Experimental Investigation of Degradation in PEMFC with Dead-Ended Anode Operation

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Fuel cell durability and cost are two important concerns for commercializing Polymer Electrolyte Membrane Fuel Cell (PEMFC) systems. A Dead-Ended Anode (DEA) system has lower cost because fewer components are required (no hydrogen humidification and anode recirculation hardware). However, there may be a design trade-off between cost/system complexity and degradation. Yet very few experimental reports published in the literature address the degradation phenomena when operating with a DEA. Our prior work reported the various types of degradation phenomena progressed at different locations during DEA operation [1]. At the inlet the dry hydrogen gas supply contributed to membrane decomposition and delamination, whereas carbon corrosion was observed near the end of the channels. These results also showed that the current level affects degradation rate. The fuel cell membrane failures were predicated by high current operation.

In this study, the degradation phenomena of the PEMFC operated with DEA at the mid current range is observed. A single cell with 54cm^2 active area is tested with a specially designed DEA system until clear performance loss is observed or until the operation time reached 1000 hours. During this test, the cell temperature is maintained at 60 ºC and cathode inlet relative humidity is maintained at 100%. During DEA operation, the anode hydrogen supply is totally dry. Cathode stoichiometry is maintained at 2.5. During DEA mode, the cell is operated with a galvanostatic 0.4 A cm^{-2} load. Periodic performance evaluation and AC impedance measurements while operating the cell in flow through (FT) mode were performed during the experiment. In FT mode, cell temperature is maintained at 60 ºC or 45 ºC and relative humidity is maintained at 100% for the anode and cathode. Stoichiometry is maintained at 2.5 for the cathode and 1.2 for the anode.

Figure 1 shows the time evolution of i-V(a) and i-R(b) curves during the test when the cell temperature was maintained at 60 ºC. The result shows the cell performance reduced gradually over the 1000 hours. The Ohmic resistance increased initially then remained very stable, whereas the activation loss continually increased. This indicates that the catalyst layer degradation progressed gradually throughout the test.

Figure 2 shows data from the AC impedance measurements. The High Frequency Resistance (HFR) is related to the membrane resistance, which is indicated by the left edge of the circle. The HFR has only a very small increase during the initial portion of the experiment. The Low Frequency Resistance (LFR) increases throughout the duration of the experiment, tripling in magnitude by the end of the test. Hence electrode degradation, carbon corrosion, and the resulting ECSA loss may be the dominant mechanisms responsible for the performance drop.

This study showed that, when operating at mid-range load with a DEA, gradual and continuous electrode degradation occurs. This degradation is related to nitrogen and water accumulation in the anode channel during DEA operation. The degradation could be reduced by controlling when the anode is purged [2].

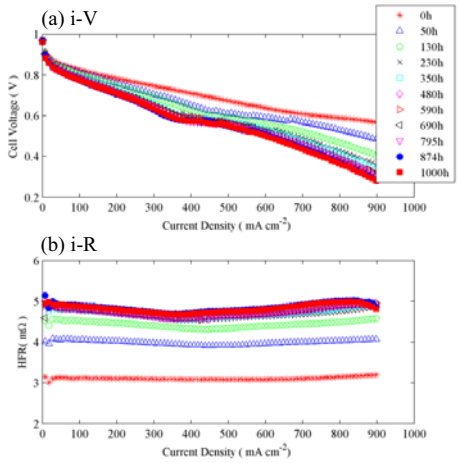

Figure 1: Time evolution of i-V and i-R curves (Cell temperature = 60 ºC)

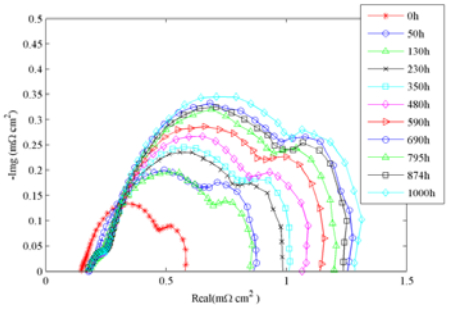

Figure 2: Time evolution of AC impedance spectra when 0.2 A cm^{-2} load applied to the cell (Cell temperature = 60 ºC)

ACKNOWLEDGMENT
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1. T.Matsuura, J.B.Siegel, J.Chen, A. G. Stefanopoulou, 9th Fuel Cell Science, Engineering and Technology Conference (2011)

2. J.Chen, J.B.Siegel, T.Matsuura, A. G. Stefanopoulou, Journal of The Electrochemical Society, 158 B1164-B1174 (2011)