V.B.3 Corrugated Membrane Fuel Cell Structures

Stephen Grot
Ion Power Incorporated
720 Governor Lea Rd.
New Castle, DE 19720-5501
Phone: (302) 832-9550
Email: s.grot@ion-power.com

DOE Managers
Donna Ho
Phone: (202) 586-8000
Email: Donna.Ho@ee.doe.gov
Reginald Tyler
Phone: (720) 356-1805
Email: Reginald.Tyler@go.doe.gov

Technical Advisor
Thomas Benjamin
Phone: (630) 252-1632
Email: benjamin@anl.gov

Contract Number: DE-EE0000462

Subcontractors:
- Graftech International Holdings Inc., Parma, OH
- General Motors Corporation, Flint, MI

Project Start Date: September 1, 2010
Project End Date: August 31, 2013 (Discontinued)

Overall Objectives

- Achieve a platinum catalyst utilization target of 0.2 g Pt/kWe
- Demonstrate target properties <10 mOhm-cm^2 electrical resistance at >20 psi compressive strength
- Offer at least 80% of the power density that can be achieved by using the same membrane electrode assembly (MEA) in a flat plate structure
- Successfully test a corrugated fuel cell single cell, meeting a minimum power density of 70 mW/cm^2 at 0.8 V

Fiscal Year (FY) 2013 Objectives

- Develop cell fixturing equipment
- Test electrical resistance of the convoluted single-cell structure
- Develop a new gas diffusion layer (GDL) that can be corrugated for the fuel cell

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(B) System Cost (GDL, lower plate/GDL, manufacturing costs)

(C) Performance (high power density with low Pt-loaded MEAs)

Technical Targets

In this project, corrugated membrane fuel cell structures are being constructed to assist the Fuel Cell Technologies Office in making progress toward meeting the important DOE objectives of power density (650 W/L) and platinum utilization (0.125 g/kW) by 2017 [1]. Ion Power has tested many fuel cell configurations with a wide variety of GDLs with varying pore sizes to determine the configuration with the greatest ability to meet power density needs when used in a corrugated structure.

FY 2013 Accomplishments

- Performed a finite element analysis of the convoluted cell structure to anticipate expected voltage drops and temperature profiles in the fuel cell
- Demonstrated a new wire screen-based GDL that exceeds the performance of traditional graphite fiber paper-based GDLs
- Developed a method for incorporating the membrane into the corrugated fuel cell structure
- Met target for areal resistance under compression for a fuel cell with corrugated membrane structure

✧ ✧ ✧ ✧ ✧

INTRODUCTION

The DOE supports research to overcome critical technical barriers in fuel cell technology. Corrugated membrane fuel cell structures possess the potential to meet the targets of the DOE power density targets, by essentially packaging more membrane area into the same fuel cell volume as compared to conventional stack constructions. Ion Power's targets consist of meeting a power density measurement of 1 W/cm^2 while simultaneously achieving a platinum utilization of 0.2 g Pt/kW.

In order to meet the DOE's goal of reducing the use of platinum in fuel cell cathodes, Ion Power has proposed a novel concept of a corrugated membrane fuel cell structure with a two-fold increase in the membrane active area over the geometric area of the cell. A comparison of the corrugated geometry and traditional flat fuel cell geometry can be found in Figure 1.

APPROACH

For the development of the corrugated membrane electrode structure, Ion Power's approach will consist of compressing additional membrane area into the same geometric plate footprint. A fuel cell consisting of a 50-cm^2 single-cell test jig will be designed and fabricated to allow testing of both conventional, flat MEAs possessing standard flow fields and the corrugated single-cell assemblies. This test jig will also allow the hand assembly of each of the individual components. Inserts will be created to generate both straight through flow and serpentine flow in both the flat and corrugated MEAs. Water, thermal, and gas flow management issues will be investigated.

RESULTS

Early in FY 2013, a three-dimensional finite element analysis of the cell was performed to examine the expected voltage drops in the convoluted fuel cell and to look at the expected temperature and stress profiles in the cell. The results of the structural and thermal analyses can be seen in Figure 2.

The stresses in the cell were found to fall well within the strength capabilities of the materials and should provide sufficient contact pressure for the cell to function properly. However, the thermal analysis displayed one potential issue: the temperature differential between the coolant and the membrane at the center of the convolution is 9-11°C at full power. This high temperature is a result of the longer thermal path of this area of the membrane to the coolant cavity of the cell stack. These high temperatures may be problematic for the membrane. We propose to address this issue by slightly lowering the operating current density, thereby reducing the amount of heat generated.

As a result of the General Motors recent re-organization and the consequent limit on GM's fuel cell-dedicated resources, they are no longer able to support this project. The loss of GM as a partner and key manufacturer subcontractor has delayed the project's progress.

Dozens of fuel cell configurations have been tested during FY 2013 with significant improvements in the microporous layer integration into the coated-wire screen GDL. Traditional Teflon®/carbon black microporous layers were integrated onto the wire screen in order to allow for proper water management of the GDL. Figure 3 shows the dramatic differences in performance of various microporous layer application methods to the wire-screen GDL. The microporous layer optimization work shown in Figure 3 was performed in flat cell configurations at a cell temperature of 65°C. The wire screen enables the GDL to be corrugated and improves microporous layer functionality.

Once a suitable wire-screen GDL was developed, the next challenge of integrating a catalyzed membrane into the structure was addressed using two approaches. The first approach involved applying a catalyst/membrane coating to each of the GDLs and then bringing the two GDL halves together. The second approach involved forming a full

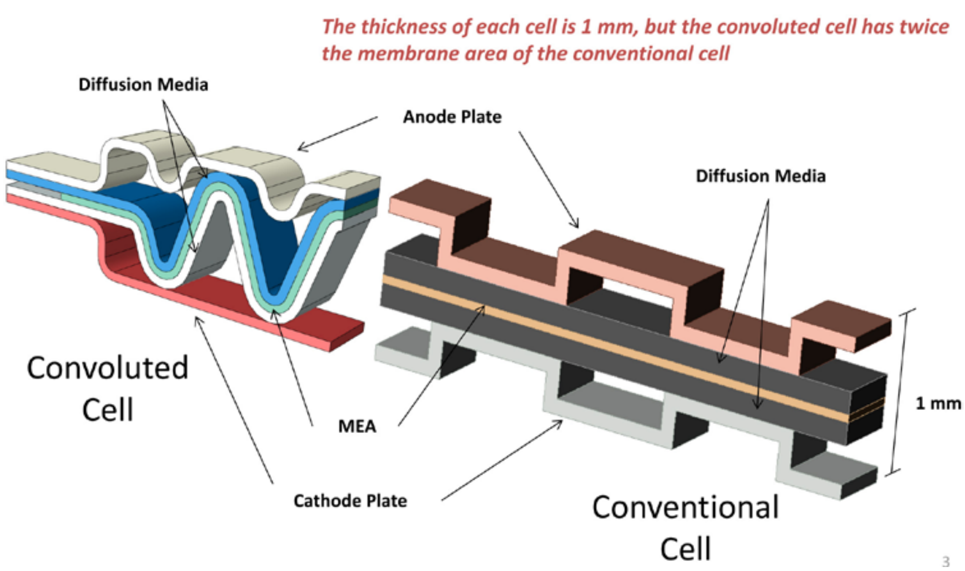

FIGURE 1. Comparison of Convoluted Cell and Conventional Cell

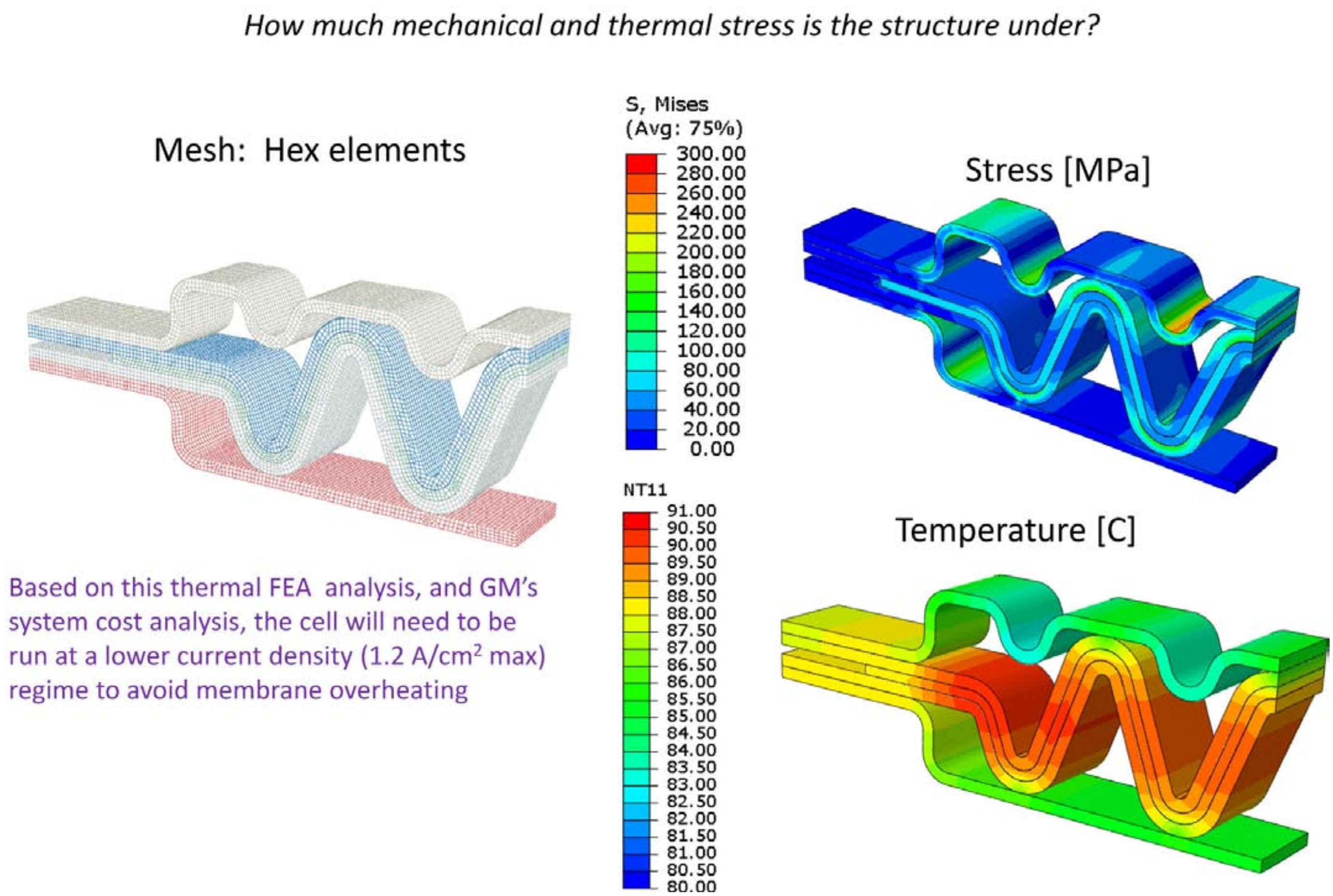

FIGURE 2. FEA Structural and Thermal Results

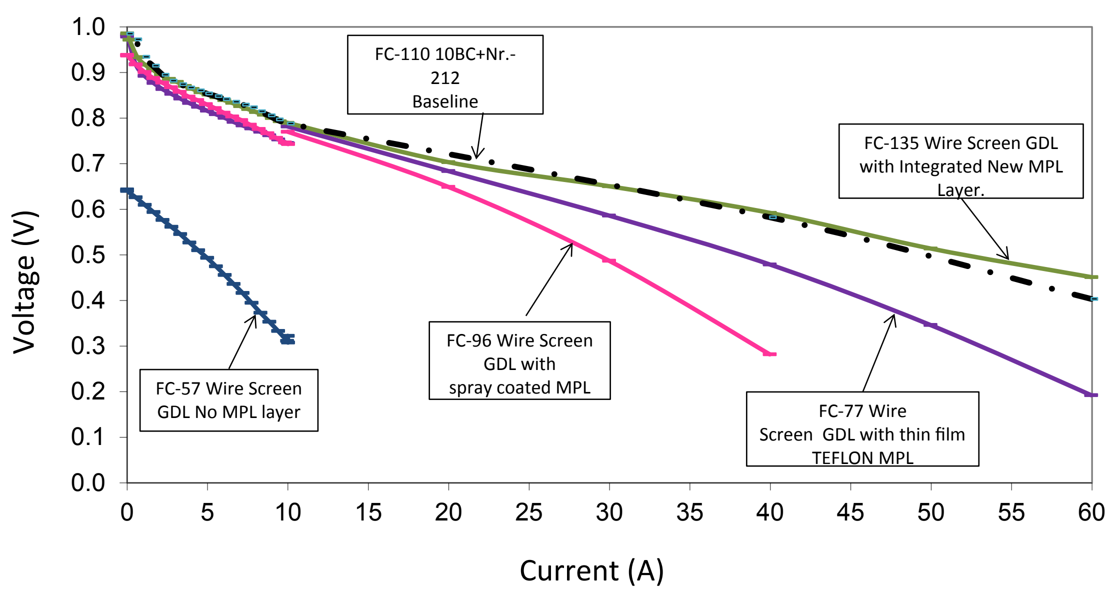

FIGURE 3. Improvements in Performance of Wire-Screen GDLs by the Incorporation of Various Microporous Layers

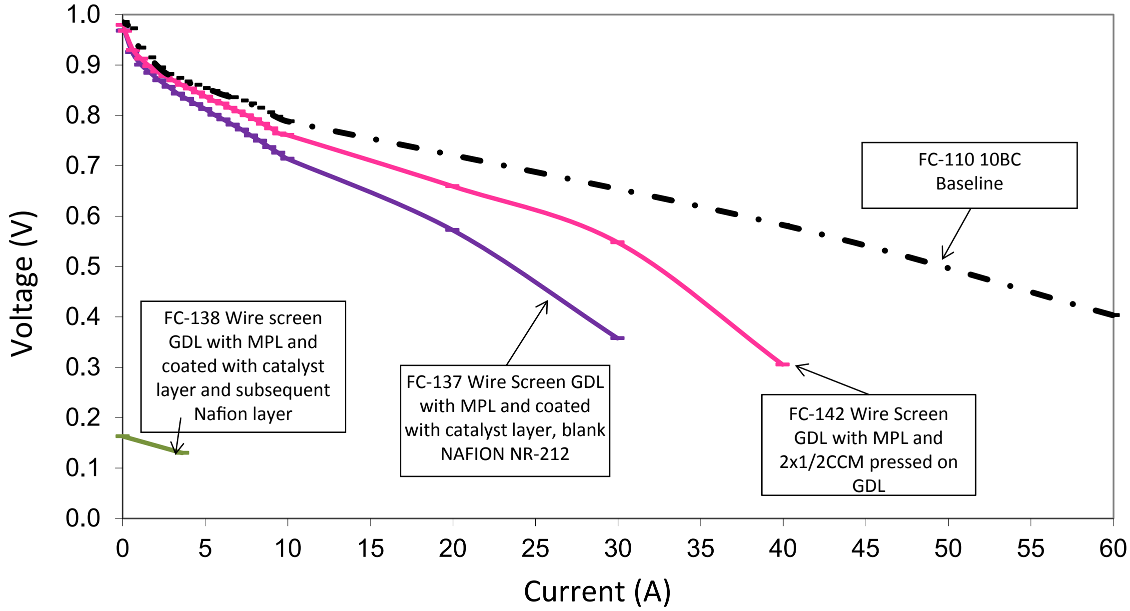

FIGURE 4. Membrane Incorporation into Wire-Screen GDL

catalyst-coated membrane into a corrugated form and then placing it on the corrugated GDL during cell assembly. In order to demonstrate the feasibility of using two membrane halves as the membrane component in the fuel cell, Ion Power compared several flat fuel cell configuration tests to the performance of a single, 50-micron Nafion® NR 212 membrane baseline. The following configurations were tested at 65°C and the results can be seen in Figure 4:

- Wire-screen GDL coated with catalyst on the microporous layer, using blank membrane
- Wire-screen GDL coated with catalyst and ionomer, no separate membrane necessary
- Wire-screen GDL with microporous layer and one-half catalyst-coated membrane pressed on both GDLs

The results shown in Figure 4 demonstrate that challenges remain in using the first approach for integrating the catalyst/membrane coating onto the GDL.

By August 2013, Ion Power was able to demonstrate a power density of 40 mW/cm^2 on a corrugated fuel cell, which reaches 60 percent that of the Go/No-Go decision criteria of 70 mW/cm^2. This result was achieved on a fuel cell single cell with a silicon seal material utilizing the second approach, whereby the catalyst-coated membrane was formed using the membrane corrugation tool. Ion Power saw improvement in this area throughout July and August on corrugated fuel cells, while working through obstacles related to the corrugation, lamination, and sealing of the cell. However, Ion Power was not able to meet the Go/No-Go decision performance target by the deadline of August 31.

CONCLUSIONS/FUTURE DIRECTIONS

- As Ion Power was unable to meet the Go/No-Go decision criteria of achieving a minimum power density of 70 mW/cm^2 on a corrugated fuel cell single cell, this project was discontinued by the DOE effective August 31, 2013. Ion Power is pleased with its work on this project, and its contributions to fuel cell industry, as well as having laid the groundwork for the field of corrugated fuel cells.
- One major accomplishment of this project is that we demonstrated a new type of metal-based GDL that has the potential to reduce the costs associated with the traditional fiber-based GDLs.
- While nothing in this project has shown that the concept of corrugated fuel cells lacks merit, technical challenges remain in order to properly build the structures. Ion Power believes that further development work in the field of corrugated fuel cell structures will be able to reach the power density target of 70 mW/cm^2 in the future.

FY 2013 PUBLICATIONS/PRESENTATIONS

1. 2013 Hydrogen and Fuel Cells Program Annual Merit Review Presentation

REFERENCES

1. U.S. Department of Energy. *Multi-Year Research, Development, and Demonstration Plan*. Fuel Cell Technologies Office. July, 2013. <http://www1.eere.energy.gov/hydrogenandfuelcells/mypp/pdfs/fuel_cells.pdf>