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Operational Parameters Study of Micro PEMFCs with Different Flow Fields

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Abstract

The effect of different operating parameters on micro PEMFCs performances was experimentally studied for three different flow field configurations (interdigitated, mesh, and serpentine). Experiments with different cell operating temperatures, different backpressures on the H_2 flow channels as well as various combinations of these parameters have been conducted for three different flow geometries. The micro PEMFCs were designed and fabricated in-house through a deep UV lithography technique and the SU-8 photoresist was used as microstructure material for fuel cell flow field plates. Results are presented in the form of the polarization VI curves and PI curves under different operating conditions. The possible transport mechanisms associated with the parametric effects were discussed. In addition, it was found that, among the three flow patterns considered, significant improvements can be reached with a specified flow geometry.

Keywords: *Micro PEMFC, Cell performance, Flow field plates, Operational parameters*

1 INTRODUCTION

Proton exchange membrane (PEM) fuel cells have long been recognized as one of the most promising candidates for future power generating systems especially in portable electronic devices. This is because the PEMFC presents a high power density and operates at a relatively low temperature, which made it ideal for portable systems. However, the performance of low temperature fuel cells, like PEMFC needs substantial improvement on several technical issues. As far as we know, there are several different kinds of flow field plates used in the conventional fuel cells. The application of fuel cells to portable power is motivated by numerous occasions such as 3C products [1, 2] and challenged by several factors. For example, high power density and high energy-to-weight ratio [1, 2, 3]. For Micro PEMFC to become a commercial reality, it needs a lot of work to be done. However, only few work have been done so far and most of them focused on the microfabrication processes development [2, 3, 4].

Based on the discussion above, it is therefore an essential need to broaden our basic understanding of the effects of the operational parameters as well as the reactant gases flow channel geometry on cell performance either on micro fuel cell design or its operation. In the present study, the cell operating temperatures were at 25, 35, and 50℃, with the backpressure at anode of 97(≅1 atm), 152(≅1.5 atm), and 207(≅2 atm)kPa for three different flow fields configurations of interdigitated, mesh, and serpentine types.

2 MEA PREPARATION

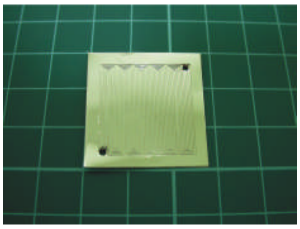
To achieve the cell as small as possible, the thin fuel platinum deposited MEAs was used in this study. It was made through process using an ultra-thin sputtered platinum films deposited directly onto Nafion 117 (183 μm) membranes (ElectroChem. Inc.).

3 MICROSTRUCTURED FLOW FIELD PLATES FABRICATION

There are three types of flow fields configurations to be presented and discussed in the present study incorporated with the present micro fuel cells. The three types are traditional interdigitated, mesh, and serpentine as mentioned before. The schematics of these three flow field patterns are illustrated in Fig. 1.

(a) interdigitated flow field
ribxchannel
(500 μm×2000 μm)

(b) mesh flow field
ribxchannel
(1000 μm×500 μm)



(c) serpentine flow field
ribxchannel
(100 μm×200 μm)

Fig.1 Flow channel configurations of the present study

4 EXPERIMENTAL

The experiments were conducted by using in-house made micro PEMFCs, which were microstructured by the SU-8 photoresist material, as stated previously, for flow field plates. The detailed design concept and fabrication processes are similar to that used in [3, 4]. An active area of 5 cm^2 single cell with about 700 μm in thickness was tested with H_2/air fed on anode and cathode sides. The MEA consists of a Nafion 117 membrane in combination with platinum loadings of 0.12 mg/cm^2. There is no carbon paper used for gas diffusion layer. The MEA positioned between two silver sputtered loading SU-8 photoresist flow field plates. The SU-8 plates were microfabricated with interdigitated, mesh, and serpentine gas channels.
In addition, the cell operating temperature was kept at three different temperatures of 25°, 35° and 50°C with different backpressures of 97, 152 and 207 kPa at anode through a computer.

5 RESULTS AND DISCUSSION

The experiments with ambient air were directed to the examination of the effect of the flow field structure on performance, by using different cell operating temperatures and backpressures of the anode, listed in Table 1.

Table 1 Operating conditions and relevant parameters of this study

Cell temperature (°C)	25, 35, 50
Backpressure	
anode	97 kPa,152 kPa,207 kPa
cathode	forced air
SU-8 Flow field Channel (H×W×L)	
interdigitated	500 μm × 2000 μm × 22.5 mm
mesh	1000 μm × 500 μm × 22.5 mm
serpentine	100 μm × 200 μm × 22.5 mm
Catalyst Layer	
Pt (99.99%)	30nm × 22.5 mm × 22.5 mm
MEA	
Nafion 117 (Electrochem)	183 μm × 22.5 mm × 22.5 mm
Electrode	
Silver (anode/cathode)	200 nm × 22.5 mm × 22.5 mm

5.1 Effect of Cell Operating Temperature

Three operating temperatures 25, 35 and 50°C were carried out to study the effect of fuel cell temperature on Micro PEMFC performance. During the experiment, the mass flow rates of H_2 and air were 10 and 25 sccm, respectively. Backpressures on anode side were kept at 97, 152, and 207 kPa with a fixed cathode backpressure of 97 kPa. One of the polarization curves at the anode back pressure 152 kPa for each experiment was selected as a typical example shown in Fig. 2 to illustrate such effect. It shows that the cell performance increases at the cell temperature increases. This is because the ion conductivity of the ionomer (Nafion 117) increased with the cell temperature. In fact, such an increase would be slightly diminished by the decrease in the reversible potential with a cell temperature increase based on the Nernst equation. Consequently, theoretically speaking, an optimum cell operating temperature can be expected. Although the highest cell temperature in this study is only 50 °C, it is expected that the present cell temperature may reach the best cell performance. One good explanation was given in the above. Moreover, Nafion membrane dehydration may occur as the cell temperature is over 50 °C, which would deteriorated the cell performance. It is also shown in Fig. 2 that the maximum current density of the cell increases as the cell temperature increases. This strongly suggests that a "mass transport" enhancement would take place due to an increase in diffusivity as the cell temperature increases. With an increase in two key factors of ion conductivity of the Nafion membrane and the diffusivity of the reactant gases, the VI curves shift towards higher voltage at lower current densities when increasing the cell temperature are expected as Fig. 2 indicates. The trend and shape of VI and PI curves are similar to those in conventional PEMFCs with an absence of polarization activation process.

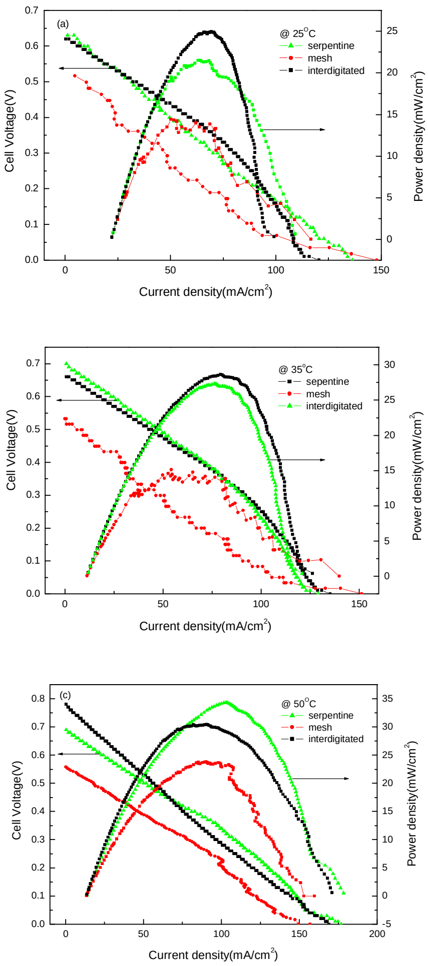


Fig.2 Micro PEMFC performance test at hydrogen inlet pressure 152 kPa

5.2 Effect of Backpressure

The effect of backpressure of the flow field in the anode channels on the cell performance is shown in Fig. 3, 4, and 5, respectively, with H_2 backpressure at 97, 152, and 207 kPa and a fixed air backpressure for three different flow channel configurations. Generally, a higher backpressure would enhance the cell performance via accelerating the reaction at both anode and cathode of the cell due to a partial pressure increase of the reactant gases. In addition, based on the Nernst equation, a higher voltage can be attained at a higher pressure. Figures 3-5 show such trend in VI and PI curves. Additionally, it is also found that a backpressure increase would cause a less cell performance improvement on anode than that on cathode. This is because such a pressure drop across the membrane would result in a barrier for back-diffusion which takes place to keep the membrane hydrated. This situation becomes dominant as the backpressure at anode increases (e. g. the anode pressure 207 kPa). In fact, for three backpressure considered, the anode pressure of 152 kPa seems to have a better cell performance in both VI and PI curves.

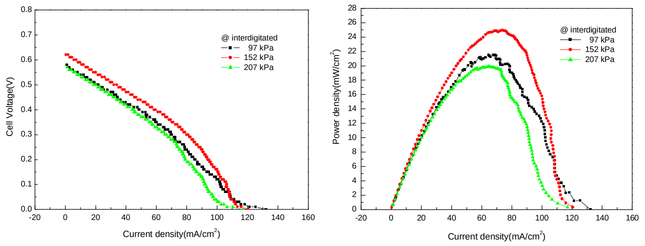


Fig.3 Micro PEMFC performance test at different inlet pressure for 25℃

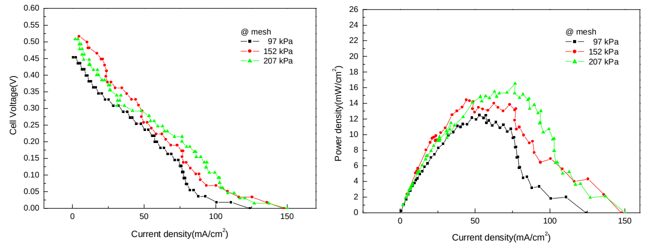


Fig.4 Micro PEMFC performance test at different inlet pressure for 25℃

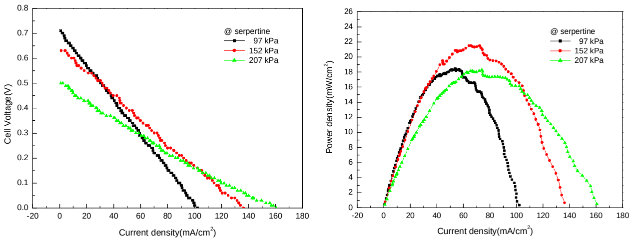


Fig.5 Micro PEMFC performance test at different inlet pressure for 25℃

5.3 Effect of Flow Configuration

The pressure drop, for instance, shown in Fig. 6 for these three flow patterns was measured to be 50, 55, 60 kPa for the H_2 side for mesh, serpentine, and interdigitated types at operating temperature of 25°C and H_2 feeding rate at 10 sccm. The highest pressure drop found in interdigitated channels was again assessed the previous report [5]. In addition, the pressure drop across these three channels are all linearly proportional to the H_2 feeding rates.

Overall, based on the discussion above, one may conclude that the interdigitated type flow channel design is superior to these channels under study as far as the cell performance (high power density) is concerned. However, for the pressure drop across anode flow channels, the mesh type channel has the smallest flow resistance as one would expect. This results in the existence of an optimum operating condition. Namely, higher cell performance and lower pressure drop across flow channel are essentially needed for a micro PEMFC.

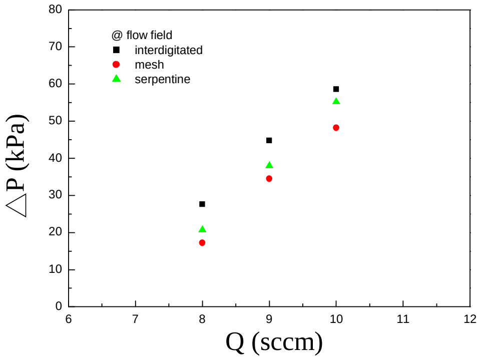


Fig.6 Pressure drop across three different H_2 channels at 25 ℃

6 CONCLUSIONS

In this paper, three different flow plates configurations with different cell temperatures, and backpressures have been conducted to examine the effect of three operational parameters on the cell performance for a single micro PEMFC. The major features of the study can be drawn as follows:

1. The cell performance increases as the cell temperature increases form 25°C to 50°C. In spite of the limitation of the present cell temperature (≦50°C), it is expected that the cell performance would go down as the temperature exceeds 50°C due to dehydration and subsequently loss of the ion conductivity of the ionomer (i.e. Nafion 117 membrane). Such behavior is expected to be consistent with the conventional PEMFCs.
2. Like the conventional PEMFCs, the higher flow backpressure is, the higher cell performance has for a single micro PEMFC at a fixed cell operating temperature. This is partly due to reaction enhancement taking place on both electrodes and partly due to an increase in reversible cathode potential on air side if the cathode backpressure increases.
3. Among three flow fields configurations studied herein, the interdigitated type seems to have a better cell performance; while a lower pressure drop was found for mesh type flow channels at a fixed active area of the MEA. This finding is similar to that of the conventional PEMFCs in which an interdigitated flow channel design is also found desirable [5].
4. Based on the present study, it reconfirms that the water removal problems in a single micro PEMFC on the cathode seems not as significant as that in a conventional PEMFC.

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