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# EFFECT OF MEA HOT-PRESSING ON THE PERFORMANCE OF DIRECT METHAND FUEL CELLS

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## ARTICLE DETAILS

## **ABSTRACT**

#### Article History:

Received 26 June 2018 Accepted 2 July 2018 Available online 1 August 2018 MEA based on Nafion 115 has been prepared with GDL-based method for direct methanol fuel cell applications. The results of unit cell tests show that different temperature and pressure of hot-pressing during MEA preparation presents different polarization curve. Optimization of temperature and pressure during hot-pressing can effectively improve the performance of direct methanol fuel cells.

### **KEYWORDS**

DMFC, MEA, hot-pressing.

## 1. INTRODUCTION

Direct methanol fuel cell (DMFC) is a kind of fuel cell based on proton exchange membrane (PEM) technology using methanol solution as fuel, while oxygen or air as oxidant. It has a number of advantages such as small volume, light weight, compact structure, high energy density, convenient storage and carrying etc... It is suitable for various potential applications including stationary and portable applications. Based on a study, it can meet the increasing demand of high energy consumption of portable electronic devices such as mobile phone, notebook computer, video camera, personal digital assistant and medical device system as well as spacecraft power supply, microelectronic mechanical system power and so on [1,2]. In recent years, it has become a hot research topic in the world and has been considered as a highly promising power source.

Membrane electrode assembly (MEA) is the core component of direct methanol fuel cell. It is made up of polymer electrolyte membrane, catalytic layer and diffusion layer. The conductivity and mass transfer ability of the membrane electrode are very important for the fuel cell reaction. Therefore, the preparation of MEA has been the focus of the research and development of DMFC.

According to research, there are two main methods widely used to fabricate the MEA, that is, gas diffusion layer (GDL)-based method and membrane-based method [3-6]. The hot-pressing is a key step in the GDL-based method of MEA fabrication. The purpose of this work is to investigate the performances of MEAs that prepared by different hot-pressing temperature and pressure.

## 2. EXPERIMENTAL

## 2.1 Preparation of Membrane Electrode Assembly (MEA)

Based on a study, the proton exchange membranes used in this experiment are all Nafion 115 (DuPont, USA). All membranes should be pretreated before using, which means that they were boiled at  $80^{\circ}\text{C}$  in 3%  $\text{H}_2\text{O}_2$  solution, deionized water (DI) 0.5M  $\text{H}_2\text{SO}_4$  solution and again in DI water, each for 1 hour firstly [7]. Then the membranes were preserved in the deionized water for reserve. Before using, the membranes were removed from the deionized water, and were dried naturally in the air for no less than 4 hours.

MEAs were fabricated with home-made electrodes. The catalyst of anode and the cathode used supported Pt-Ru/C (40%Pt and 20%Ru on Vulcan

XC-72R Carbon, ca. atomic ratio 1:1, from Johnson Matthey) and supported Pt/C (60%Pt on Vulcan XC-72R Carbon, from Johnson Matthey) respectively. The catalyst inks were prepared by mixing catalyst, distilled water, Nafion solution and ethylene glycol together. The mixtures were stirred for about 30min and sonicated for at least 1h. based on a research, after sonication, the catalyst ink became quite viscous, then the catalyst slurry was evenly sprayed on carbon paper (GDL 30BC) with a spray gun (GP-2, Fuso Seiki, Japan) [8,9]. The load of the catalyst for the anode and cathode are all 3mg.cm<sup>-2</sup>.

The proton exchange membrane was sandwiched between two electrodes mentioned above and the resulting membrane electrode assembly (MEA) was then hot-pressed for 5 minutes at different temperatures (140°C, 150°C, 160°C, 170°C) and different pressures (40kgf.cm-², 80kgf.cm-²), thus fabrication of MEA under different hot-pressing conditions finished. The hot-pressing duration in our work was not included and it was maintained at 5min, which is enough to get an MEA for unit cell in the short-term operation [10]. All MEAs had an active area of 2cm×2cm.

## 2.2 Performance Test of Unit Cell

The MEA was coupled with gas-sealing gaskets and fixed between bipolar plates and assembled into unit cell. The performance of unit cell was tested by a single cell test station. In this experiment, the anode was supplied with 2M methanol at a flow rate of 0.6mL.min-1 while the cathode was supplied with non-humidified oxygen at a flow rate of 100mL.min-1. In order to ensure that the concentration of methanol is constant, the methanol solution is used in a single flow through the cell without recirculation when the cell performance is tested.

The performance tests of unit cell operated at  $30^{\circ}$ C,  $60^{\circ}$ C and  $80^{\circ}$ C were carried out in this experiment. The methanol solution and oxygen were heated to the same temperature as the cell body by passing through a preheating device before entering the cell. All the temperatures of methanol solution, oxygen and cell body were controlled by the precise temperature control instrument. The unit cells performances were characterized by polarization curves which were obtained using an electronic loader by varying the current. All the experimental results were obtained under steady-state conditions.

## 2.3 Physical Characterizations of MEA

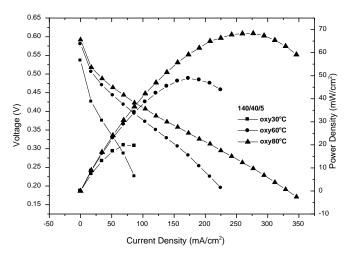
Scanning electron microscopy micrographs (FE-SEM, Hitachi S-4300)

were taken to obtain information of the cross-sectional view of MEA that fabricated under the studied hot-pressing conditions.

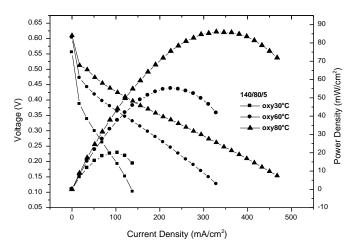
## 3. RESULTS AND DISCUSSIONS

## 3.1 Effect of MEA Hot-pressing Pressure on Unit Cell Performance

Figure 1 and Figure 2 showed the polarization curves for MEA fed with 2M methanol and oxygen at different operation temperatures,  $30\,^{\circ}\text{C}$ ,  $60\,^{\circ}\text{C}$  and  $80\,^{\circ}\text{C}$ . The figures compared two unit cells performances that used MEA hot pressed at temperature of  $140\,^{\circ}\text{C}$  and duration of 5 min, with pressure of  $40\text{kgf.cm}^{-2}$  and  $80\text{kgf.cm}^{-2}$  respectively. For the MEA with hot-pressing pressure of  $40\text{kgf.cm}^{-2}$ , maximum power density of  $68\text{mW.cm}^{-2}$  was observed at  $80\,^{\circ}\text{C}$ , and the MEA with hot-pressing pressure of  $80\text{kgf.cm}^{-2}$  yielded maximum power density of  $86\text{mW.cm}^{-2}$  at the same operation temperature. At the same hot-pressing temperature, the unit cell performance of MEA which prepared under higher pressure is better.

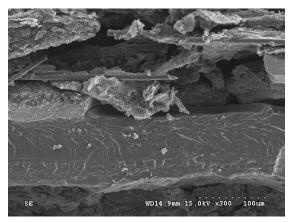


**Figure 1:** Polarization curves of unit cell based MEA hot-pressed under temperature of 140°C, pressure of 40kgf.cm $^{-2}$  with operation temperature of 30°C, 60°C and 80°C.

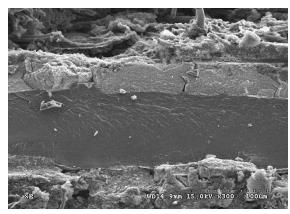


**Figure 2:** Polarization curves of unit cell based MEA hot-pressed under temperature of 140°C, pressure of 80kgf.cm $^{-2}$  with operation temperature of 30°C, 60°C and 80°C.

The morphologies of the cross-sections of MEAs were investigated by SEM presented as figure 3 and figure 4. The total electrode thickness decreases from  $630\mu m$  to  $585~\mu m$  as the pressure applied during hot-pressing is increased.



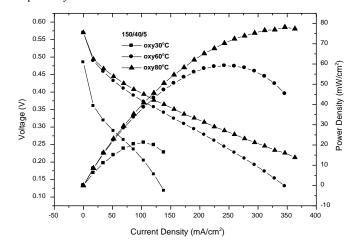
**Figure 3:** SEM image of MEA hot-pressed under temperature of 140°C, pressure of 40kgf.cm<sup>-2</sup>.



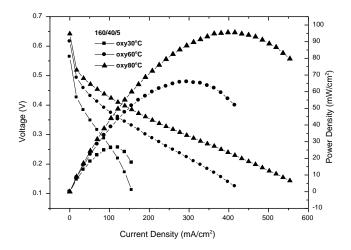
**Figure 4:** SEM image of MEA hot-pressed under temperature of 140°C, pressure of 80kgf.cm<sup>-2</sup>.

## 3.2 Effect of MEA Hot-pressing Temperature on Unit Cell Performance

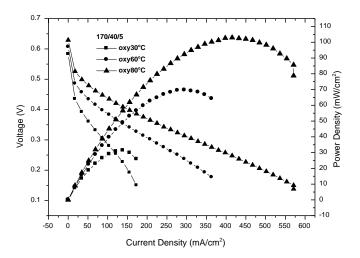
Figure 5,6,7 are the performance comparison of the MEAs prepared by hot-pressing at pressure of  $40 \text{kgf.cm}^{-2}$  and temperature of  $150^{\circ}\text{C}$ ,  $160^{\circ}\text{C}$ ,  $170^{\circ}\text{C}$ , with cell operation temperature of  $30^{\circ}\text{C}$ ,  $60^{\circ}\text{C}$  and  $80^{\circ}\text{C}$ . When hot pressed at the same pressure, it can be seen from the diagrams that the performance of unit cell based on MEA which hot pressed at  $170^{\circ}\text{C}$  is best. In the case of unit cell operated at a temperature of  $80^{\circ}\text{C}$ , with all MEAs prepared by hot-pressing for 5 minutes at pressure of  $40 \text{kgf.cm}^{-2}$ , the maximum output power density of MEAs with hot pressed at  $140^{\circ}\text{C}$ ,  $150^{\circ}\text{C}$ ,  $160^{\circ}\text{C}$  and  $170^{\circ}\text{C}$  is  $68 \text{mW.cm}^{-2}$ ,  $78 \text{mW.cm}^{-2}$ ,  $95 \text{mW.cm}^{-2}$  and  $100 \text{mW.cm}^{-2}$  respectively.



**Figure 5:** Polarization curves of DMFC unit cell based MEA hot-pressed under temperature of 150°C, pressure of 40kgf.cm<sup>-2</sup> with operation temperature of 30°C, 60°C and 80°C.



**Figure 6:** Polarization curves of DMFC unit cell based MEA hot-pressed under temperature of 160°C, pressure of 40kgf.cm<sup>-2</sup> with operation temperature of 30°C, 60°C and 80°C.



**Figure 7:** Polarization curves of DMFC unit cell based MEA hot-pressed under temperature of 170°C, pressure of 40kgf.cm<sup>-2</sup> with operation temperature of 30°C, 60°C and 80°C.

According to a study, it was determined that the cell resistance increases when the applied pressure during MEA fabrication is greater than 20kgf.cm-2 [11]. However, our experiments showed that an increase in the temperature and pressure would increase the cell performance. The cell resistance of the MEA hot pressed at higher temperature and pressure would decrease because of the good contact between the electrodes and membrane. An increase of hot-pressing temperature and pressure increase the compression ratios of electrodes, which in turn raise the activating time required for cell to reach optimum performance.

## 4. CONCLUSIONS

The membrane electrode assembly of direct methanol fuel cell was prepared with GDL-based method by hot-pressing, and the performance of the membrane electrode assembly prepared under different hot-pressing pressure and temperature was tested. The test results show that optimizing the preparation temperature and pressure of the membrane electrode can effectively improve the performance of DMFC.

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