European Fuel Cell Car Workshop | March, 1st - 3rd 2017, Orléans, France

Water management in the Gas Diffusion Layer of PEM fuel cells: dynamic breakthrough effects on porous media liquid water saturation

S. Chevalier, C. Josset, and B Auvity
Laboratoire de Thermique et Énergie de Nantes (CNRS UMR 6607), Polytech Nantes, Rue C. Pauc, CS 50609, 44 3016 Nantes Cedex 3, France

bruno.auvity@univ-nantes.fr

Keywords: Gas Diffusion Layer, water management, liquid saturation, porous media, dynamic breakthrough

Polymer Electrolyte Membrane (PEM) fuel cells are just beginning to reach the market place. They are being used in backup power applications as well as in the transportation sector. Worldwide, major automotive manufacturers, such as Toyota [1], Nissan, Hyundai and Volkswagen, are developing fuel cell vehicles that will extend the range of battery-only electric vehicle and drastically reduced the refueling time.
However, the widespread adoption of fuel cell technologies has been hindered by high costs and limited durability – to which insufficient water management is a key contributor. PEM fuel cells are fed with hydrogen and oxygen gas from air to produce electricity with water and heat as the only by-products, and porous materials (termed the gas diffusion layers (GDLs)) are used to evenly distribute the reactant gases. A small portion of the water produced by the electrochemical reaction is actually required to humidify the polymer membrane minimizing the ionic resistance. However, in practice, an excess of liquid water tends to accumulate in the GDL and block the pathways that are needed for the reactants to reach the catalytic sites. This excess liquid water can lead to flooding, uneven power generation, and irreversible material damage. With the physical barriers of excess liquid water removed, the power density and affordability of fuel cells for transportation will reach the targets needed for commercial success.

Liquid water flow inside a GDL is intrinsically unsteady. Whatever is the way the water enters the GDL, i.e. under vapor or liquid state, most part of the water travels through the porous media to the gas channel under discontinuous form. Manke et al. [2] observed the dynamic breakthrough of liquid water in an operating fuel cell using X-ray radiography. They noticed that the liquid saturation at a given location fluctuates, not only inside the GDL but also in the channel. The liquid water breakthrough at the channel/GDL interface induces strong transient pressure variations inside the liquid phase. The pressure fluctuation can affect the local liquid saturation and may explain the change in breakthrough location, that is not predicted by classical invasion-percolation methods used to compute the two-phase flow inside the GDL.

In this communication, a droplet growth model in a two-pore network will be presented to clarify the flow interaction between two neighbouring pores. This work is based on a recently published “one-drop” model [3]. The model takes into account both viscous and capillary effects dominating the fluid transport in porous media. Results obtained with this model show that, as the viscous effects get predominant over capillary effects, a change in the preferential location of droplet emission is revealed. The model is validated using experimental visualizations of the droplet formations at the tip of two connected capillaries. Furthermore, a simple capillary network is realized in a microfluidic device. With this basic network, the change in preferential paths for liquid water invasion is confirmed. It clearly highlights the modification of the network saturation as the flow regime is varied from the capillary to the viscous regime.

REFERENCES

1. T. Yoshida, K. Kojima, Toyota MIRAI Fuel Cell Vehicle and Progress Toward a Future Hydrogen Society, *Interface Mag*. **24** 45–49 (2015).
2. I. Manke, C. Hartnig, M. Grünerbel, W. Lehnert, N. Kardjilov, a. Haibel, a. Hilger, J. Banhart, and H. Riesemeier, Investigation of water evolution and transport in fuel cells with high resolution synchrotron x-ray radiography, *Applied Physics Letter* **90** (17), 174105 (2007)
3. G. Flipo, C. Josset, G. Giacoppo, G. Squadritto, B. Auvity and J. Bellettre, Eruptive water transport in PEMFC: A single-drop capillary model” *Int. J. Hydrogen Energy*, **40** (12), 14667–14675 (2015).