WATER DISTRIBUTION MEASUREMENTS WITHIN PROTON EXCHANGE MEMBRANE FUEL CELLS

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ABSTRACT

Polymer electrolyte membrane (PEM) fuel cells are pursued for electrical power applications ranging from small handheld devices to transportation and stationary units. Despite the promise of high efficiencies with little to no harmful emissions, PEM fuel cells require additional development to reach the performance and cost targets needed to displace existing technologies. A significant level of effort is being applied to the development of numerical modeling techniques required to support these improvements. Unfortunately, there are only a limited number of experimental methods available to validate these models. In most cases, only overall, integrated results are used to validate the complex results produced by these models.

Low-temperature PEM fuel cell performance is highly dependent on water within critical components of the fuel cell, including the membrane, electrodes, gas diffusion layers, and plate flow channels. In-situ measurement of water would provide critical insight on the impact of water distribution on fuel cell performance, as well as provide much needed data for more thorough validation of numerical models.

Neutron imaging has been proven as a valuable tool for in-situ, non-invasive measurement of water in flow channels and gas diffusion layers of PEM fuel cells. In this work, we have demonstrated that neutron imaging is sensitive enough to detect small variations in hydration *within* the membrane. Recent advances in neutron imaging methods have produced sub-20 μm spatial resolutions. These advancements in detection technology were utilized to measure water concentration distributions throughout Nafion® 117 membranes within operating fuel cells as a function of anode and cathode humidification, current density, and temperature.

The measured water concentration distribution across the membrane thickness was unexpected and complex. Most models predict continuously increasing membrane hydration from the anode to the cathode, with peak hydration located at the cathode electrode interface. We found peak water concentrations located near the center of the membrane, shifting toward the cathode with increasing current (as expected). The anode membrane interface contained less water than at the cathode membrane interface (also as expected). The cause of these unexpected water concentration distributions within the membrane is unknown but might be due to various factors including non-homogeneity of material properties or localized heating/temperature distributions.

Impedance measurements taken during the same experiments were compared to predicted impedance by using the water concentration distribution in the well-accepted hydration-conductivity model suggested by Springer. There is alignment in the general trend of the hydration – conductivity behavior but with significant deviations between the predicted and measured conductivities. The basic difference between the present work and that of Springer is the use of in-situ measurements (taken during realistic fuel cell operating conditions) versus ex-situ measurements, respectively.

Further refinement of experimental techniques and hardware will better reveal the complex mechanisms which drive fuel cell performance. Continued testing will provide a more extensive database which could be used to challenge, validate, and develop the basic to the most complete PEM fuel cell models.