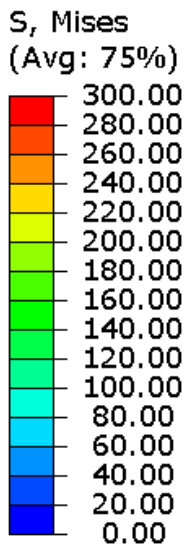
FEA Structural & Thermal Results

How much mechanical and thermal stress is the structure under?

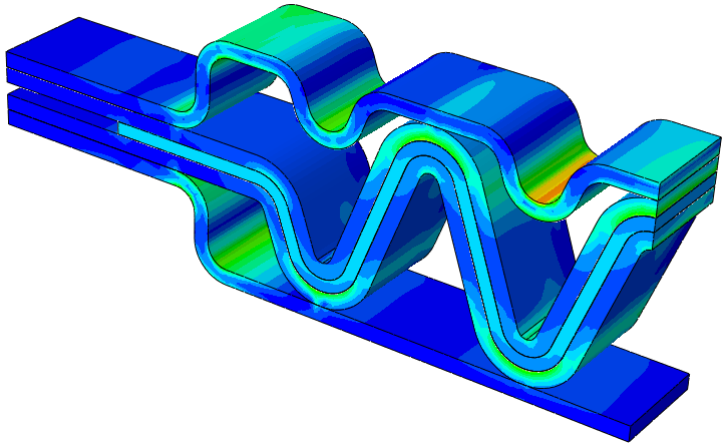
Mesh: Hex elements

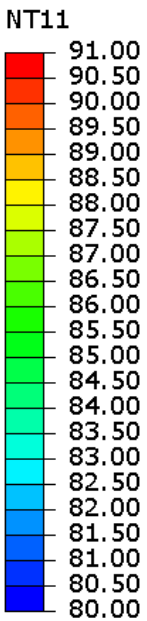


Based on this thermal FEA analysis, and GM's system cost analysis, the cell will need to be run at a lower current density (1.2 A/cm^2 max) regime to avoid membrane overheating

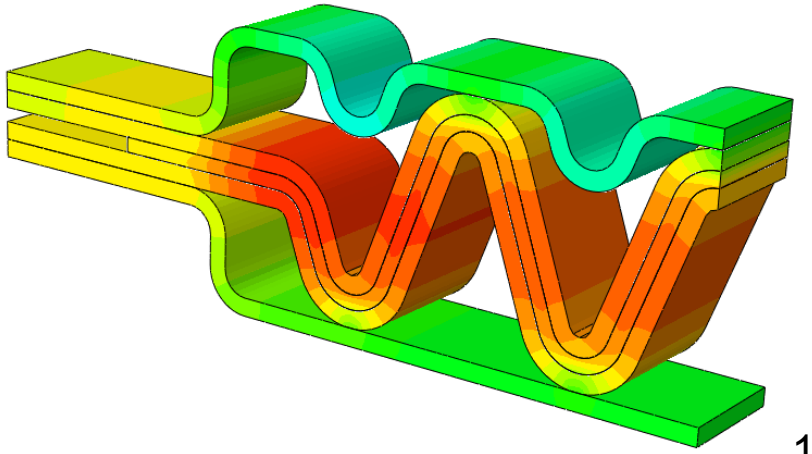


Stress [MPa]





Temperature [C]

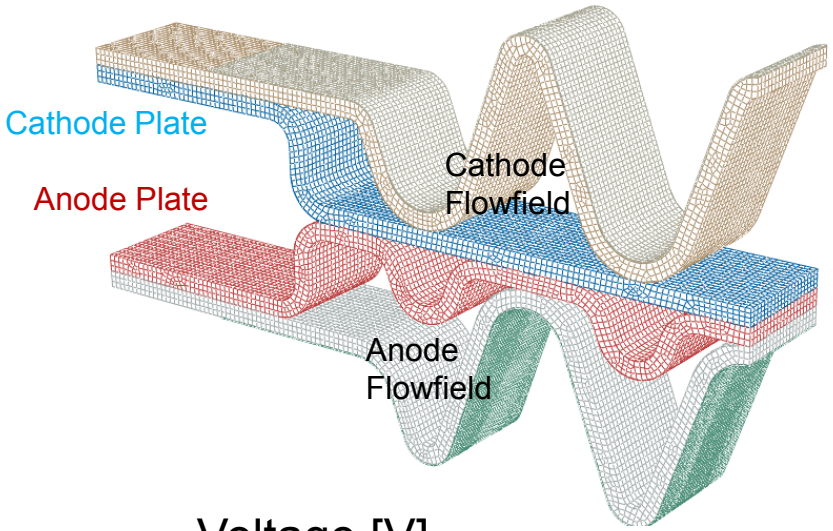


FEA Electrical Results

What is the voltage drop when running 1.0 A/cm² through the structure?

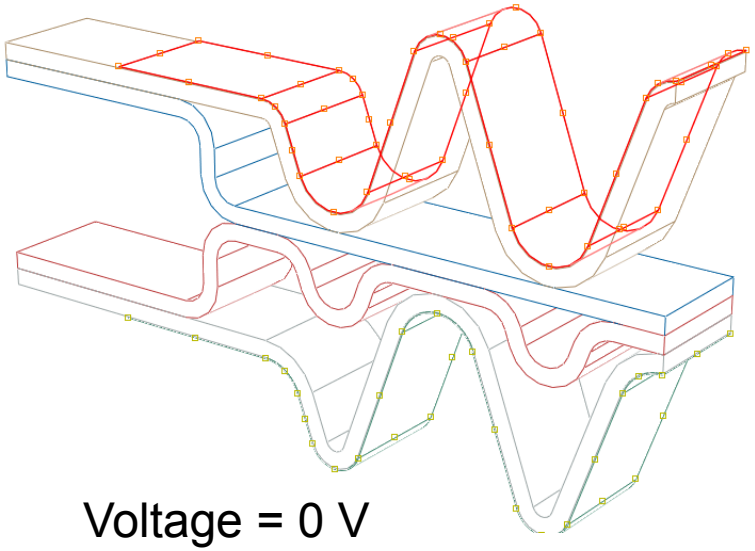
Demonstrates that the bulk of the voltage drop is in the contact resistance between the membrane and the flowfield and should not be an issue

Mesh: Hex elements



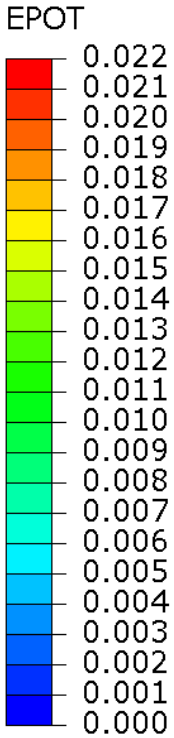
Electrical loading

Current = 1.0 A/cm²

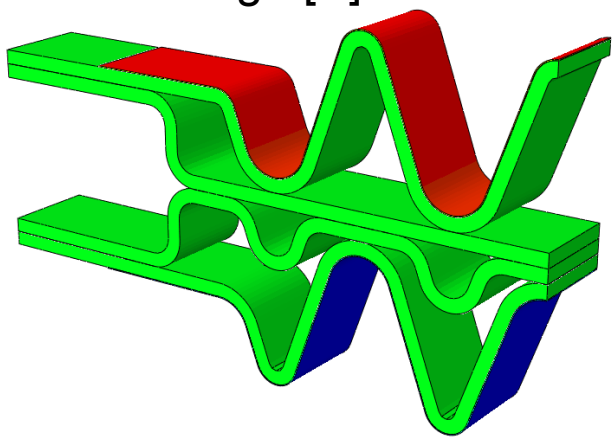


Voltage = 0 V

Note: Joule heating fraction set to 0 for all parts, result is no thermal loading – only result is electrical.



Voltage [V]



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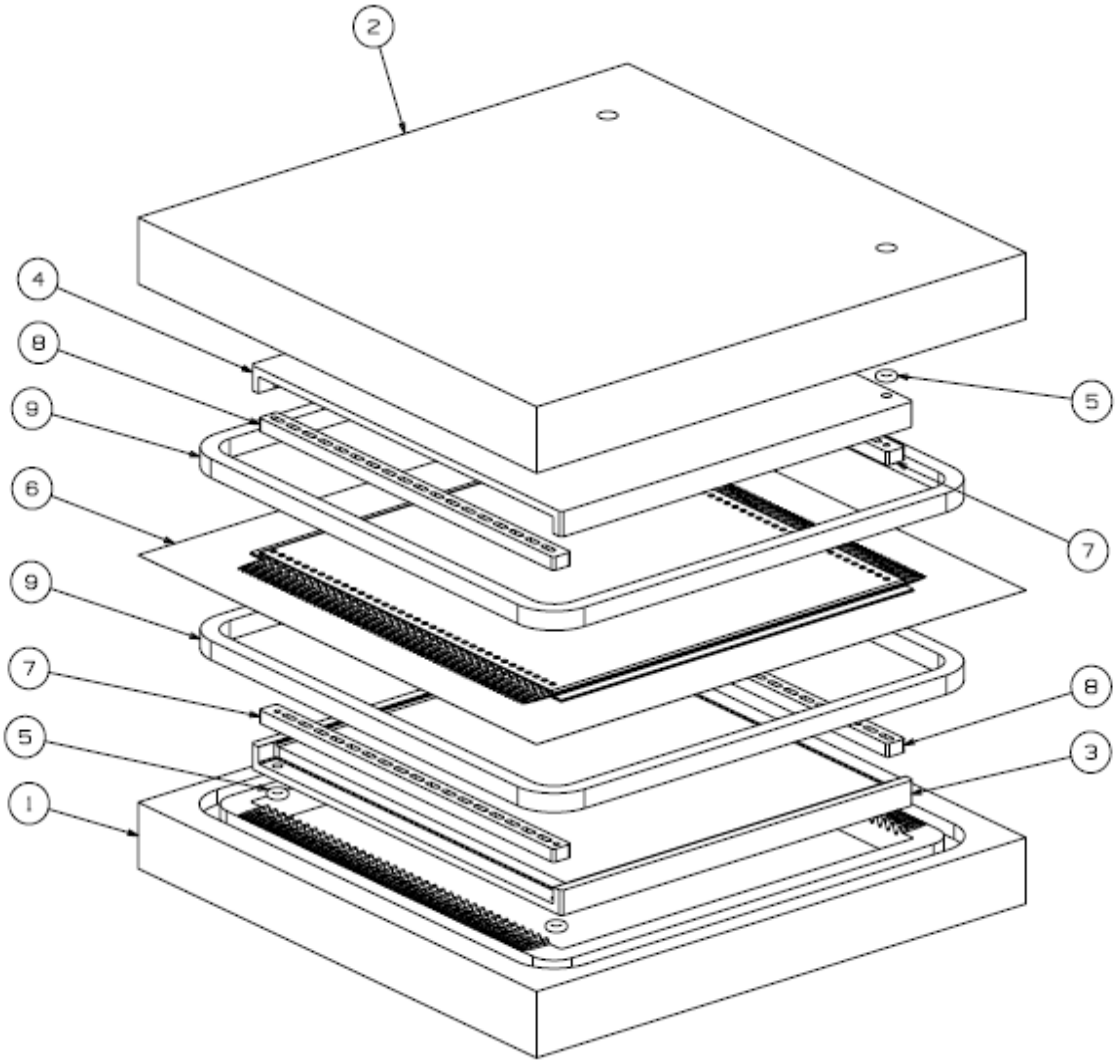
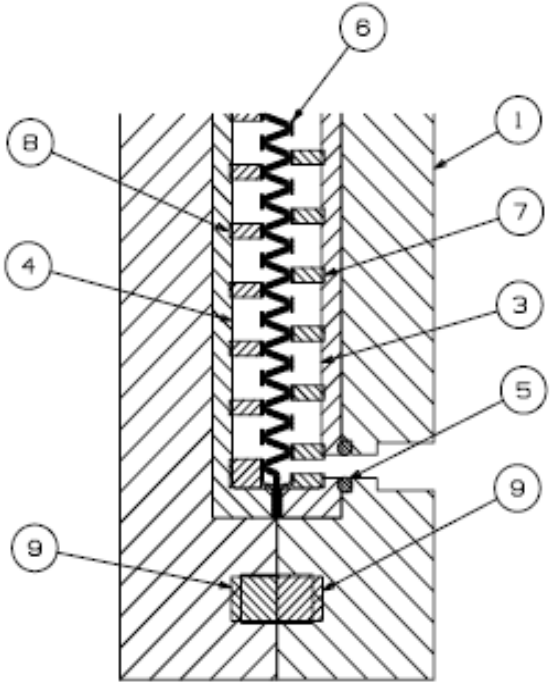
Single Cell Layout with Die Cut Seals

1. Anode Plate
2. Cathode Plate
3. Anode Spacer
4. Cathode Spacer
5. Plate to Spacer O-Ring
6. Cell Assembly
7. Anode Flow Directors
8. Cathode Flow Directors
9. Die Cut Membrane Seals





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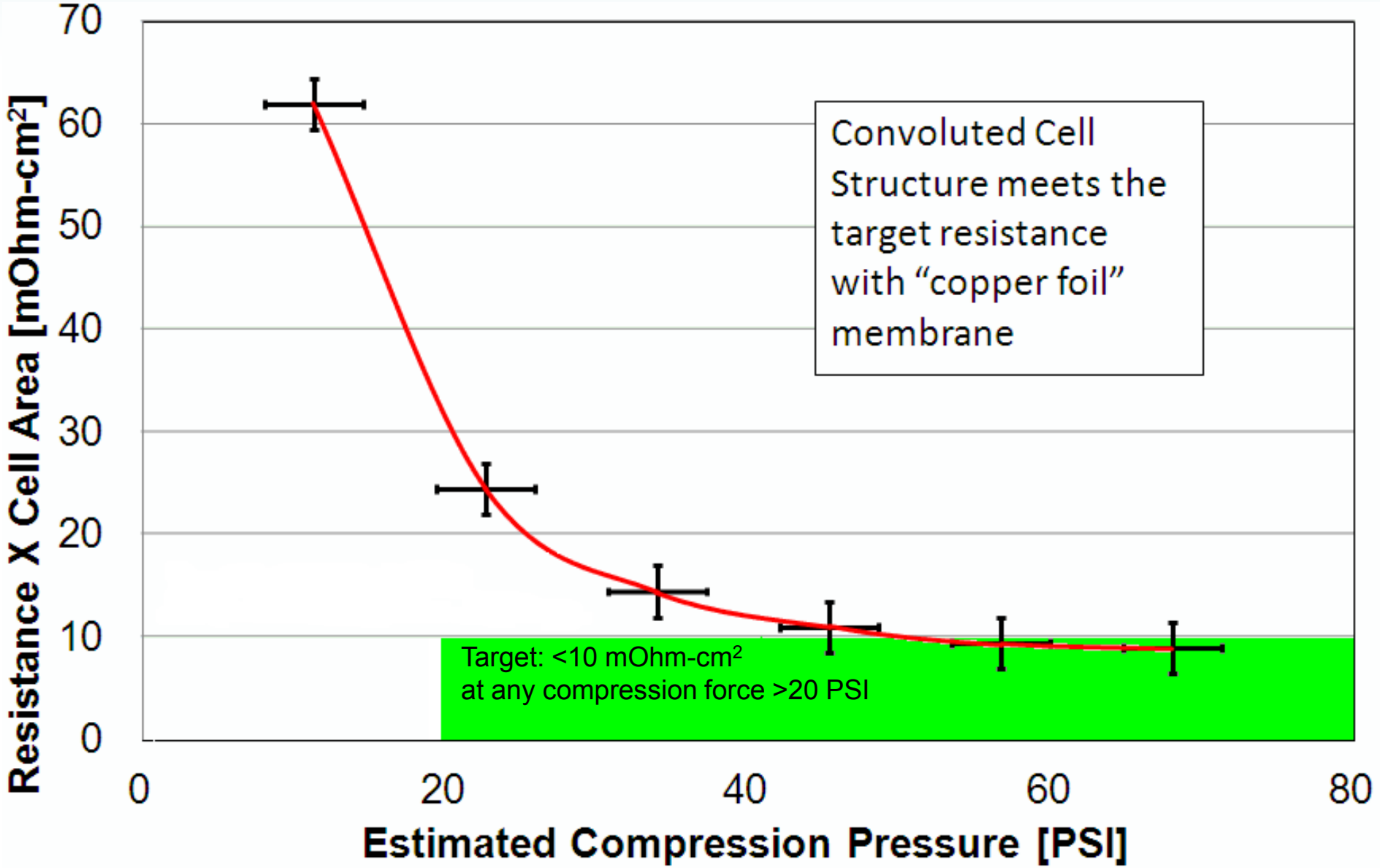
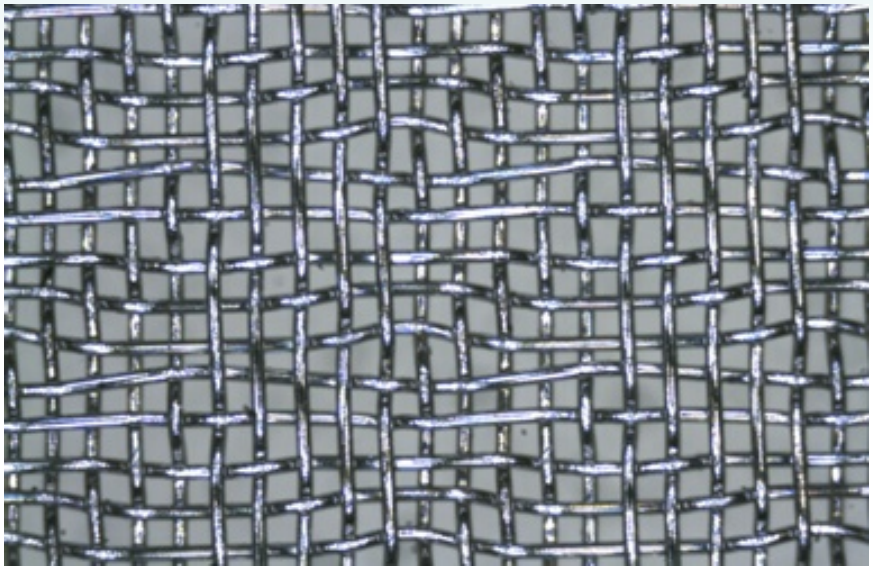
Convoluted Cell Structure Meets Target Resistance



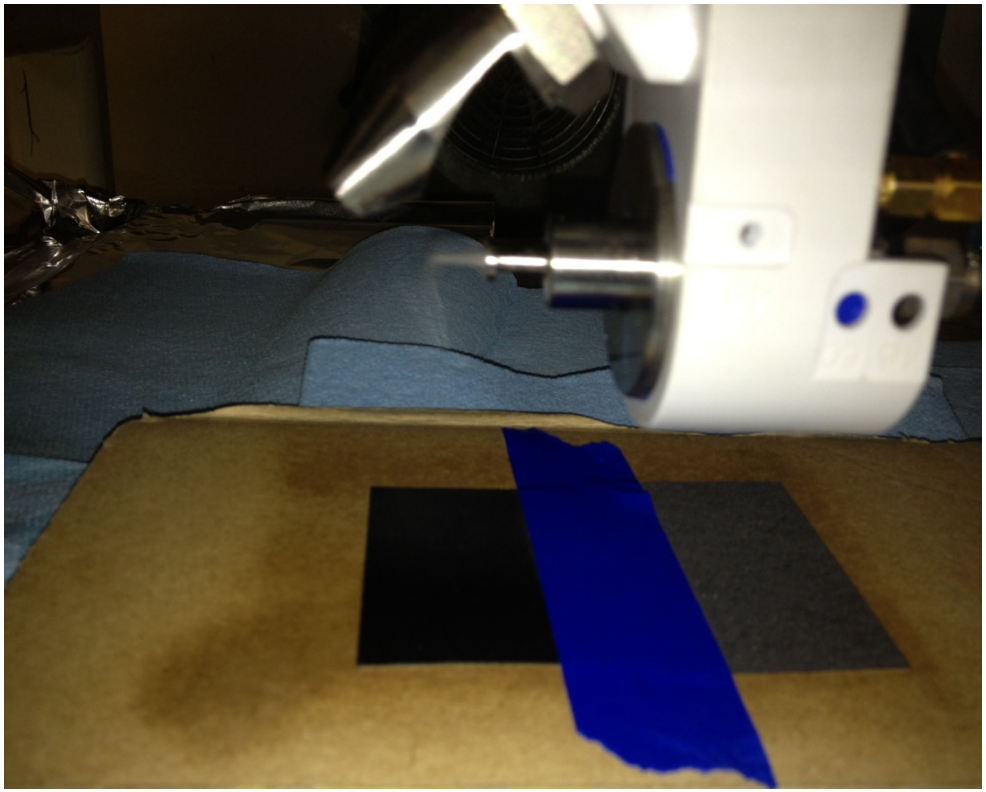
Proposed MEA Manufacturing Process



As Received GKC Wire Screen

Sonotek's Spray Coating Technology:

- Apply and cure microporous layer
- Apply and cure catalyst ink
- Apply and cure ionomer membrane



Sonotek Spray-Coater

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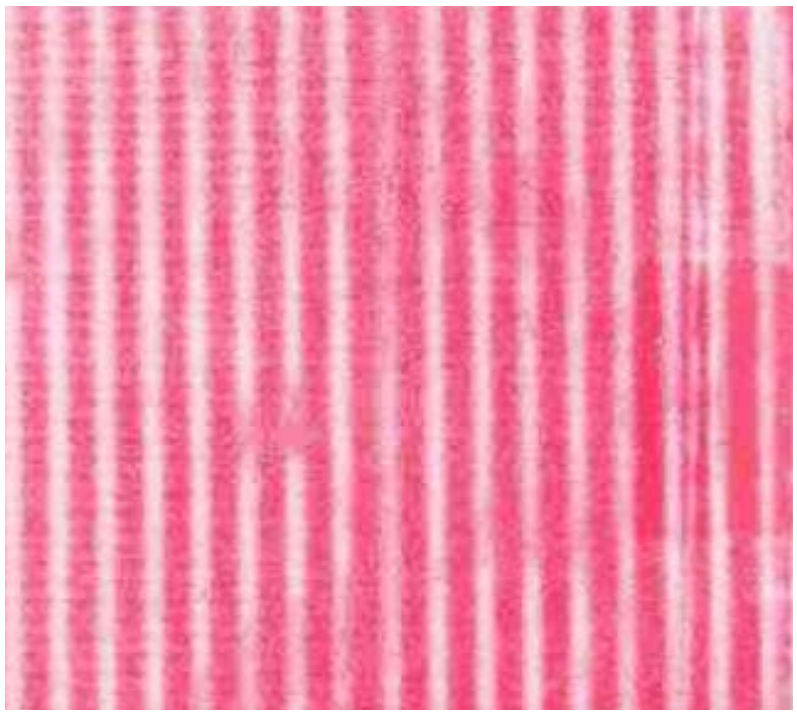
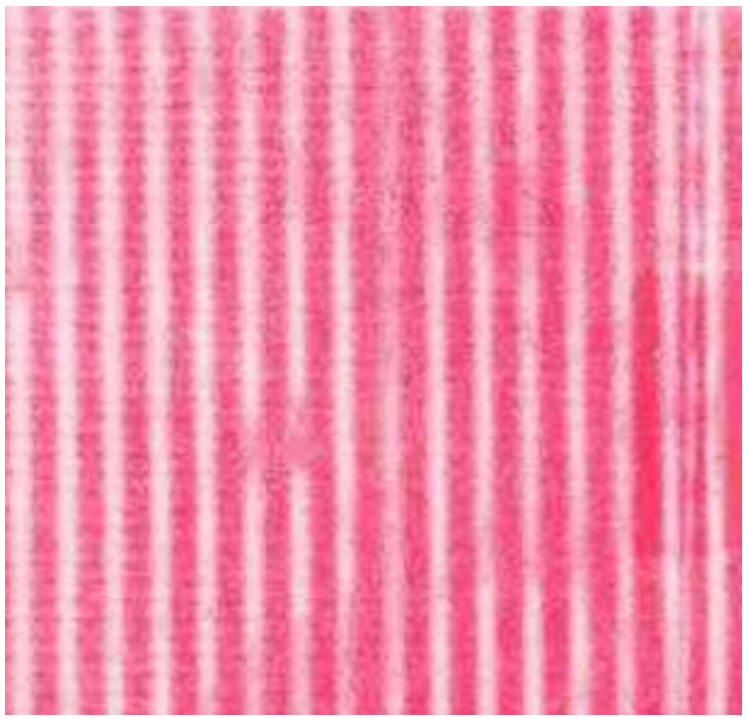
Compression Images are Similar with Baseline Graphite GDL, and Wire Screen GDL with Microporous Layer



Anode = Sigracet® 10BC Graphite Fiber Paper

Cathode = Sigracet® 10BC Graphite Fiber Paper



Anode = Gold Screen with microporous layer

Cathode = Gold Screen with microporous layer

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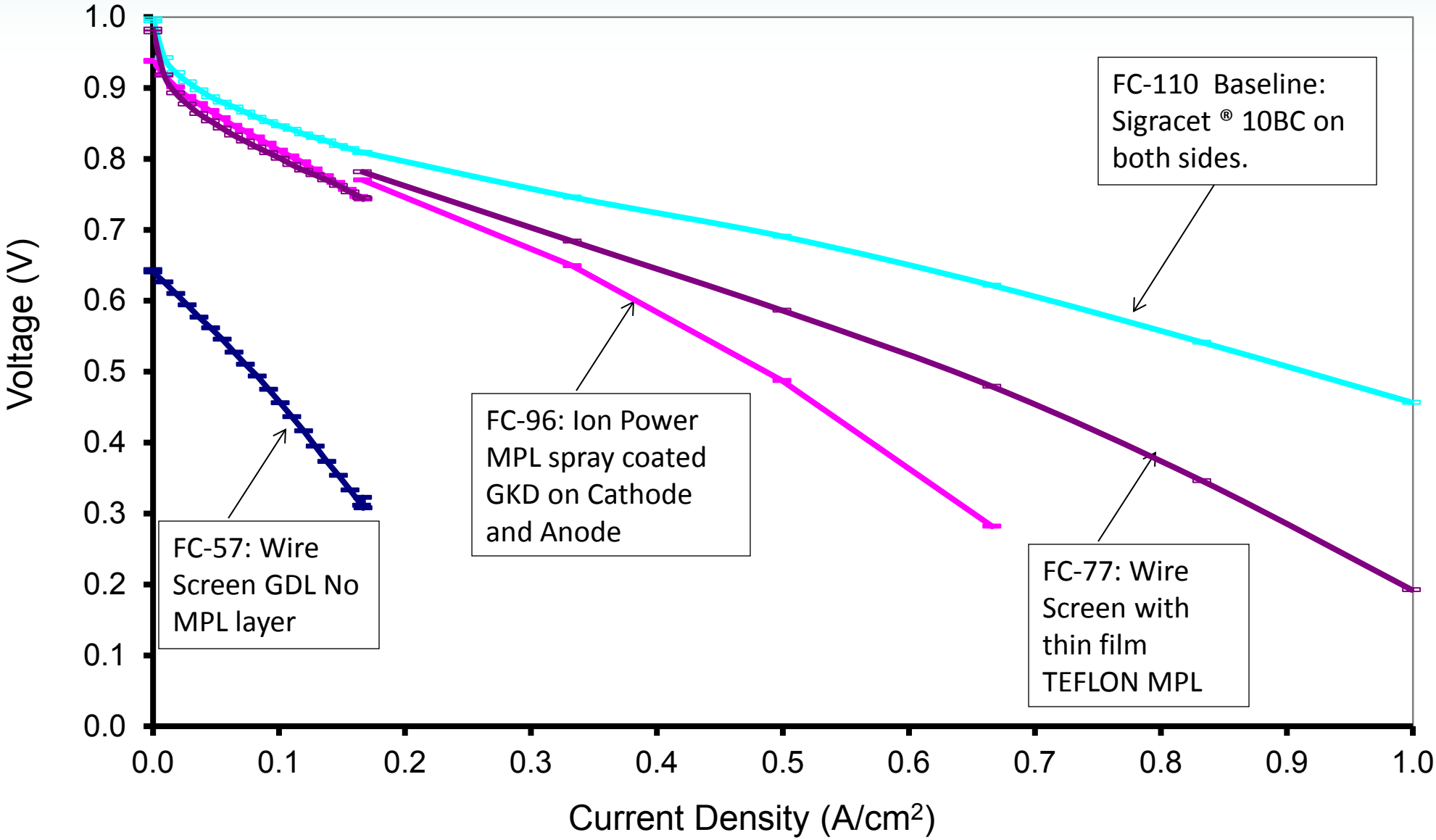
Micro-Porous Layer Incorporation into Wire Screen GDL



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Collaborations

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Subcontractor	• **General Motors**: Modeling, Testing, and Jig Design
Subcontractor	• **GrafTech**: Graphite-based GDL - Plate Sub-assembly Development
Suppliers	• **Dexmet**: Expanded Ti metal screens and plates, in different shapes • **GKD**: Woven SS metal screens • **Sonotek**: Spray coating MEA layers

Project Summary

- Demonstrated project goal of <10 mOhm-cm^2 electrical resistance at several compressive forces >20 psi with “copper foil” membrane
- Metal screen diffusion media with microporous layers performs as well as state-of-the-art graphite based diffusion media
- Forming fixtures and convoluted cell hardware have been built

Proposed Future Work

- Finish the de-bug and sealing issues with the convoluted single-cell hardware so that the first convoluted MEA fuel cell can be tested
- *MEA performance metric*:

  Successful test of a corrugated fuel cell meeting a minimum power density of 70 mW/cm^2 at 0.8V

De-bug of Convoluted Hardware

- Develop process for forming subgasket
- Investigate imbedding inner edges of subgasket into outer edges of mesh flowfield
- Modify cell hardware to achieve proper compression of membrane and to achieve seal between MEA and subgasket