Electrochemical Energy Conversion in Direct Methanol Fuel Cells

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Abstract

Direct methanol fuel cells (DMFC´s) are promising candidates as portable power sources due to their lower weight, volume and high-energy density. They can potentially provide an energy content that exceeds current battery technology, with the possibility of instantaneous recharge. However, DMFC´s have several serious drawbacks such as slow methanol oxidation kinetics, poisoning by CO of the catalyst surface, the high methanol crossover through the polymer membrane, the high costs of the Nafion membrane and catalyst. The flowing streams of fuel and oxidizer need to be evenly distributed over the entire surface of the catalyst layer in order to achieve a good performance together with an efficient removal of reaction products. This is achieved through the optimal design of the flow field. In this work the effect of flow field design on cell performance is studied, using polarization curves.

A testing fuel cell was designed and implemented consisting of two stainless steel end plates, two sets of graphite collector plates, two carbon cloth diffusion layers, two catalyst layers of platinum black (0.70 mg.cm^{-2} and 0.75 mg.cm^{-2} Pt on cathode and anode, respectively) and an electrolyte polymer membrane (Nafion 117). Pt-Ru catalyst on the anode with a load of 4 mgcm^{-2} of catalyst was also studied. The active surface area of the cell is 25 cm^2. An own built fuel cell and a Lyntech testing station were used in this work. The effects of temperature, methanol concentration, feeding flow rates of fuel and flow field design on the cell performance were studied.

Results showed that the performance of the fuel cell increases with increase in cell temperature due to improvement in methanol oxidation kinetics and cathode kinetics, as indicated by polarization curves. The effect of temperature is complex; the oxygen partial pressure decreases with temperature increase due to the increase in vapor partial pressure, which causes decreases in the open-cell voltage and increases the concentration overpotential; the rate of methanol crossover increases with temperature, so the cell performance decreases; water transfer from anode to cathode through the membrane increases with temperature and the additional water increases the liquid water fraction in both the cathode catalyst and diffusion layers, thus causing an increase in concentration polarization.

Increase in methanol concentration affected the performance of the DMFC, as expected due to a higher methanol crossover with higher concentrations. The methanol transferred from the anode to the cathode through the polymer electrolyte membrane is oxidized at the platinum electrocatalyst and causes a mixed potential, which lowers the cathode performance and thus the overall cell voltage output.

The effect of the flow field design, single serpentine and parallel, on cell performance was also investigated. The serpentine flow field was better than the parallel design. The obtained results point towards an enhancement in the mass transfer of methanol improving the cell performance. Another important issue is the eventual blocking of the flow channels, by CO_2, at high current densities. A reduction of the effective contact area between the fuel (methanol) and the gas diffusion layer is expected, as CO_2 gas bubbles accumulate in the channels, bearing implications in the continuous supply of methanol to the catalyst sites through the gas diffusion layer. This is less likely to occur with the serpentine design. Cathode kinetics indicates slightly lower methanol crossover and better voltage efficiency at low current densities.

Comparison is made with results obtained for the two different catalyst layers used emphasizing the effect of Ru.

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References

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