

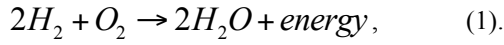
Neutron Radiography of Water Freezing in the Gas Diffusion Layer of a Hydrogen Fuel Cell

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INTRODUCTION

Research on hydrogen fuel cells is of considerable importance due to the need for dependable, renewable energy source solutions. The proton exchange membrane fuel cell (PEMFC) has proven promising for application to transportation vehicles. The PEMFC is an open electrochemical system capable of producing electromotive force from the catalytic reaction between hydrogen and oxygen. Within the PEMFC, water is produced through the reaction:



Water accumulation can pose a problem as its presence in the gas diffusion layer (GDL) can hinder fuel cell performance. Frozen water in the GDL can also damage fuel cell components and prevent startup, thereby hindering the use of the PEMFC in automobiles in cold climates. In-situ imaging techniques would help to elucidate the effects of freezing so that different materials and designs can be implemented to solve this freezing problem.

DESCRIPTION OF THE ACTUAL WORK

Neutron radiography (NR) is well suited for imaging water freezing within the PEMFC because neutrons interact strongly with water but are weakly attenuated by metals such as aluminum, out of which a fuel cell is often made. While NR has been used to image water in the channels of the fuel cell,¹ we will apply the method to imaging the freezing process in the GDL.^{2,3} To accomplish this, a simplified fuel cell mockup has been developed and is shown in Fig. 1 below.

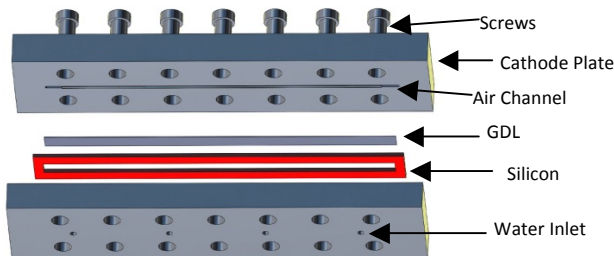


Fig. 1. Fuel Cell Mockup.

The top and bottom plates and screws are made of aluminum, a silicon gasket is used as a sealant, and the GDL is comprised of a carbon paper that is infused with

water for the purpose of the experiment. The infusion of water and an air channel on the opposite side mock the interactions that a GDL has in a fully working fuel cell. This mockup is advantageous since it allows observation of a single layer of a fuel cell and allows full control of operating and ambient conditions.

Neutron Radiography Experimental Setup

The neutron source at The University of Texas at Austin is a TRIGA Mark II Research Reactor which is capable of steady state operation at 1 MW. A neutron beam port provides a columnized, thermal neutron flux of 2×10^6 n/cm²-s at the sample.⁴ The neutron beam is attenuated by the sample and the resultant beam is incident on a LiF/ZnS scintillator screen. Lithium-6 has a very high (n,t) neutron cross section (960 b) which, when it absorbs a neutron, will emit a ³H atom and subsequently stimulate the phosphor that can be acquired by a single-photon sensitive ANDOR CCD camera. The sample will attenuate differently based on the neutron cross-sections of the materials in the sample. Neutrons will be heavily attenuated by water but weakly attenuated by aluminum which will give good contrast in the radiographs.

RESULTS

Neutron radiography was used to study the freezing of a 1/16" (1.6mm) water column sample contained within aluminum tubing in order to quantify a change in neutron flux due to a 7.2% change in density from water to ice.⁵ The sample was placed in the neutron beam line in front of the scintillator screen, frozen with dry ice and then allowed to thaw. At the full 1/16" thickness the expected flux difference in the column can be calculated by dividing the ice radiograph from the water radiograph as follows:

$$\frac{I_{ice}}{I_{water}} = \frac{I_o e^{-\sigma n_i t}}{I_o e^{-\sigma n_w t}} = e^{-\sigma t (n_i - n_w)} = 1.04. \quad (2)$$

The data shown in Fig. 2, are close to those predicted by Eq. (2)

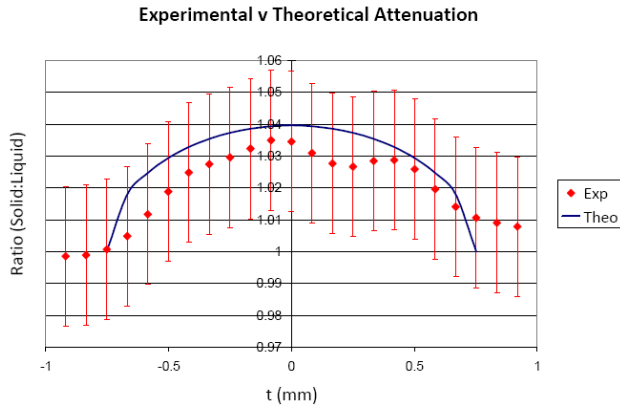


Fig. 2. Experimental density change corresponding to neutron flux change. The vertical axis whos I/I_0 and the horizontal axis is position relative to the centerline of the tube.

The varying thickness of water over the cross section of the water column is noticed in the predicted and experimental data shown in Fig. 2. The shape of the experimental data fits very well with the predicted values. However, the data has large standard deviation due mainly to image noise and it is also slightly lower than predicted,. The latter condition likely arises from a slight shift in sample position as a result of thermal expansion.

The technique outlined here will next be applied to imaging freezing water in the fuel cell mockup. The NR system must be fully optimized to be able to image water freezing at a thickness on the order of 200 μm in the GDL and will improve current methods for high resolution NR.

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