Microfluidic Investigation of Oxygen Bubble Transport through the Gas Diffusion Layer of PEM Electrolyzers

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The polymer electrolyte membrane (PEM) electrolyzer is a promising technology that reduces water into hydrogen and oxygen, from which the hydrogen is captured and stored for use in fuel cells. One of the challenging issues in PEM electrolyzers is the inhibition of liquid water flow within the porous gas diffusion layer (GDL), due to the formation of oxygen bubbles [1]. The bubbles block pores within the GDL, limiting the transport of liquid water to the catalyst layer, which in turn negatively impacts the electrolyzer performance [2]. Moreover, the presence of the oxygen bubbles can increase the solution resistance, inhibit electron transfer, and consequently increase ohmic losses, leading to efficiency reduction [1]. In this study, a microfluidic platform has been designed and fabricated to investigate the oxygen bubble invasion in simulated GDL materials. The fabrication procedure of a microfluidic chip is depicted on figure 1. The microfluidic platform was used to observe the growth, detachment, and propagation of air bubbles in a water-saturated porous medium and determine the influence of the geometrical properties of the medium on the bubble transport behavior. The representative two-dimensional structure is designed using three-dimensional (3D) volumetric pore space information, e.g. porosity distribution, calculated using micro-computed tomography (µCT). Three GDL structures (felt, sintered powder, and foam), are considered in this study.

The fabricated porous networks were fed continuously at an airflow rate corresponding to typical current density conditions for a PEM electrolyzer. Microfluidic channels were fabricated in polydimethylsiloxane elastomer, and to mimic the interfacial properties of water in titanium GDLs, ethanol was used as the wetting fluid. The visualization of the bubble movement was performed using fluorescence microscopy by adding a fluorescing dye to the ethanol to distinguish between the air bubbles and liquid. The greyscale images of the breakthrough moment for the microfluidic chips representing sintered powder, felt and foam GDLs are exhibited on figures 2, 3 and 4, respectively. The air saturation in the porous medium was calculated and used as a quantitative parameter to compare microscale GDL structures. The outcome of this study can be used to improve the GDL microstructure design to reduce gas blockage and enhance the performance of PEM electrolyzers.

Acknowledgements

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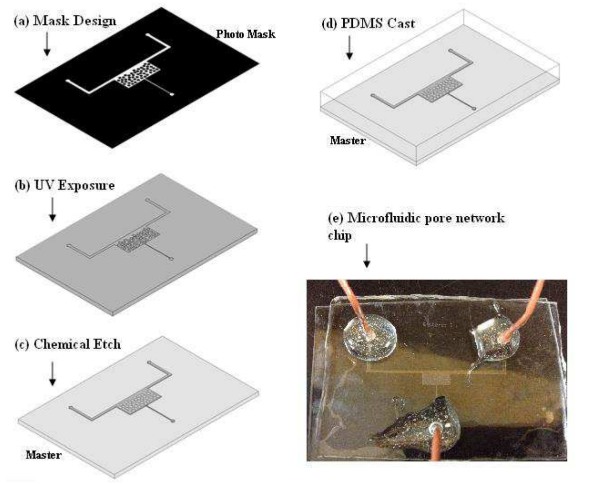

Figure 1. Fabrication procedure for a microfluidic chip (a) A photomask is produced. (b) A flat substrate coated with a thin photoresist layer is exposed to UV light. (c) Unexposed photoresist is chemically etched away, leaving a planar 3D pore network structure (master). (d) A PDMS elastomeric replica of master is cast (e) Cured PDMS is bonded to a glass slide to make the microfluidic chip.

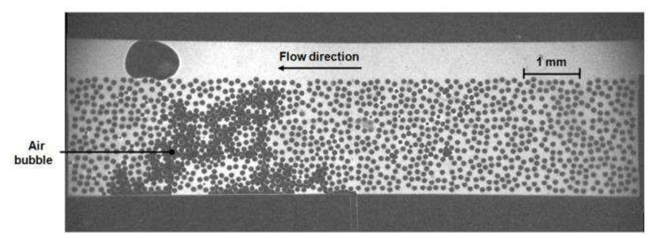

Figure 2: Greyscale image of the breakthrough moment for the microfluidic chip representing the sintered powder GDL.

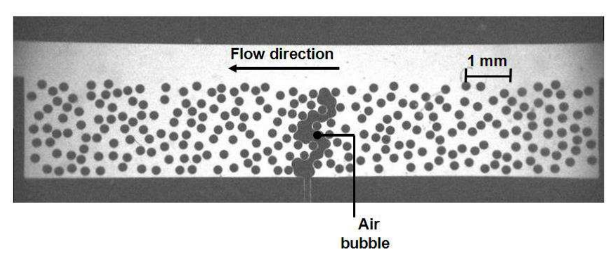

Figure 3: Greyscale image of the breakthrough moment for the microfluidic chip representing the felt GDL.

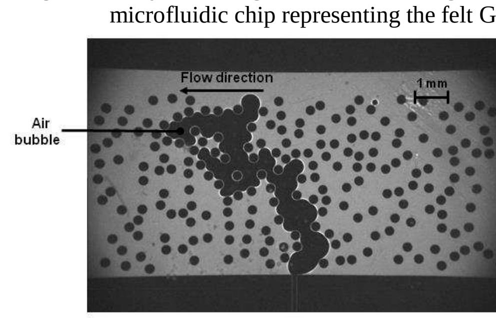

Figure 4: Greyscale image of the breakthrough moment for the microfluidic chip representing the foam GDL.

References

[1] H. Matsushima, et al., "Water electrolysis under microgravity: Part 1. Experimental technique," Electrochimica acta, vol. 48, pp. 4119-4125, 2003.
[2] H. Ito, et al., "Experimental study on porous current collectors of PEM electrolyzers," International Journal of Hydrogen Energy, vol. 37, pp. 7418-7428, 2012.