Effect of anode flow field design in direct methanol fuel cells. Preliminary studies

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Abstract
The direct methanol fuel cells are promising candidates for portable power sources due to their high energy density, however studies continue in order to give solutions for a number of drawbacks that affect cell performance and efficiency. Achieving good fuel cell performance requires that the flowing streams of fuel and oxidizer are evenly distributed over the entire surface of the catalyst layer and also an efficient removal of reaction products. This is achieved through the optimal design of the flow field, which primarily depend upon channel pattern as well as channel (and rib) shape and size. In this work the effect of anode flow field design on the performance of an own built DMFC is studied. Preliminary results are herein presented.

Keywords: *DMFC; temperature effects; methanol concentration; flow field design*

1 Introduction

Direct methanol fuel cells (DMFCs) are promising candidates as portable power sources due to their low weight, volume and high-energy density (6100 $W.h.kg^{-1}$). The DMFC has attracted much attention because of their use of liquid fuel at ambient temperatures and pressures. No requirement for fuel processing results in a simpler design and operation, higher reliability and lower capital/operating costs.

However, DMFC´s have several serious drawbacks: (i) slow methanol oxidation kinetics, (ii) the poisoning of CO intermediate on the Pt surface, (iii) the high methanol crossover through the polymer membrane, (iv) the high costs of the Nafion membrane and Pt catalyst.

Achieving good fuel cell performance requires that the flowing streams of fuel and oxidizer are evenly distributed over the entire surface of the catalyst layer and also an efficient removal of reaction products. This is achieved through the optimal design of the flow field, which primarily depend upon channel pattern as well as channel (and rib) shape and size.

In this work the effect of anode flow field on the performance of an own built DMFC is studied. Preliminary results are herein presented.

2 Experimental and Results

The experimental fuel cell consists of two stainless steel end plates, two sets of graphite collector plates with different flow fields: parallel (P) and single serpentine (SS) and parallel serpentine (PS); 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 Nafion 117 as an electrolyte polymer membrane. The active surface area of the cell was 25 cm^2.

Fig. 1 shows the test cell used in this work, together with a schematic picture of some of the tested flow field designs.

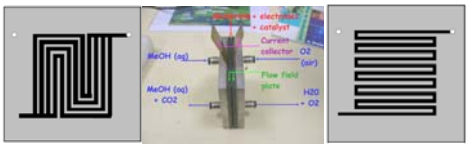

Fig. 1. Test own built fuel cell and schematic flow field designs used in this work .

A set of experiments have been carried out to study the effects of temperature on the cell performance, with the following cell operating conditions: 1M methanol solution with a feeding flow rate of 5 $mL.min^{-1}$; the cathode reactant was oxygen with a

feeding flow rate of 1000 mL.min^{-1}; temperatures between 25 and 70ºC were studied. The flow field of anode and cathode was a SS design.

The performance of the fuel cell increases with increase in cell temperature due to improvement in methanol oxidation kinetics and cathode kinetics. The ionic conductivity of the Nafion membrane also increases with temperature. Although electrochemical kinetics on cathode and anode increase with cell temperature, the following negative effects are expected: (a) the oxygen partial pressure decreases with temperature increase due to the increase in vapor partial pressure, which gives lower open-cell voltage and increases the concentration overpotential; (b) the rate of methanol crossover increases with temperature; (c) 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 causes an increase in concentration polarization. The effect of temperature is complex since both the positive effect on kinetics and mentioned negative effects contribute to cell performance [1].

Increase in methanol concentration affected the performance of the DMFC, as expected, due to a higher methanol crossover with higher concentrations [2]. 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 on cell performance was also investigated. Experiments were done, in a first approach, using the same flow field for anode and cathode for the single serpentine (SS) and parallel (P) design cases. Due to the low loading of platinum used and the absence of ruthenium in the catalyst composition, overall low cell currents are expected.

The SS flow fields gave superior cell performance than the P design; maximum power of the cell was found to increase by a factor of 2.7X, see figure 1. 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 designs [3]. Cathode kinetics indicates much lower methanol crossover and better voltage efficiency at low current densities for the single serpentine (SS) design.

Slight improvement in the cell performance was obtained when testing a different anode with a parallel serpentine (PS) design, while keeping the cathode plates design as SS. When PS design plates were tested on both anode and cathode, results showed a decrease in maximum power of ~ 25%. Cathode currents were found to be much lower.

This preliminary study shows that flow field of different designs may be required for the anode and cathode in order to obtain a better performance in DMFCs.

A more comprehensive study is under way.

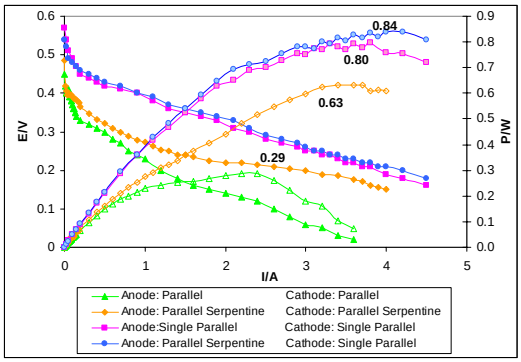

Fig. 1. Polarization curves for a DMFC at 60ºC, equipped with plates with different flow field design. Methanol concentration 1M; methanol flow rate 1.5 mL.min^{-1}, oxygen flow rate=1000 mL.min^{-1}.

References

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