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Effect of anode and cathode flow field geometry on passive direct methanol fuel cell performance

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ABSTRACT

In this paper, the effect of cathode flow field geometry on a passive direct methanol fuel cell (DMFC) performance at various concentrations of methanol is studied. Three cells with perforated current collector, parallel channels and trapezoidal channels with opening to downward current collector at the cathode side are tested at 2 to 5 molar concentrations of methanol. In order to maintain equal conditions on the anode side, the trapezoidal channels with opening to upward is used in all three cells. By placing the cathode flow field pattern on the anode flow field pattern, four zones are defined and the role of these areas on the performance of each cell at concentrations of 2 to 5 molar are investigated. It is found that the zones where the anode's open area placed directly in front of the cathode's open area has a considerable effect on the methanol cross over, and also the zones which anode and cathode current collector's walls placed on each other has more effect on the amount of surface contact.

1. Introduction

Passive direct methanol fuel cells are special kinds of DMFCs. High energy density, ability to operate at ambient temperatures, lower emission, quick start, light weight, compactness, simplicity as well as easy and fast recharging, lower volume than rechargeable batteries, are the advantages of passive DMFCs [1,2].

The principle of the operation of a passive DMFC is equivalent to that of the active type. The only difference is how the reactants feed to the cell. The oxygen of the ambient air enters the cathode side without using any auxiliary device, and on the anode side the methanol solution in the reservoir due to the concentration gradient between the catalyst surface and reservoir, reaches the reaction sites. Reaction products, i.e. water and carbon dioxide are expelled into the environment and reservoir in the same way [3].

Extensive researches have been done on the operational parameters of passive methanol fuel cells such as the concentration of methanol [4–8], type and thickness of membrane [4,6,9,10], catalyst loading on membrane [3,8], different flow field configuration with various open ratio [2,11–13].

One of the important parts of the passive DMFCs is current collector which provides pathways for feeding the reactants and removal of the products of electrochemical reactions on the anode and cathode sides. These plates are also used as the end plates which should provide uniform pressure distribution on the surface of the membrane in order to enhance the surface contact. Since the reactants are fed naturally in this type of fuel cells without using any external components, the proper design of flow field on the current collectors is one of the key parameters. Open ratio due to holes and machined channels on collector plates, and also dimension and profile of holes and channels, are important parameters in feeding reactants, managing water and CO_2 gas yielded from reaction, providing uniform pressure distribution and decreasing methanol crossover.

Most common flow field that have been used in passive DMFCs are array of holes or parallel channels [4,14–16] and stainless steel mesh [8,17]. Also trapezoidal channels with opening to upward at the anode side [11] and hexagonal holes [18] were used at this kind of fuel cell.

Kim et al. [19] examined several geometries of the flow field on the cathode current collector in a semi-active hydrogen fuel cell with the air breathing on the cathode, and demonstrated that the geometry of the flow field has a considerable influence on the cell performance in addition to the open ratio of cathode current collector. Kuan et al. [20] also studied the effect of the cathode open ratio on the performance of an active direct methanol fuel cell. They concluded that under the same total free open ratio, a longer total perimeter length of openings always gives better cell performance

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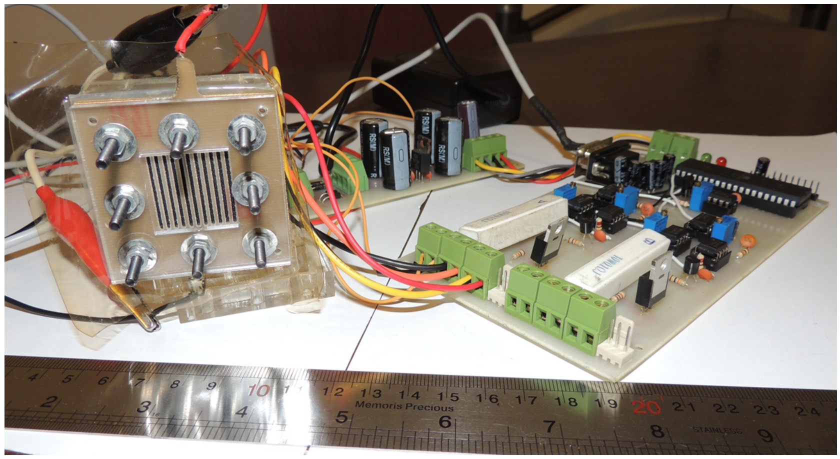

Fig. 1. Passive DMFC single cell with test system.

because the longer total perimeter length of openings shortens the diffusion length between the free open areas and the closed area behind the current collectors for the reactants and products. Hwang et al. [21] applied a three-dimensional model for the perforated current collector on the cathode side of a passive direct methanol fuel cell, and proposed an optimal hole size on the cathode side for proper feeding of oxygen and reducing the contact resistance.

In the all published articles, the effect of the anode or cathode flow field geometry is studied separately regardless of the geometry of the flow field on the other side.

In this paper, the effect of the cathode's flow field geometry on the performance of passive direct methanol fuel cells was investigated by considering the anode's flow field geometry. For this purpose, the resulting zones from placing the cathode flow field geometry on the anode flow field geometry was considered and the effect of these zones on the performance of passive DMFC was studied.

2. Experimental

2.1. Fuel cell structure

Three single cells with the following characteristics and a test apparatus were made as shown in Fig. 1.

The membrane electrode assemblies (MEA) used in this research purchased from the Fuel Cell Store, Inc. with 5 cm^2 active area and Nafion 117 as membrane, the catalyst loading on the anode side was 4.0 mg cm^{-2} of Pt/Ru (proportion 1:1) and on the cathode side was 4.0 mg cm^{-2} of Pt on the carbon cloth diffusion layer.

A printed circuit board (PCB) with 1.5 mm thickness and copper cover was used as a current collector instead of stainless steel due to the lower weight and cost and also easier machining process. To reduce corrosion and contact resistance, a thin gold film was coated on current collectors by electroplating method. Three types of flow field were machined on current collectors as shown in Fig. 2. To maintain all the components of the cell together and to provide the appropriate contact force between the components and also to create the methanol solution reservoir, Polymethyl Methacrylate (PMMA) plates were used. The fuel reservoir has a capacity of 10 ml of methanol solution. For sealing between the components, silicon gasket with the thickness of 1 mm was used.

2.2. Test apparatus

To perform the test procedures for these fuel cells, a simple test apparatus was designed and constructed which has the ability to apply an electrical load and to measure the voltage, current, temperature and also bidirectional communication with the computer. Schematic of the test apparatus is shown in Fig. 3.

The main characteristics of this test apparatus are as follows:

- The ability to apply an electrical loads up to 10 watts
- Measurement of the current and voltage up to 2000 mili amperes and 5 volts and the ability to measure the temperature of two points
- Communication with the computer via a universal serial bus (USB) port and the related software
- The ability to schedule duration of the applied loads to the cell

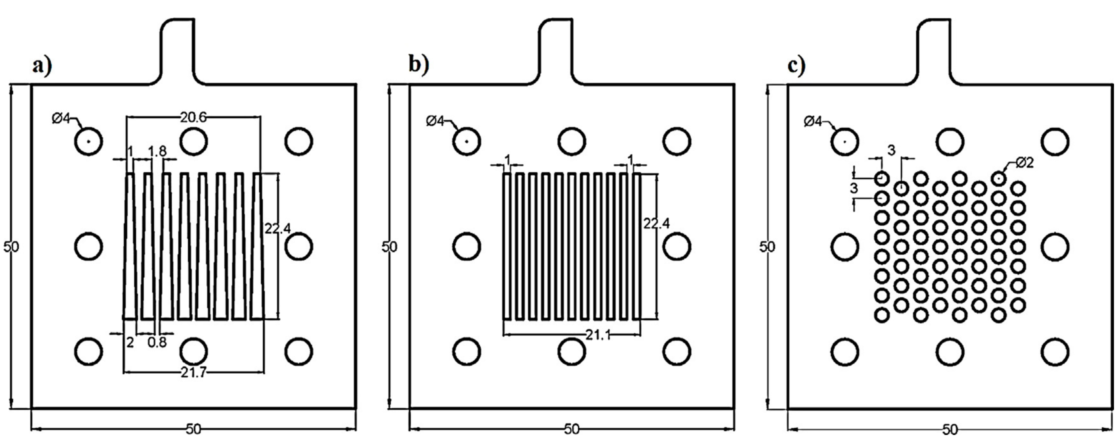

Fig. 2. a) Trapezoidal parallel channel current collector, b) Parallel channel current collector, c) Perforated current collector (Dimensions in mm) [11].