Experimental and Computational Study of Ultra-High Fuel Utilization Operation in Polymer Electrolyte Fuel Cells

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Ultra-high fuel utilization (~98%) operation and/or extreme conditions close to fuel starvation are of fundamental interest to automotive fuel cells. This combined experimental and computational study aims at investigating performance and operational stability of polymer electrolyte fuel cells (PEFC) under ultra-high fuel utilization. Polarization experiments, current distribution measurements, along with three-dimensional simulation of reactant and water distributions, have been carried out to shed light on the fundamentals of ultra-high fuel utilization operation.

Figure 1 compares the experimental polarization curves for ultra-low anode stoichiometry (i.e. 1.02) with a standard fuel stoichiometry of 1.5. It can be seen that there is no performance loss in the moderate to high current density region, i.e. >0.7 A/cm^2.

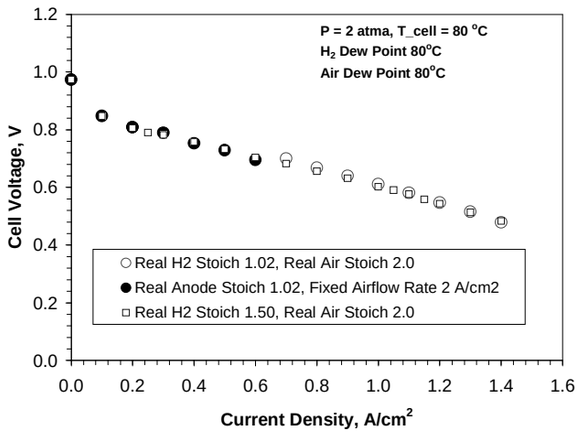

Figure 1. Polarization curves for anode stoichiometry of 1.5 and 1.02.

Our computational study, based on a three-dimensional, transport and electrochemical fully coupled model, confirmed this experimental observation. Furthermore it is revealed that the hydrogen concentration along the anode flow channel does not decrease by more than 4% even in the case of ultra-low anode stoichiometry (i.e. 1.02), as shown in Fig.2.

However, we find that for current densities less than 0.6 A/cm^2, air stoichiometry must be increased in order maintain stable and similar performance under ultra-low anode stoichiometry. This is because the ability for the anode gas to carry away water produced within the cell diminishes when the anode stoichiometry becomes so low. Consequently, the air stoichiometry has to be increased a little bit in order to manage proper water balance within the cell. This drawback of ultra-high fuel utilization strategy likely vanishes for large-scale fuel cells where the cathode air flowrate is sufficiently large even at very low current densities.

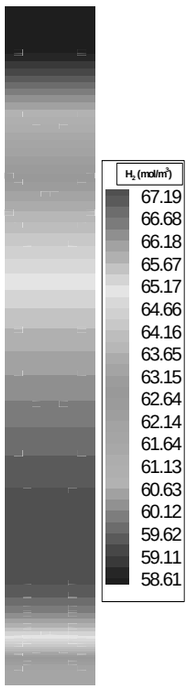

Figure 2. Hydrogen molar concentration distribution in the anode gas channel for the anode stoichiometry of 1.02.