Estimation of Localized O2 Starvation Using 3D Modelling for PEM Fuel Cells

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Abstract

Air breathing proton exchange membrane fuel cells (PEMFC) have now found its use in wide range of domestic and commercial energy based applications. Ensuring safety against oxygen starvation during transient load variation reduces the degradation of membrane electrode assembly (MEA).

A three dimensional model of a PEM fuel cell is implemented using COMSOL Multiphysics® platform. The schematic of the model is shown in Figure 1.

The cathode air humidity is stepwise increased to study the consequent oxygen starvation and fuel cell degradation mechanism.

Simulation has been performed for three cases. The first case was simulated with normal humidity where the membrane is fully hydrated. In the second case there was 50 % increase in humidity while there was 100% increase in humidity for the third case.

With normal humidity, negligible or very low O2 starvation occurs along the channel as the channel remains fully O2 rich. A highly linear variation in electrolyte potential from -0.063 V to -0.055 V along the channel is observed. In this close to optimal situation, the drop in electrolyte potential is not significant to cause any carbon corrosion. The peak power density of 370 mW/cm2 is obtained at 1.06 A/Cm2 fuel cell average current density. The lowest O2 concentration was 0.0154 mol/m3 at the extreme right end of the channel. This O2 concentration is good enough to run fuel cell normally. But in the second case, oxygen concentration found in the right side end of the cathode channel (L=20 mm) is 2.6179E-3. This O2 concentration indicates O2 starvation in the channel. Also higher nonlinearity in electrolyte potential variation along the fuel cell channel is observed with the electrolyte potential going to -0.01 V, from channel length of 16 mm where the O2 concentration has dropped considerably. Hence it is possible that heavy carbon corrosion may occur in the channel length ranging from 16mm to 20mm. Also it is found that the maximum power density drops to 230 mW per cm2 for this case of operation. This power density is 140 units less than that observed in the first case. Finally, for case 3 ,it is observed that from channel length of 6 mm onwards, O2 concentration drops to a drastically low value unsuitable for normal fuel cell operation. The electrolyte potential drops close to zero from channel length 6 mm onwards can be observed from Figure 3. From channel length 10mm onwards, the electrolyte potential goes to -0.01 V or more. . So the cell is

completely devoid of O2 from channel length 14 mm onwards. Significant carbon corrosion will occur in this region causing irreversible membrane degradation and considerable drop in fuel cell output power. Maximum fuel cell power density is found out to be only 150 mW/cm2. Figure 4 shows the oxygen starved channel length as per increment in cathode air humidity ratio.

A 3D model of the PEM fuel cell was implemented and Oxygen starvation has been observed in case 2 & 3. The position at which the oxygen starvation occurs has been carefully monitored.

Reference

[1] C. A. Reiser, L. Bregoli, T.W. Patterson, J.S. Yi, J.D. Yang, M.L. Perry, and T.D. Jarvi, "A reverse current decay mechanism for fuel cells," Electrochemical and Solid-State Letters 8, (2005) pp. A273–A276.

Figures used in the abstract

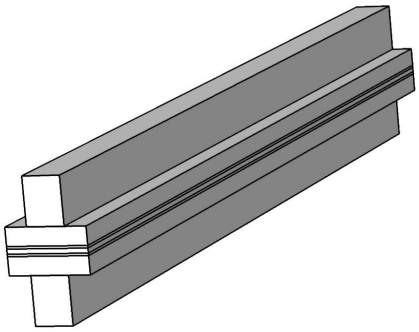

Figure 1: Schematic of the model

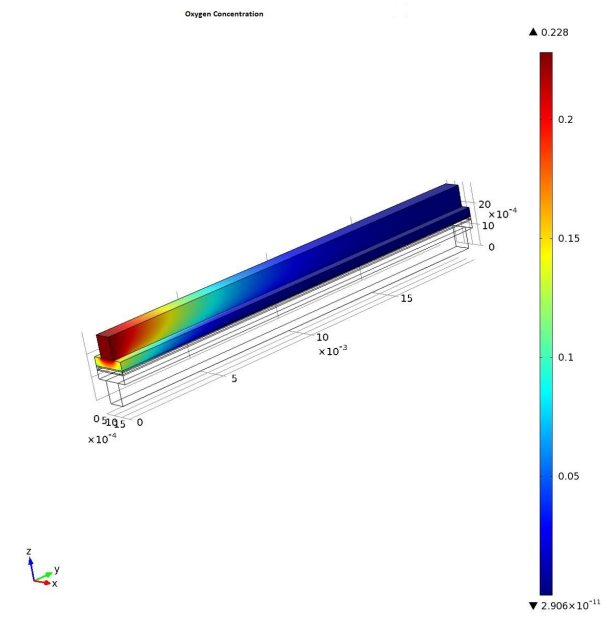

Figure 2: Oxygen concentration for case 3

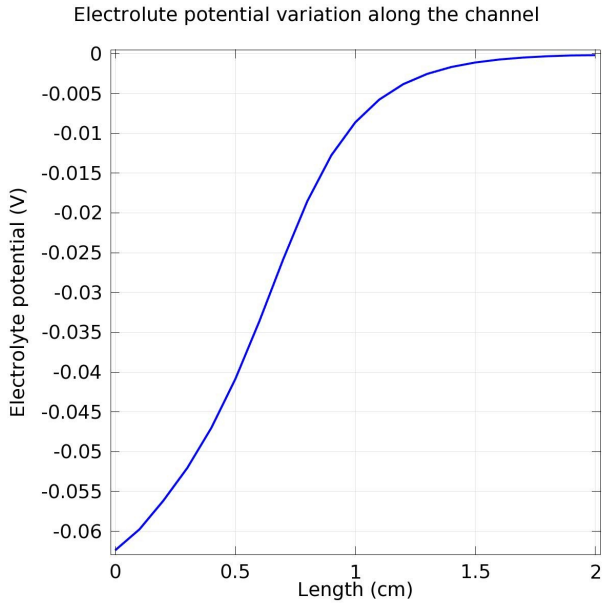

Figure 3: electrolyte potential for case 3

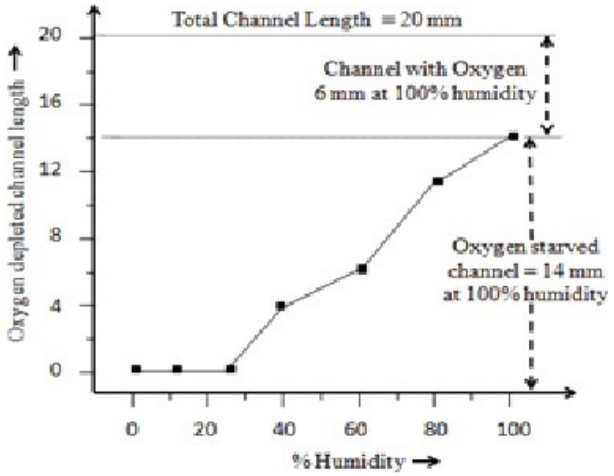

Figure 4: Humidity Vs oxygen depleted length