V.M.5 Transport Studies and Modeling in PEM Fuel Cells

Cortney Mittelsteadt (Primary Contact), John Staser
Giner Electrochemical Systems, LLC
89 Rumford Ave.
Newton, MA 02466
Phone: (781) 529-0529
E-mail: cmittelsteadt@ginerinc.com

DOE Technology Development Manager: Donna Ho
Phone: (202) 586-8000
E-mail: Donna.Ho@ee.doe.gov

DOE Project Officer: Greg Kleen
Phone: (303) 275-4875
E-mail: Greg.Kleen@go.doe.gov

Technical Advisor: John Kopasz
Phone: (630) 252-7531
E-mail: Kopasz@anl.gov

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Subcontractors:

- Tech-Etch, Plymouth, MA
- Ballard Material Products, Inc., Lowell, MA
- Virginia Polytechnic and State University, Blacksburg, VA
- University of South Carolina, Columbia, SC

Project Start Date: October 5, 2009
Project End Date: October 4, 2012

Objectives

- Design of fuel cell components targeting specific transport properties:
  - Synthesis of block copolymers.
  - Design of flow fields and gas diffusion layers (GDLs).
- Determination of bulk membrane properties:
  - Water uptake and diffusivity.
  - Gas permeability.
  - Electro-osmotic drag.
- Transient, 3-dimensional modeling of fuel cell operation

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:

(C) Performance
(D) Water Transport within the Stack
(E) System Thermal and Water Management
(G) Start-up and Shut-down Time and Energy/Transient Operation

Technical Targets

The goals of this project are not to reach specific technical targets put forth by the DOE (i.e., target catalyst loading, target cost per kilowatt). Instead, this project aims to develop fuel cell components (i.e., membranes, GDLs, bipolar plates and flow fields) that possess specific properties (i.e., water transport and conductivity). A computational fluid dynamics model will then be developed to elucidate the effect of certain parameters on these specific properties (i.e., the effect of membrane type and thickness on membrane water transport). Ultimately, the model will be used to determine sensitivity of fuel cell performance to component properties to determine limiting components and guide research.

Accomplishments

- Specified first iteration of GDL:
  - 150-190 μm thick.
  - One with no wet-proofing, one with 10 wt% Teflon® – poly-tetrafluoroethylene.
  - Target 77–80% porosity.
- Developed test station to measure diffusion coefficient of water through membrane. Test station measures diffusivity by contacting membrane with water vapor at different percent relative humidity (RH) on each side at nearly identical total pressures (i.e., by controlling ~10% RH difference between both sides of the membrane).
- Developed first iteration of fuel cell flow fields to achieve specific water transport and thermal management targets.
- Designed segmented cell to quantify fuel cell voltage vs. current at different points along the active area. Segmented cell will be used to identify regions of varying water transport and thermal management properties.
- Preliminary development of proton exchange membrane.

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Introduction

Many fuel cell component properties that influence water transport and thermal management are not well-understood [1,2]. A better understanding of how water transport and thermal management can be controlled would represent a significant step forward in meeting the DOE's stated 2015 targets. This project aims for a better understanding of water transport and thermal management by tailoring fuel cell components to exhibit specific transport properties. These transport properties will then be modeled, which will enable the prediction of the effect of changing component parameters on transport properties.

Approach

This project seeks to develop fuel cell components possessing specific transport properties. Membranes will be developed to achieve certain water transport and conductivity. Bulk membrane properties (i.e., diffusivity, water uptake, conductivity) will be evaluated and modeled. GDLs and bipolar plates and flow fields will be developed, also tailored to achieve specific water transport and thermal management targets. The fuel cell performance will be evaluated using these components. The model will be used to predict the effect of changing component parameters (i.e., changing membrane type and thickness, changing flow field configuration) on component transport properties and fuel cell performance.

Results

The first iteration of GDLs has been developed by the University of South Carolina and Engineered Fibers Technology, a subcontractor that has recently been replaced by Ballard Material Products. The GDLs are carbon-paper based and tailored to specific water transport properties. Engineered Fibers Technology is no longer able to supply customer-designed GDL materials; the subcontract has recently been moved to Ballard Material Products who can supply GDL materials possessing properties that are specified.

A test station designed to measure water diffusion in membranes has been developed, the schematic of which is shown in Figure 1. The test station consists of two sets of fuel cell hardware. One set serves as a membrane saturator, while the second set is the diffusion cell. Liquid water is kept on one side of the membrane saturator while the water vapor RH on the other side is controlled by a proportional valve. This is the water vapor in contact with one side of the membrane in the diffusion cell. The other side of the diffusion cell is in contact with water vapor at a lower RH, also controlled by a proportional valve. The flow rate of water through

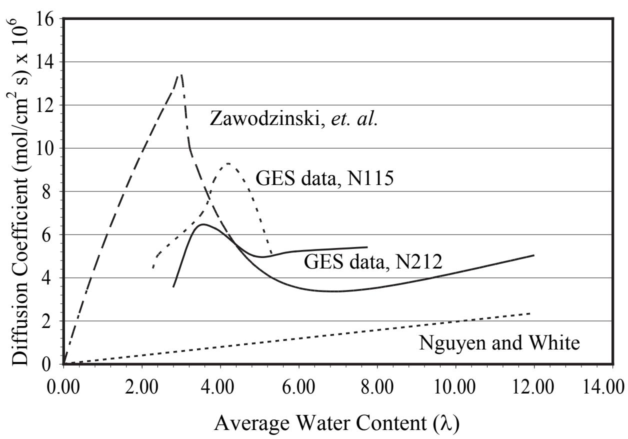

FIGURE 2. Preliminary Diffusion Coefficient Data for Nafion® 212 at 80°C

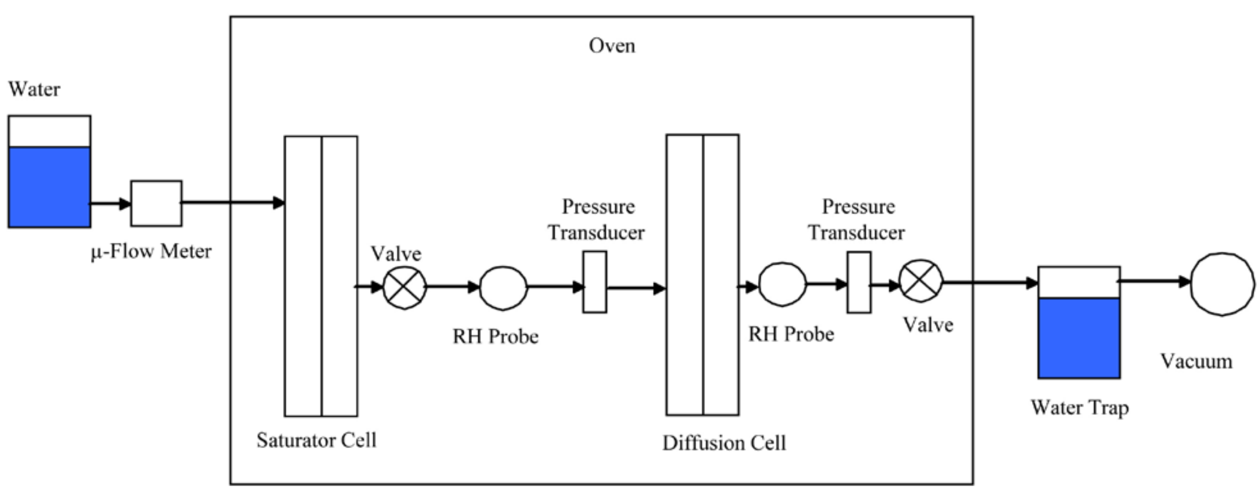

FIGURE 1. Diffusivity Test Station

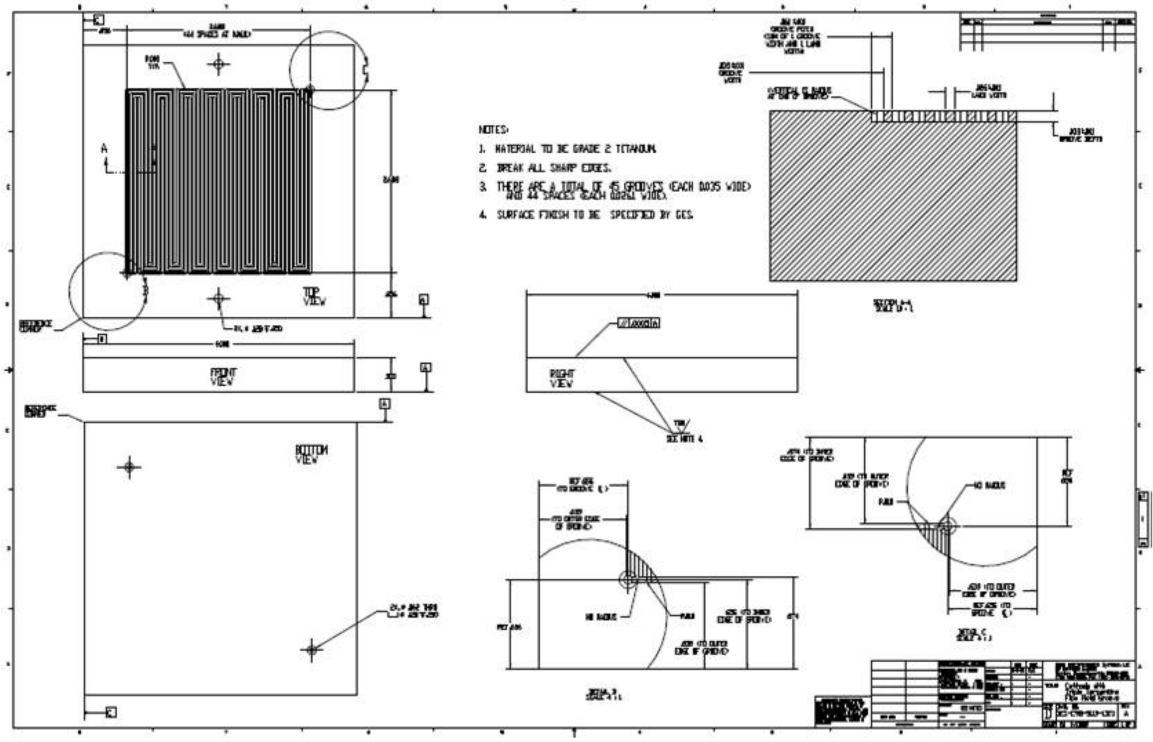

FIGURE 3. First Flow Field Design

the system is measured by a micro-flow meter. The diffusion coefficient is calculated by Fick's law assuming steady state. Figure 2 presents preliminary data measured.

The first flow field has been designed by the University of South Carolina and will be manufactured by Tech-Etch. A schematic of the design is shown in Figure 3. Virginia Tech has been exploring options to design proton exchange membranes for this project. GES has designed a segmented cell to measure voltage and current density in separate regions of the active area, along with water transport and thermal management properties.

Conclusions and Future Directions

Continued determination of bulk membrane properties will be a main focus of this ongoing project. These properties will be included in future modeling activities.

- Continue to measure diffusivity.
- Develop water uptake/conductivity test station.
- Work with new subcontractor (Ballard Material Products) to design GDLs.
- Develop bipolar plates and flow fields for system design.
- Implement rigorous fuel cell testing protocol.
- Develop computational fluid dynamics model to predict water transport and thermal management.
- Extend model develop components possessing optimal transport properties.

FY 2010 Publications/Presentations

1. "Transport Studies and Modeling in PEM Fuel Cells," DOE Annual Merit Review, poster FC054, June 8, 2010.

References

1. T.A. Zawodzinski, C. Derouin, S. Radzinski, R.J. Sherman, V.T. Smith, T.E. Springer and S. Gottesfeld, *J. Electrochem. Soc.*, **140**, 1041 (1993).

2. T.V. Nguyen and R.E. White, *J. Electrochem. Soc.*, **140**, 2178 (1993).