A New Diagnostic Tool for Liquid Water Management in PEM Fuel Cells Using Interdigitated Flow Fields

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INTRODUCTION

In PEM fuel cells, excessive amount of liquid water in the electrode can flood the backing and catalysts layers, which leads to poorer fuel cell performance. Electrode flooding problem is more severe in the cathode where water is generated by oxygen reduction and electro-osmotic drag of protons. It is now well-known that cathode flooding is the dominant controlling factor of the performance of PEM fuel cells operated at medium to high current densities. To minimize the effect of electrode flooding, the interdigitated flow distributors are employed in some PEM fuel cells [1]. This flow field design forces gas flow through the porous backing layer. The convective gas flow provides more effective gas transport and liquid water removal [1]. In addition to evaporation and back diffusion through the membrane, liquid water can also removed by the shear drag force of the convective gas flow. To develop an efficient water management scheme, one needs to know the extent of electrode flooding and the relative rates of different water transport mechanisms. The objective of this study is to develop a diagnostic tool that can provide such information.

Experiments have shown that the pressure drop between the inlet and outlet of the cell can be used as a diagnostic signal for monitoring the extent of electrode flooding in a PEM fuel cell using interdigitated flow distributors [2]. Since the gas has to flow through the porous backing layers in the interdigitated flow field design, the pressure drop across the cell is predominantly controlled by the pressure drop caused by the convective flow through the backing layers. The gas permeability of the backing layer is a strong function of liquid water saturation (or the amount of liquid water in the porous layer). For a constant gas flow rate, the pressure drop is directly proportional to the gas permeability (Darcy's law); therefore pressure drop measurements can be correlated with liquid water level in the electrode.

EXPERIMENTAL

Two pressure transducers were placed at the inlets of both anode and cathode; the outlets of the cell were exposed to atmosphere. The cell was running under either voltage stepping mode (between open circuit voltage and 0.5 volts) or current stepping mode (between 0 and 0.3 A/cm^2). The cell temperature is controlled at 30, 35, 40 ^{o}C ($\pm$0.5 ^{o}C). Hydrogen and air flow through sparging bottles at room temperature (~ 20 ^{o}C) before they are fed into the cell. The flow rate of hydrogen is held at 1.2 A/cm^2 equivalent. Flow rate of air for most the experiment is held at 1.0 A/cm^2.

RESULTS AND DISCUSSIONS

Figure 1 shows the pressure drop experiment at 35 ^{o}C. When we started the experiment, both the cathode and anode were relatively dry. Therefore, there was no change in the pressure drops in both cathode and anode for the first hour of the experiment, when the cell was at open circuits. As soon as the cell voltage was lower to 0.5 V, the current densities went to 0.42 A/cm2 and then quickly drop in the first 20 minutes of the step. In the same time frame, a sharp increase in the cathode pressure drop is observed. The increase of cathode pressure drop was attributed to liquid water accumulating in the backing layer. After 40 min, the pressure drops oscillates around 0.56 psi. The oscillation is caused by liquid water being flushed out and re-accumulation. Assuming the exhaust stream was saturated with water vapor, one could estimate that the water removed by evaporation accounted for only about 35% of the total water generated. During the next cell open-circuit step, the cathode pressure drop quickly decreased because the water removal by shear drag is faster than evaporation and back diffusion. A slight increase in anode pressure drop was observed, which could be attributed to back diffusion of water. Under these operating conditions, cathode pressure drop took about one hour to stabilize out after it was put under open circuit.

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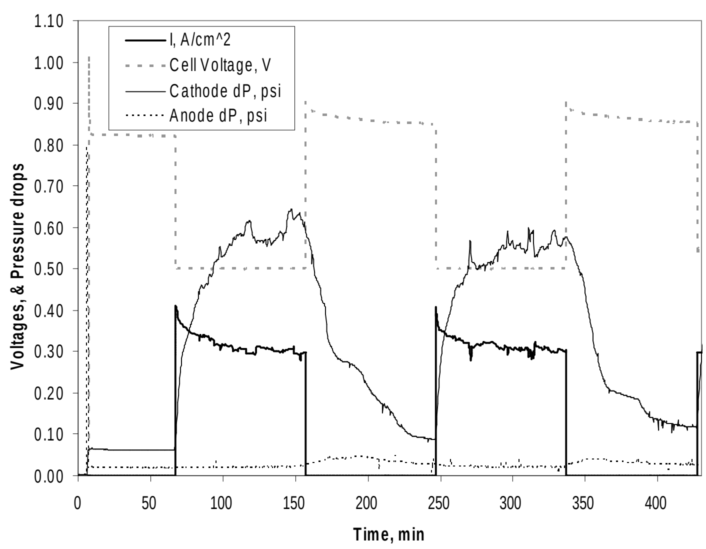

Figure 1. Pressure drop at 35 ^{o}C, voltage stepping mode.