Visualizing liquid water in PEM fuel cells using X-ray based radiography in through- and in-planes

Jongmin Lee, James Hinebaugh, and Aimy Bazylak
Microscale Energy Systems Transport Phenomena Laboratory, Dept. of Mechanical & Industrial Engineering
Faculty of Applied Science and Engineering
University of Toronto
5 Kings College Rd
Toronto, Canada, M5S 3G8

The polymer electrolyte membrane (PEM) fuel cell electrochemically converts hydrogen into electricity with zero local-green house gas emissions. Improving the performance of PEM fuel cells can lead to reduced costs through the need for smaller fuel cells; however, the performance is currently limited by mass transport limitations caused by excess liquid water. Water produced from the electrochemical reactions occupies pores of the gas diffusion layer (GDL) and hinders reactant transport. In addition, the properties of the GDL (porosity, pore sizes, wettability, etc.) and operating conditions significantly impact the water transport behaviour. Understanding the relationship between the GDL, operating conditions, and the resulting water transport behavior is needed to improve water management strategies for PEM fuel cells.

We previously investigated the accumulation and distribution of liquid water in an operating PEM fuel cell with synchrotron X-ray radiography (1-4), where distinct, separate fuel cells were designed for either through-plane or in-plane investigation. The through-plane studies provided two-dimensional water distribution maps of the cross-section of the cell (2), while the dynamic evolution of liquid water clusters within the GDL and droplets on the surface of the GDL were observed with in-plane imaging (1, 4). In this work, we present a new PEM fuel cell designed for sequential through-plane and in-plane imaging.

Visualizations took place at the BioMedical Imaging and Therapy Bending Magnet (05B1-1) beamline at Canadian Light Source Inc. (Saskatoon, Canada). Measures were taken to increase the image quality after our previous work (3). The active area was reduced to $5 cm^2$ from $25 cm^2$ in order increase the visualized fraction of the active area. A thin membrane (N212) was employed to lessen the impact of membrane swelling, which led to artifacts in our previous work.

Although it was not possible to capture both the through-plane and in-plane images simultaneously, the through-plane and in-plane experiments were performed sequentially and immediately one after the other with the same operating procedures. Example through-plane and in-plane images are presented in Figure 1 and 2, respectively. While we do not expect the liquid water distributions to be identical between images taken at the same operating conditions, the common trends observed between the through-plane and in-plane experiments are of interest and will be discussed in detail. The work presented here will provide a three dimensional perspective into the liquid water transport behaviour in an operating PEM fuel cell.

References:

1. J. Lee, J. Hinebaugh and A. Bazylak, *219th Electrochemical Society Meeting, Montreal, QC.*, **Abstract # 211** (May 1-6, 2011).
2. Hinebaugh, J.,Lee J., Bazylak A., *Journal of the Electrochemical Society.*, 159 (12), F826-F830 (2012).
3. J. Hinebaugh, P. R. Challa and A. Bazylak, *J. Synchrotron Rad.*, 19, 994-1000 (2012).
4. J. Lee, J. Hinebaugh and A. Bazylak, *J.Power Sources.*, (2012 (accepted)).

Figure 1: In-plane image of the PEM fuel cell. Solid grey regions are the ribs, and dark regions correspond to the presence of liquid water.

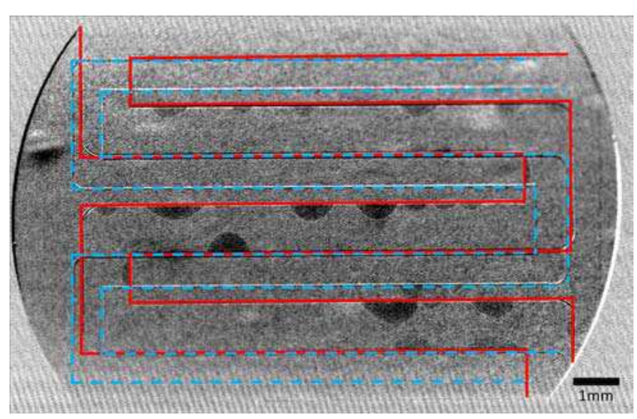

Figure 2: Through-plane image of the PEM fuel cell. The cathode channel is highlighted with solid red lines, and the anode channel is highlighted with dashed blue lines. The dark regions correspond to the presence of liquid water.