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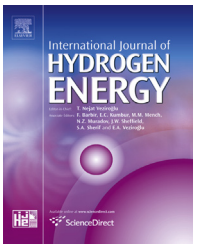

Effect of cathode flow field configuration on the performance of flowing electrolyte-direct methanol fuel cell

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ABSTRACT

A major challenge in direct methanol fuel cells is the crossover of methanol, from the anode to the cathode. The flowing electrolyte (FE) concept is one potential method to reduce or eliminate the effects of this problem, and the corresponding fuel cell is known as a flowing electrolyte – direct methanol fuel cell (FE-DMFC). In this study, the effect that the cathode flow field has on the performance of the FE-DMFC was investigated in a COMSOL Multiphysics environment. Methanol concentration, oxygen concentration, pressure distribution and velocity distributions were simulated for a single serpentine, parallel serpentine, triple serpentine and a grid type flow field configuration. The results of this study demonstrate the importance of the velocity distribution on the oxygen transport and its impact on the fuel cell's performance. As such, of the tested flow fields, the grid flow field obtained the lowest performance due the formation of locally low concentration zones (or dead zones) causing an increase in the cathode's concentration polarization. The single serpentine flow field on the other hand provided the best performance due to the better reactant coverage over the CCL.

Introduction

Direct methanol fuel cells (DMFCs) are considered to be one of the promising technologies for portable power applications, and functions by converting the chemical energy stored within the fuel (diluted methanol solution) into electrical energy. This electrochemical conversion occurs as follows: diluted methanol solution is supplied to the anode compartment, whereas an oxidant (oxygen or air) is supplied to the cathode compartment of the fuel cell. Protons and electrons are released at the anode as a result of the methanol oxidation reaction (MOR). The generated protons conduct to the cathode through the membrane (typically Nafion®). Since the membrane has a very high electronic resistance, the produced electrons conduct to the cathode via an external circuit. The protons and electrons reaching the cathode side react with the oxidant to produce water. Although the DMFC is an attractive technology, especially for off-grid portable power applications due to its advantages associated with using liquid methanol solution as the fuel (e.g. easy to store, readily available, and high energy density), the DMFC's performance needs to be further improved for its widespread usage. These performance limitations mainly originate from the problems such

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as slow MOR kinetics and unwanted methanol crossover from the anode to the cathode. In the latter issue, when methanol crosses over to the cathode, the open circuit voltage (OCV) decreases and the cathodic polarization increases; which in turn reduces the overall performance of the cell. To solve these issues, several studies have been conducted on the development of different anode catalysts (e.g. Refs. [1–3]) and membranes (e.g. Refs. [4–6]) to improve the MOR kinetics and reduce the methanol permeation, respectively.

A potential solution to the methanol crossover problem, discussed above, is using the flowing electrolyte concept, which was proposed by Kordesch et al. [7]. The flowing electrolyte-direct methanol fuel cell (FE-DMFC) is shown schematically in Fig. 1. In this concept, the flowing electrolyte channel (FEC) and an additional membrane separate the anode and cathode sides. A dilute electrolyte, such as sulfuric acid, is pumped through FEC to remove any methanol that attempts to crossover. Since little or no methanol oxidation occurs within the cathode catalyst layer (CCL), the cathodic activation polarization is decreased. However, the Ohmic polarization increases due to the two additional layers (the FEC and the second membrane) in the cell.

There are several publications in the literature on the development of FE-DMFC through modeling and experimental studies. For example, Kjeang et al. [8] developed a three dimensional (3D) CFD model that includes the relevant transport phenomena (convection-diffusion mechanisms) in the FEC. They studied the effect of fuel concentration, FEC thickness and flow rate of the sulfuric acid on the methanol crossover rate. In another study by Kjeang et al. [9], developed a CFD model to analyze the methanol transport within the FE-DMFC. Methanol crossover was defined as a flux at the cathode surface in this study. The results of both of these studies showed the benefits of using the flowing electrolyte concept in reducing the methanol crossover problem. Colpan et al. [10,11] developed 1D and 2D models of the FE-DMFC to study the effect of operating parameters (e.g. flowing electrolyte thickness, methanol concentration, and fluid velocity at the fuel, air, and flowing electrolyte channel inlets) on the performance of the fuel cell. The results of these studies showed that when the operating parameters are adjusted to give the highest performance, there is no significant difference between the peak power densities of the DMFC and the FE-DMFC; however, the electrical efficiency of the cell increases significantly when the FEC outlet is recirculated to the AFC inlet. It was also shown that the FEC thickness has a significant effect on the overall Ohmic polarization of the cell. Therefore, to obtain better performance, this channel must be as thin as possible and the inlet fluid velocity should be as high as possible. Duivesteyn et al. [12] developed a non-isothermal fuel cell model to observe the effects of the fluid dynamics on the FEC channel and to compare the results with those obtained under isothermal conditions. The results showed that there is no significant temperature difference between the inlet and outlet of the FEC; and it was recommended that a FEC material with lower porosity and higher permeability should be selected to increase the fuel cell performance. Kablou [13] fabricated and tested a FE-DMFC stack under different

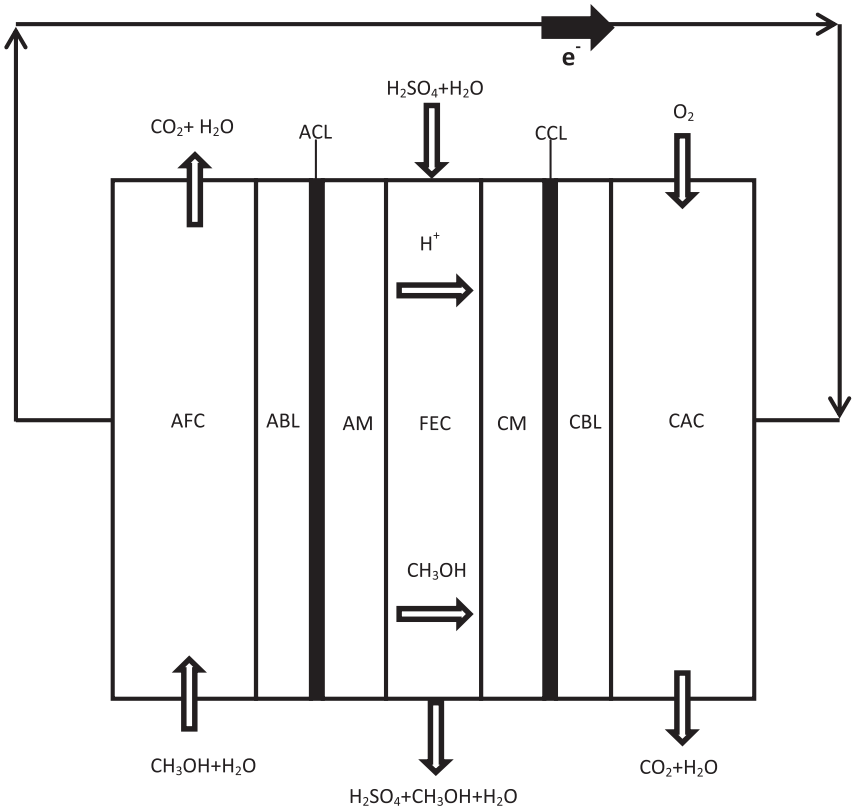

Fig. 1 – Schematic of the flowing electrolyte-direct methanol fuel cell (AFC: Anode Fuel Channel, ABL: Anode Backing Layer, ACL: Anode Catalyst Layer, AM: Anode Membrane, FEC: Flowing Electrolyte Channel, CM: Cathode Membrane, CCL: Cathode Catalyst Layer, CBL: Cathode Backing Layer, CAC: Cathode Air Channel).

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