Fundamentals of Two-Phase Flow Phenomena in Fuel Cells

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Description: In the past two decades, environmental concerns and stronger emission regulations have led to a renewed interest in Proton Exchange Membrane Fuel Cells (PEMFC). Performance gains in PEMFC can be attained by utilizing microchannels (0.05 – 1 mm) to improve gas routing. However, they complicate water management particularly in terms of flooding. The complexities of water management have been previously investigated, but there still exists an urgent need for a detailed study of two-phase flow in microchannels and water transport interactions with the GDL.

This work focuses on the experimental investigation, visualization and modeling of mass transport induced two-phase flow in microchannels. Test samples replicating the distributed water injection that occurs in actual fuel cell microchannels are either microfabricated or produced by stereolithography (see Figure 1). Side channels or slots perpendicular to the main microchannel are used in the microfabricated samples while the stereolithography samples incorporate a sandwiched gas diffusion layer (GDL) for distributed water injection into the main channel.

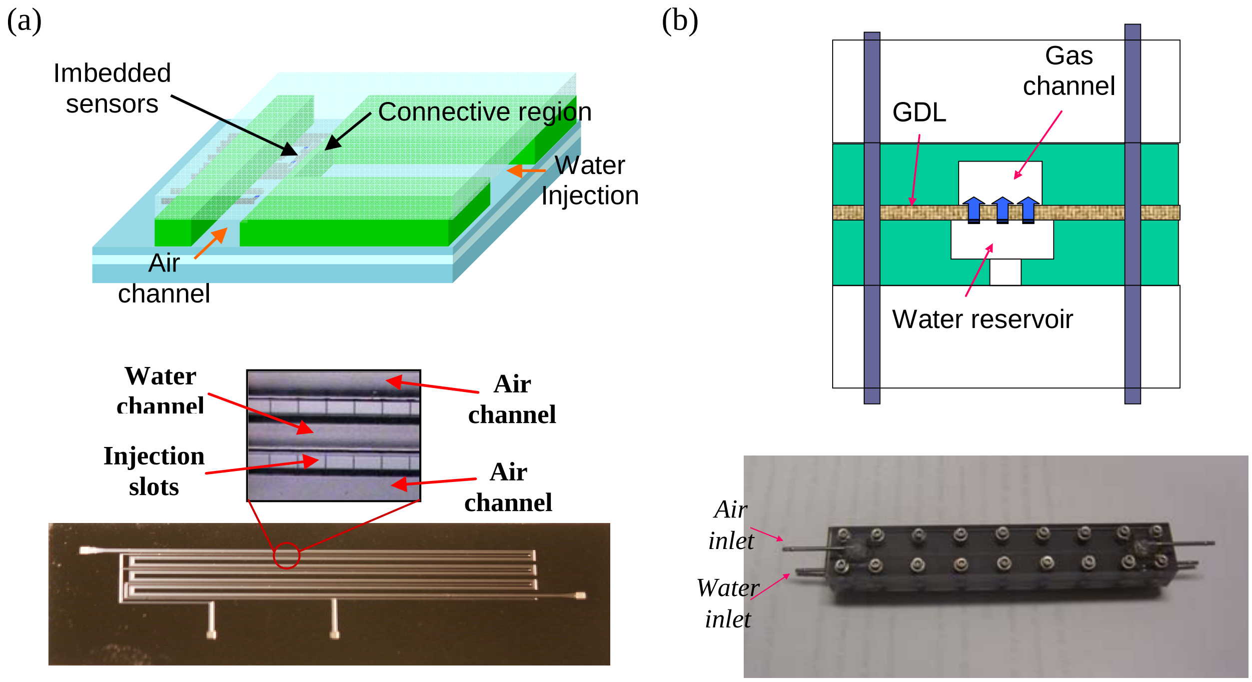

Figure 1: Microchannel test samples are either (a) microfabricated or (b) produced by stereolithography.

Important flow parameters such as friction factor and Nusselt number, which govern the fluid mechanics and heat transfer characteristics of the flow, can be extracted from measurements performed using these samples. Likewise, flow visualization studies provide information in terms of flow structure, regimes and transitions characteristics.

Figure 2 shows flow and detachment regime maps constructed using imaging data. The flow regime map on the left relates flow structure to superficial air and water velocities (equivalent to volumetric flow rates). The liquid droplet detachment regime map on the right relates the two major forces involved in the detachment of liquid droplets, namely pressure gradient drag and inertial drag, as a function of Reynolds number. Detachment of liquid droplets occurs when either one of these two forces (or both) overcomes surface tension.

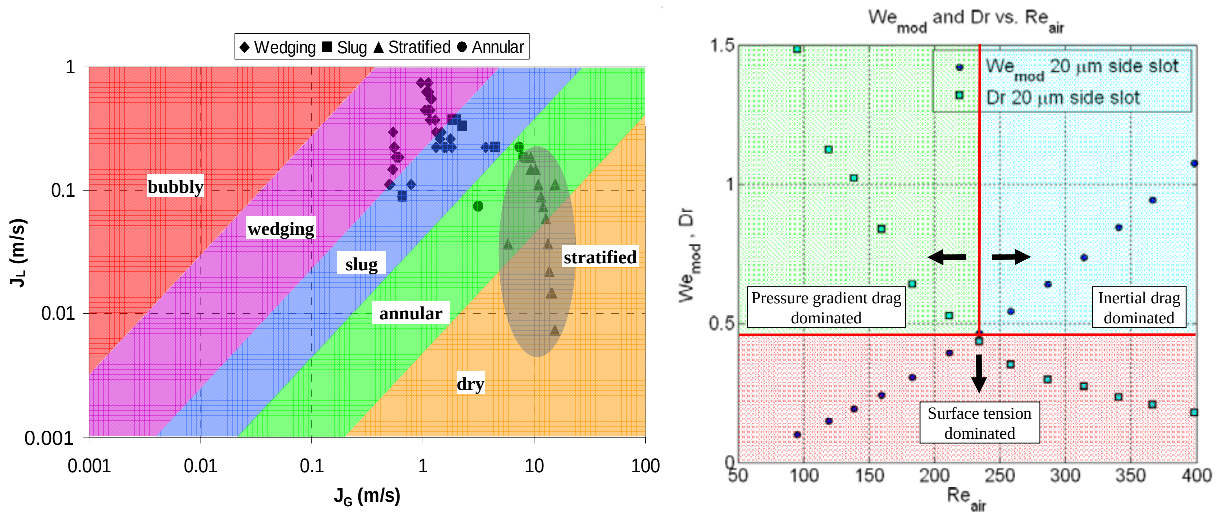

Figure 2: Flow regime (left) and liquid droplet detachment regime (right) maps.

Status: We continue to investigate the effects of water injection on flow behavior and develop models that accurately capture the physics of some simple flows.

Publications:

C. H. Hidrovo et al., "Water Slug Detachment in Two-Phase Hydrophobic Microchannel Flows", ICMM2005.
E. S. Lee et al., "Flow Structures and Frictional Characteristics on Two-Phase Flow in Microchannels in PEM Fuel Cells", FEDSM2005.
F.-M. Wang et al., "Investigation of Two-Phase Transport Phenomena in Microchannels Using a Microfabricated Experimental Structure", HeatSET 2005.
J. E. Steinbrenner et al., "Measurement and Modeling of Liquid Film Thickness Evolution in Stratified Two-Phase Microchannel Flows", HeatSET 2005.
C. H. Hidrovo, et al., "Experimental Investigation and Visualization of Two-Phase Flow and Water Transport in Microchannels", IMECE04.
S. Vigneron, et al., "1D Homogeneous Modeling of Microchannel Two-Phase Flow for Water Management Purposes in Proton Exchange Membrane Fuel Cells", IMECE04.

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