VI.2 Reduction in Fabrication Costs of Gas Diffusion Layers

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Subcontractors:
- The Pennsylvania State University
  University Park, PA
- Ballard Power Systems, Burnaby, BC

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Project End Date: September 30, 2011

Objectives

- Reduce the fabrication costs of gas diffusion layer (GDL) products by:
  - Reducing the number of process steps.
  - Replacing batch processes with continuous processes.
  - Utilizing in-line measurement tools to reduce costly ex situ testing.
- Develop and implement new, high volume GDL process technologies.
- Produce high-performance, low-cost GDLs at sufficient volumes for near-term fuel cell markets.
- Research, develop, and implement new in-line process control and measurement tools consistent with high volume manufacturing.
- Advance the understanding of the relationship between process parameters, ex situ GDL properties and fuel cell performance to maximize production of high performance, low-cost GDLs for near-term markets.

Technical Barriers

This project addresses the following technical barriers from the Manufacturing R&D section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Lack of High-Volume Membrane Electrode Assembly Processes

(F) Low Levels of Quality Control and Inflexible Processes

Contribution to Achievement of DOE Manufacturing Milestones

This project will contribute to the achievement of the following DOE milestones from the Manufacturing R&D section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Milestone 1: Develop prototype sensors for quality control of MEA manufacturing. (4Q, 2011)
- Milestone 2: Develop continuous in-line measurement for MEA fabrication. (4Q, 2012)
- Milestone 3: Demonstrate sensors in pilot scale applications for manufacturing MEAs. (4Q, 2013)

Accomplishments

- Reduced GDL costs by 40% from $36/kW to $21/kW from Fiscal Year (FY) 2008 to FY 2009 by:
  - Increasing the manufactured width from 40 cm to 80 cm wide.
  - Implementing process control tools to improve product uniformity, reduce the amount of ex situ testing and improve yield and scrap rates.
  - Installing new equipment allowing us to process rolls over 800 m long.
- Demonstrated multilayer coating capability on our production line:
  - Produced short rolls of both anode and cathode material.
  - Verified performance of both in a 50 cm^2 test stand against a commercial baseline material.
  - Addressed issues relating to micro-cracking in the microporous layers (MPLs) by modifying MPL ink properties and modifying process drying conditions.
- Demonstrated the ability to manufacture MPL inks using a dynamic mixer:
  - Produced three separate commercial inks on a 2-inch continuous extruder designed for our process.
  - Produced a short roll of anode material.

  - Verified performance of this anode GDL in a 50 cm^2 test stand against a commercial baseline material.
- Identified, purchased and installed new process control tools for multilayer coating, in-line mixing and heat treatment processes.
- Used Raman and Fourier transform infrared (FTIR) spectroscopy to determine the impact of sintering on Teflon® – poly-tetrafluoroethylene (PTFE) distribution in the GDL and are currently developing a link between the size and frequency of PTFE agglomerates and PTFE distribution in the GDL.
- Examined the size and shape of pores in the GDL using high-resolution X-Ray tomography (HRXRT) in an effort to find a link to performance.
- Examined each step of the manufacturing process and found relationships between specific process parameters and critical GDL properties. This will help make a more stable, consistent product and allows for the development of enhanced designs to improve performance in specific applications.

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Introduction

This project addresses the Manufacturing R&D sub-program's goal of research, development and demonstration of technologies and processes that reduce the manufacturing cost of proton exchange membrane (PEM) fuel cell systems. Specifically, this project reduces the fabrication costs of high-performance GDL products, while increasing manufacturing capacity and improving product uniformity. The end result of this program will be low-cost, high-performance GDLs for near-term fuel cell markets, such as back-up power or materials handling. A conceptual design of a Greenfield manufacturing plant that is capable of meeting the 2015 GDL target price of $4/kW at specified volumes will also be developed.

Approach

The largest barrier to the implementation of fuel cell products is cost. The cost of the GDL was evaluated in 2008 and was determined to be around $36/kW, almost 10 times the DOE cost target for 2015. A breakdown of the cost of the GDL revealed that the majority of BMP's GDL cost was due to manufacturing labor, specifically for ink mixing, coating and quality control, as shown in Figure 1.

It was determined that much of that cost could be removed by reducing the number of process steps, replacing slow batch processes with faster continuous processes, and utilizing modern on-line tools to improve product quality and reduce the amount of ex situ testing.

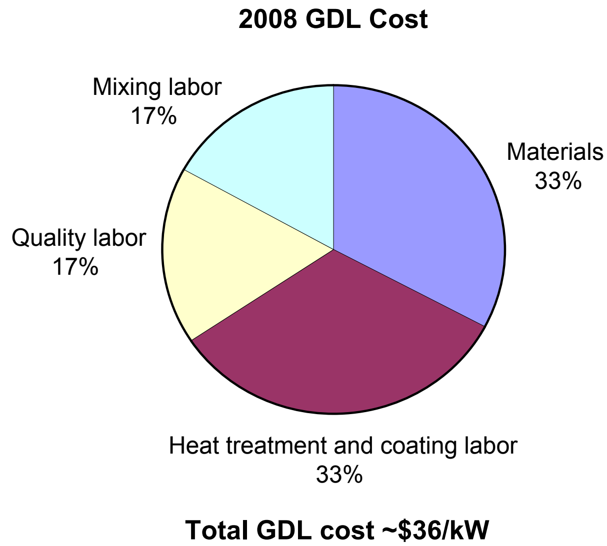

FIGURE 1. 2008 GDL Manufacturing Cost Breakdown

Results

Throughout the first two years of this project, BMP has been able to reduce the fabrication costs of GDLs by 40% from $36/kW to $21/kW, as shown in Figure 2. This has been accomplished by increasing the manufactured width of the GDL from 40 cm to 80 cm, installing new web-handling equipment to allow for processing of rolls in excess of 800 m long, and implementing better process controls to improve yield and scrap rates. As a result of these efforts, the plant capacity has more than doubled, which allows for production of low-cost, high-performance GDLs at volumes suitable for near term markets.

Ballard has also identified further cost reductions for 2010 and 2011 based on the implementation of multilayer coating and in-line mixing. Initial single cell validation work, shown in Figure 3, has been done to demonstrate that GDLs manufactured with this new technology perform as well as standard baseline materials. For this validation work multilayer coating was performed with standard inks and the in-line ink was applied with standard single layer coating processes, so that each process could be evaluated independently.

In addition to the cost reduction work, Ballard has examined every step in their manufacturing process to find relationships between process variables and critical GDL properties. These relationships have allowed Ballard to make adjustments during processing to meet specific customer targets, allowing for more stable, consistent product leading to improved yield

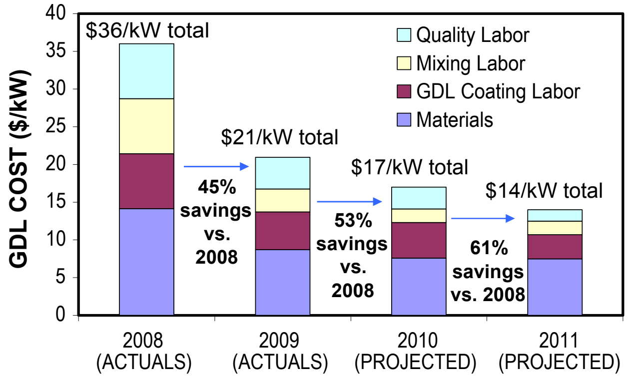

FIGURE 2. GDL Cost Reduction Data

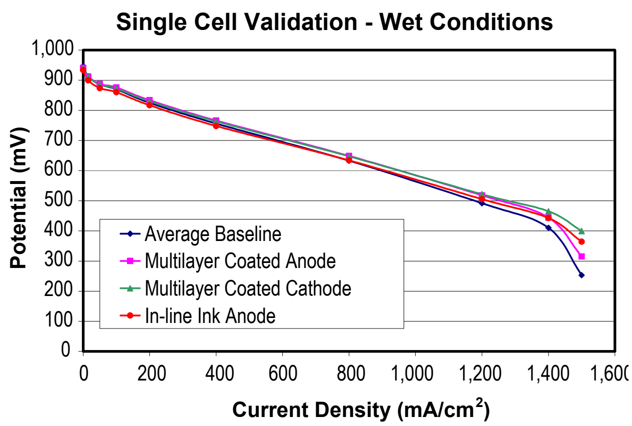

FIGURE 3. Single Cell Performance Validation

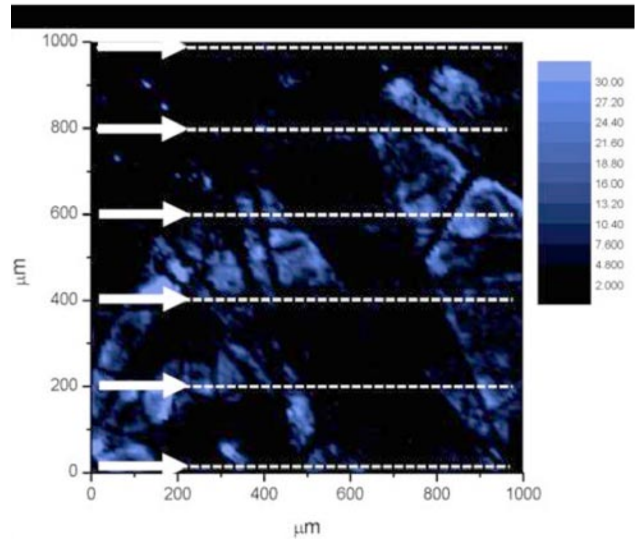

FIGURE 4. Linear Raman scanning being used to Measure PTFE Agglomerate Size Without Two-Dimensional Analysis

rates and cell performance. This work should allow for the development of enhanced GDL designs that are tailored for a specific application and should help in manufacturing parts with tight tolerances.

The Pennsylvania State University, under the direction of Dr. Michael Hickner, is working with BMP to develop an in-line method for measuring the chemical homogeneity of the GDL. Specifically, Penn State is looking at using Raman spectroscopy to determine the PTFE agglomerate size and frequency prior to sintering utilizing one-dimensional scanning, as shown in Figure 4. It is believed that this work will be useful in more accurately controlling the PTFE distribution in the GDL and allow for real-time adjustments of processing parameters to reduce variability both down-web and cross-web. HRXRT is also being used by Penn State to evaluate the effects of pore size and shape on GDL performance. They are also working on actively doping the powders used in the MPL inks, to allow us to determine the amount of penetration or MPL intermixing associated with both of our standard and multilayer coating processes.

Conclusions and Future Directions

BMP was able to significantly reduce the fabrication costs of GDLs, while more than doubling manufacturing capacity and improving product quality throughout Phase 1 of this project. Multilayer coating and in-line mixing technologies have been demonstrated and single-cell validation testing showed no significant performance difference when compared to baseline material. In addition, Ballard has been able to relate critical process parameters to key GDL properties and performance, which will allow for more stable, consistent GDL product, improved GDL design and increased production yields. This work will be beneficial for production of high-performance, low-cost GDLs for near-term fuel cell markets.

The Pennsylvania State University, under the direction of Dr. Michael Hickner, has developed a method for characterizing PTFE distribution in the GDL using Raman scanning. They have also used HRXRT to examine the size and shape of pores in the GDL. This work is important in understanding how variations in the PTFE distribution or pore structure may influence GDL performance.

In the next year, the future activities of this project include:

- Conduct short roll uniformity studies to establish product uniformity with new process technologies.
- Generate a production length roll to demonstrate capability.
- Validate performance of new low-cost GDLs utilizing all new process technologies with both single cell and stack testing.

- Complete installation of all on-line process control tools including vision system for the coating line.
- Determine manufacturing capability with all new process technologies with a goal of achieving six sigma standards.
- Continue development of process variable, product property, and fuel cell performance relationships to direct new process specifications.
- Continue investigation of Raman scanning and HRXRT work as a method of characterizing GDL properties.

FY 2010 Publications/Presentations

1. DOE Hydrogen Program and Vehicle Technologies Program Annual Merit Review and Peer Evaluation Meeting, Washington, DC, June 11, 2010.

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