V.C.4 Corrugated Membrane Fuel Cell Structures

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Fiscal Year (FY) 2012 Objectives

The following objectives characterize the project goals for FY 2012:

- Develop the forming fixture required for corrugating gas diffusion layer (GDL) materials.
- Develop a GDL material that can meet or exceed the baseline performance in a flat configuration. This material must then have the ability to be formable for corrugation.
- Demonstrate the target properties of <10 mOhm-cm^2 electrical resistance at >20 psi compressive strength over the active area, in combination with offering at least 80% of the power density that can be achieved by using the same membrane electrode assembly (MEA) in a flat plate structure (This is the next DOE Go/No-Go decision point).

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Fuel Cell Technologies Program 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 Program in meeting the important objectives of power density (1 W/cm^2) and platinum utilization (0.2 g/kW). In order to meet these technical targets, Ion Power has tested several GDLs with varying pore sizes, to determine the configuration with the greatest ability to meet power density needs when used in a corrugated structure. Table 1 illustrates Ion Power's findings:

In summary, Ion Power has identified GDL material that meets or exceeds the baseline without micro-porous layer (MPL) for the GKD Woven Wire Screen (Gold Screen 10BC) – when using the Ti Metal Screen, MPL is required.

FY 2012 Accomplishments

The following is a list of accomplishments achieved to date in FY 2012:

- Completed the development and production of cell fixture and sub gasket forming tools for the single-cell 50-cm^2 fuel cell test jig.
- Designed and manufactured the tooling fixture to allow for corrugation of the GDL screen.
- Initiated a new method for the manufacture of a catalyst-coated membrane, that directly applies the catalyst and membrane onto the GDL surface using coating operations.
- Identified a suitable, formable, metal-based GDL material that meets or exceeds baseline performance in a flat cell configuration (the GKD woven wire screens).

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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 targeted demands of the DOE by 2015. These targets consist of meeting both the power density objective

TABLE 1. Comparison of GDL Polarization Curves Impacted by Openings/cm^2

Comparison of GDL Polarization Curves Impacted by Pore Size							
GDL Data							
Fuel Cell #	FC45	FC65	*	*	FC56	FC29	FC55-1
Membrane	XL100 (Baseline)	NR212	XL100	XL100	XL100	XL100	NR212
MPL	Yes	No	No	Yes	Yes	No	Yes
Gas Diffusion Layer	10BC	10AA	10BC Ti Screen	10BC Ti Screen	GrafTech 28.49% OA	GrafTech FFP 300	Gold screen 10BC
Openings/cm^2	~10,000	~10,000	2,500	2,500	200	300	10,000
Current (A) at Voltage (V) of 0.8	3	5	5	7.5	7.5	2.5	5
Current (A) at Voltage (V) of 0.4	39.5	26	27	50	32	5	75

Sources: Annual report Feb 6, 2012 without FC Number

of 1 W/cm^2 and platinum utilization of (0.2 gPt/kW) simultaneously.

For the past 40 years the traditional proton exchange membrane (PEM) fuel cell stack has been the dominant method of construction of multi-kW fuel cells. These stacks featured grooved bipolar plates, with flat MEAs and GDLs, seals and heavy compression end-plates. Some smaller sub-watt and portable applications featured the "jelly roll" concept cell design variation. However, these design concepts were never able to achieve the power density of the traditional stack construction due to inefficient collection of currents and inefficient distribution of reactant flows.

In order to meet the DOE's goal of reducing the use of platinum in fuel cell cathodes [1], Ion Power has demonstrated the novel concept of a corrugated membrane fuel cell structure. The target is a fuel cell single cell (50 cm^2) with a two-fold increase in the membrane active area over the geometric area of the cell by corrugating the MEA structure.

Approach

Achieving the platinum catalyst utilization target of 0.2 g Pt/kWe set forth by the DOE [2,3] is one of the most challenging aspects of traditional PEM fuel cell stacks. 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 such that it will 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

The forming fixture for corrugating GDL materials has been designed and built (Figure 1). The first set of tests using the newly built forming fixture revealed a minor challenge; the blades forming the individual convolutions were dragging prematurely on the membrane, causing resistance for an accurate sliding motion and resulting in the improper forming of the corrugation. In order to resolve this issue, modification slides were designed and added to the fixture to hold the blades off of the membrane. A release mechanism was implemented to release the blades at the appropriate location on the membrane. A second set of tests will be conducted.

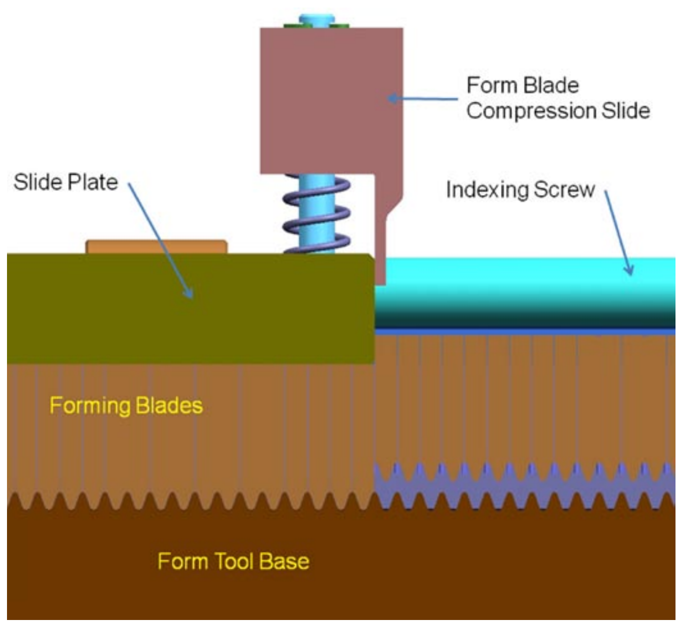

FIGURE 1. Forming Fixture for Corrugating GDL Materials

Ion Power has made significant progress in the sourcing of metal screen diffusion media. Research has shown that for non-traditional gas diffusion media, small pore sizes are extremely beneficial. Small pore sizes on the order of 70 microns, or roughly 10,000 openings/cm^2 outperformed Graftech's 300 openings/cm^2 material. They also outperformed an expanded titanium screen with 2,500 openings/cm^2 as shown in Figure 2. The results clearly indicate that the finer the pore size, the higher the performance. Thus, moving forward Ion Power will seek materials consistent with this research.

Performance tests have been completed to analyze the GKD woven wire screens. For these performance tests, test conditions were standardized to 1 atm dry air/hydrogen at 65°C with 60 cm^2 of cell hardware. Ion Power is quite pleased with the improved performance of the GKD woven wire screen over the baseline, however when the GDK screen was applied to both sides of the fuel cell, the performance was quite low (Figure 3). When the GKD wire screen is used as an anode or a cathode the performance is above the baseline, however when used as both anode and cathode together the performance is far below the baseline. Ion Power does not understand this phenomenon but is aggressively investigating its cause.

Additional developments have occurred on the manufacturing process for the catalyst-coated membrane. Although the MEA forming fixture is designed to allow the introduction of a flat catalyst-coated membrane sheet into the corrugated structure, this approach has inherent risks and challenges associated with it. The ultimate in manufacturing cost savings would be to form in place the catalyst layer and the membrane layer via a two-step spray coating process on the corrugated GDL-plate subassembly (Figure 4). Thus the process will allow for a spray coating of the corrugated GDL-plate subassembly with a catalyst coating, followed by an ionomer coating. When these two halves are brought together the two membrane halves form a reliable membrane separator between anode and cathode. The large manufacturing cost savings comes about since no membrane needs to be purchased, and furthermore, no membrane insertion fixture would be required. In order to demonstrate the process in the flat geometry, Ion Power used a SIGRACET™ 34BC gas diffusion layer, roll-coated the catalyst ink on the top surface, and cured it. Next, Ion Power re-coated the catalyzed SIGRACET 34BC with a 13-micron thick ionomer layer. Then we took two pieces of the two-step coated SIGRACET™ and bonded them face to face through a 2-mil thick KAPTON™ perimeter frame. This MEA, sized at 900 cm^2 active area, was submitted to a customer for

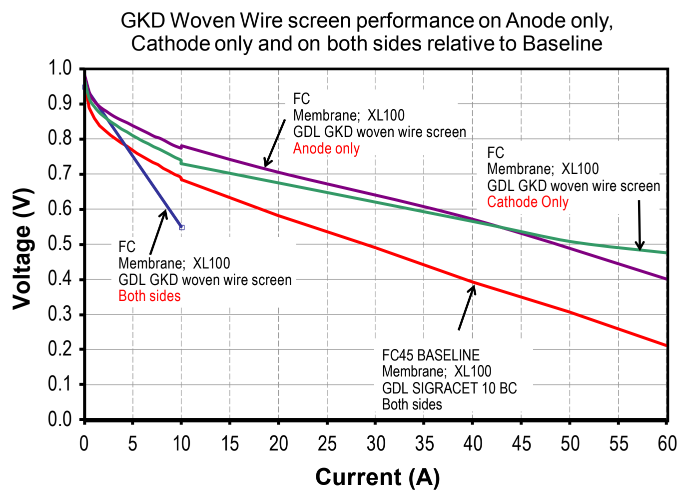

FIGURE 3. GDK Woven Wire Screen Performance

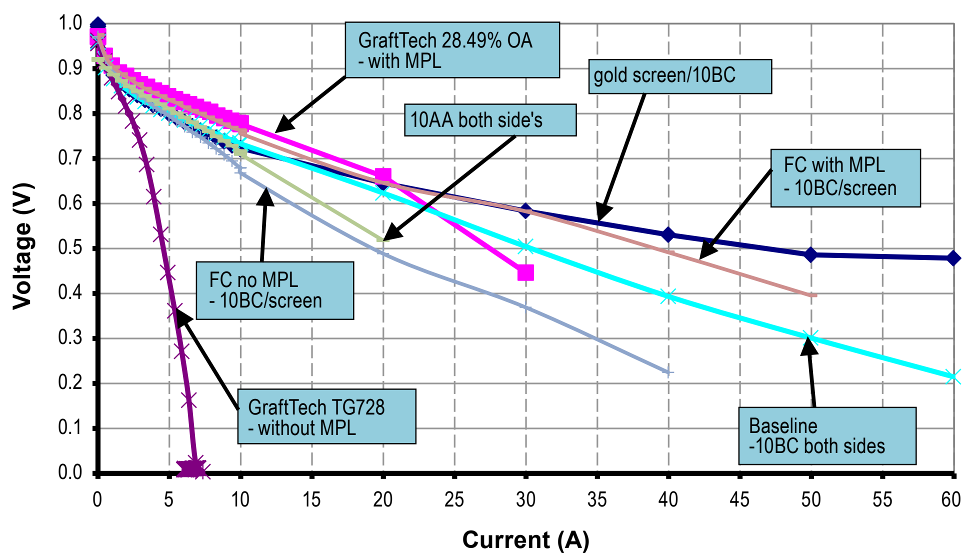

FIGURE 2. Impact of Gas Diffusion Layer Openings/cm^2

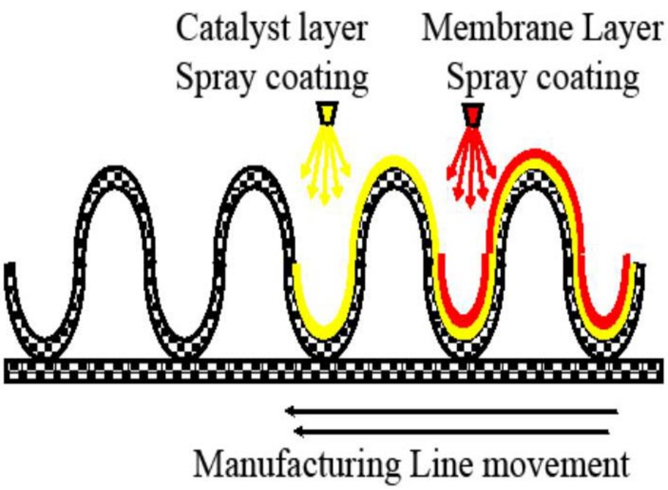

FIGURE 4. Continuous Spray Coating of Corrugated GDL Plate Subassembly

evaluation and testing. The first testing conducted will be the leak test, followed by the performance testing.

Ion Power has further identified Sono-tek, a company that specializes in the application of the catalyst-coated membrane via ultrasonic spray nozzles, as a well suited vendor for the spray coating approach. Ion Power is in the process of negotiating a trial at Sono-tek's facility, using Ion Power's coating materials and substrates.

Conclusions and Future Directions

Over the past year, Ion Power has reached the following conclusions:

- Ion Power has completed a significant amount of work in the design and manufacture of tooling fixtures.
- Ion Power has performed extended research to determine the most effective materials for use in the corrugation design process. Ion Power has concluded that the GKD woven wire screen with 10,000 openings/cm^2, provides the highest and best value.

Future Directions for the project include:

- Ion Power will pursue the corrugation of metal screens to metal plates and begin actual fuel cell testing of authentic corrugated fuel cell structures.
- Ion Power will further work with Sono-tek to implement a spray coating manufacturing process for the MEA.

FY 2012 Publications/Presentations

2012 Hydrogen and Fuel Cells Program Annual Merit Review Presentation

References

1. United States. U.S. Department of Energy. Energy Efficiency and Renewable Energy. "Parts of a Fuel Cell" Web. <http://www.1.eere.energy.gov/hydrogenandfuelcells>.

2. HFCIT Program "Multi-Year Research, Development and Demonstration Plan", U.S. DOE Office of Energy Efficiency and Renewable Energy, February 2005, <www.eere.energy.gov/hydrogenandfuelcells/mypp/>.

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