
V.R.1 Visualization of Fuel Cell Water Transport and Performance Characterization under Freezing Conditions

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Contract Number: DE-FG3607GO17018

Subcontractors:
General Motors, Honeoye Falls, NY
Michigan Technological University, Houghton, MI

Project Start Date: March 1, 2007
Project End Date: February 28, 2010

- (A) Durability
- (B) Cost
- (C) Performance
- (D) Water Transport within the Stack

Technical Targets

This project is directed at developing a better water management strategy within PEMFC stacks. Insight gained from this study will be applied toward the design and demonstration of a robust fuel cell that meets the following DOE 2010 fuel cell targets:

- Durability: 5,000 hours
- Cost: \$45/kW_e
- Energy density: 2 kW/L



Approach

The objectives of this project will be accomplished through an iterative approach that starts at the component level, synthesizes this fundamental learning into combinatorial ex-situ experiments with nearly full visual access, and then progresses to increasingly more complex *in situ* experiments that utilize advanced diagnostic methods such as current density and high-frequency resistance (HFR) distributions and neutron radiography. Both experimental and modeling tools will be used to evaluate ex-situ and *in situ* performance.

The success of the proposed project lies in new materials, improved design concepts and operating strategies. These can be combined to improve fuel cell performance through control of liquid water, mitigation of water accumulation and dehumidification, and suppression of the effects of freezing on start-up time and material degradation.

Accomplishments

To date, we have completed the “baseline” material package selection, the flow channel design, and ex-situ multichannel flow experiment design. Fundamental studies of the GDL and flow channel components have been started.

- Grafil U-105 (Mitsubishi Rayon, Tokyo, Japan) carbon fiber material was selected as the “baseline” GDL substrate due to its excellent *in situ* fuel cell performance (measured by General Motors internal testing) coupled with its roll-good processing

Objectives

- Improve fundamental understanding of the water transport processes in the proton exchange membrane fuel cell (PEMFC) stack components under freezing and non-freezing conditions.
- Optimize materials, design, and surface properties of the gas diffusion layer (GDL) and bipolar plate (BPP) to alleviate flooding and suppress regions of dehumidification.
- Develop experimental and modeling tools to evaluate ex-situ and *in situ* performance of PEMFC stack components.

Technical Barriers

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

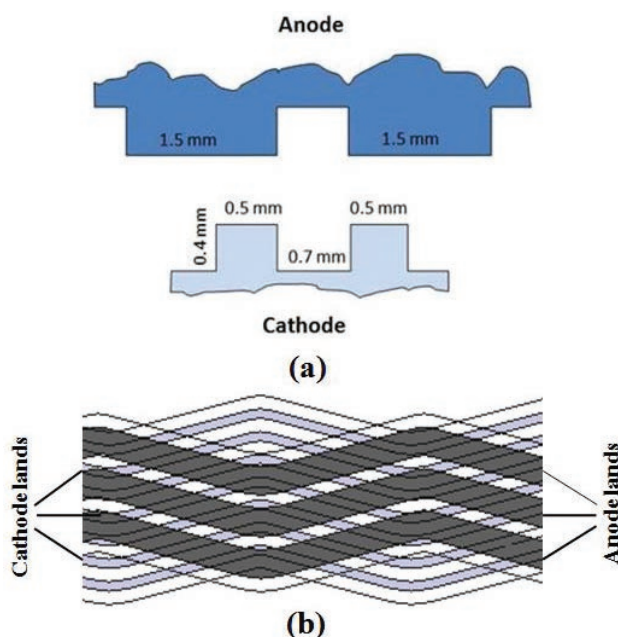
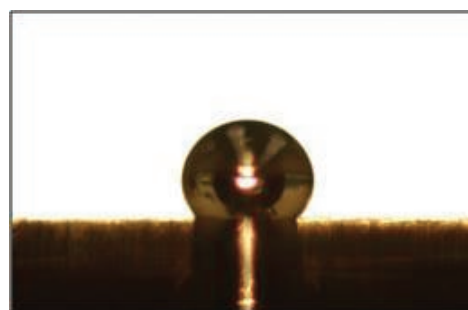


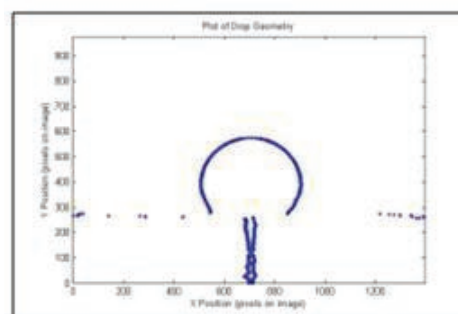
FIGURE 1. Flow Field Design: (a) Anode/Cathode Gas Channel Cross-Section; (b) Flow Field Pattern

properties. The microporous layer (MPL) coating and hydrophobic treatment procedures have been established “in-house” in General Motors Fuel Cell Activities [1].

- A flow field which simulates bipolar plates used in full fuel cell stacks has been designed by General Motors, as shown in Figure 1. This activity included definition of the channel size, cross-sectional shape, channel pitch, active area aspect ratio and the flow pattern. Close attention has been paid to accommodate the volumetric power density target of 2 kW/L set by DOE for automotive PEMFCs.
- An ex-situ multi-channel two-phase flow experiment setup with full visual access has been designed and is in fabrication. This setup allows the measurement of gas flow rate and pressure drop in each channel, and simultaneous visualization of water droplet/film formation and their distribution on the GDL surface and channel wall. The results from ex-situ experiments will be used in developing the two-phase flow models of the dynamic characteristics of the multi-channel flow.
- The wettability, expressed as contact angle and contact angle hysteresis, is a key parameter relative to liquid water transport in the GDL. The method to precisely measure the contact angles of fluids on GDL substrates has been established. An image produced by the edge detection program can be seen in Figure 2.
- A network model is being developed to predict water transport within the GDL. This network



Side View - Raw Image



Edge Detection of Drop

FIGURE 2. Image Processing of Drop Profile

model consists of a regular lattice with spherical pores represented by nodes. In the preliminary results, a 2D network model has been established to analyze the viscous fingering in porous media.

- A high-speed microscopy experiment setup for investigating the effect of channel geometry and contact angle on air-water flow behavior is nearly complete. The setup will allow for high-speed visualization of flow behavior and precise measurement of pressures of two-phase flow in small channels. The results from these channel component studies will be used to help develop the two-phase flow models.

FY 2007 Publications/Presentations

1. “Visualization of Fuel Cell Water Transport and Performance Characterization under Freezing Conditions”, poster presentation FCP22 at the 2007 DOE Hydrogen Program Annual Merit Review.

References

1. Ji, C., O’Hara, J.E. and Mathias, M.F., “Diffusion media with microporous layer,” World Patent Application WO 2006/025908, March 9, 2006.