FABRICATION OF A 2W PASSIVE DMFC OPERATING WITH HIGH CONCENTRATION METHANOL.

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Abstract: In this study, a prototype of a 2W passive DMFC which employed porous carbon plate in order to use high concentration methanol was designed and fabricated, based on the experiment for the material used and the performance of a single cell, and its basic power generation characteristics were experimentally investigated. The prototype was octagonal with total volume at 430 ml and consisted of 8 cells and a 160ml fuel reservoir which was shared with the 8 cells in each backside. The DMFC prototype was successfully operated with 100% methanol showing a maximum power out put of 2 W.

Key words: Passive DMFC, Porous carbon plate, Energy density, Stack, Methanol crossover

1. INTRODUCTION

Direct methanol fuel cells (DMFCs) have received considerable attention as an alternative to the Li-ion battery. The theoretical energy density of DMFC is calculated to be much higher than that of Li-ion battery when it can directly use liquid methanol for power generation. They do not need a methanol reformer then, their system volume could be miniaturized. In particular, passive DMFCs, which suck methanol from a reservoir by an osmotic action and breath air from its surrounding by natural convection and diffusion, can provide a higher energy density since they do not need pumps for fuel feeding and blowers for air breathing. However, the energy density of the DMFCs under development is still far from that expected because of the methanol crossover (MCO) and the high overvoltage at the electrode. Due to the MCO, the DMFCs usually show the highest performance at low concentrations of methanol about 5M under passive conditions. It is required for DMFCs to be used with methanol at high concentrations near 100% in order to increase its energy density up to the theoretical value.

In our previous studies [1, 2], we proposed a novel electrode structure employing a porous carbon plate, PCP, to anode of a passive DMFC. By the employment of PCP, methanol feeding rate could be controlled by it and also by CO_2 layer formed between the anode and the PCP. Methanol must be transported through the gas layer as a vapor. Therefore, methanol crossover could be significantly reduced compared with a conventional DMFC without PCP, and so, it allowed using high concentrations of methanol. Moreover, since the PCP can suck fuel by capillary action and distribute the fuel to whole area of the anode, the electrode can be expected to be arranged in vertical direction. In this study, first, we investigated the effect of head height of the fuel in contact with PCP vertically arranged on the power generation using a single cell of 55 mm in height with neat methanol. Then, based on the result of the single cell experiment, a prototype of a 2W passive DMFC with PCP was designed and fabricated. This prototype consisted of 8 cells and a 160ml fuel reservoir which was shared by each cell in each backside. And then, basic power generation characteristic were experimentally investigated.

2. EXPERIMENTAL

2.1 Porous carbon plate (PCP)

The porous carbon plate, PCP, of which dimension was 0.5 x 15 x 55 mm, used for anode was supplied from Mitsubishi Pencil Co. Ltd. In our previous study [2], we recognized that pore structure of PCP quite influenced on the cell performance. For this reason, we prepared 4 types of PCPs which with different pore structure in order to choose an appropriate PCP for the prototype. Fig.1 shows influence of the apparent density, a relative value, and types of PCPs, S, Y, F and SS, on the methanol permeation rate. At higher apparent densities, permeation rates of SS and S were extremely low. This means that these PCPs had higher mass transfer resistances. Accordingly, to achieve using neat methanol in the prototype, it was considered that S and SS were appropriate, and so, we used SS with apparent density around 0.8 in the following experiment.

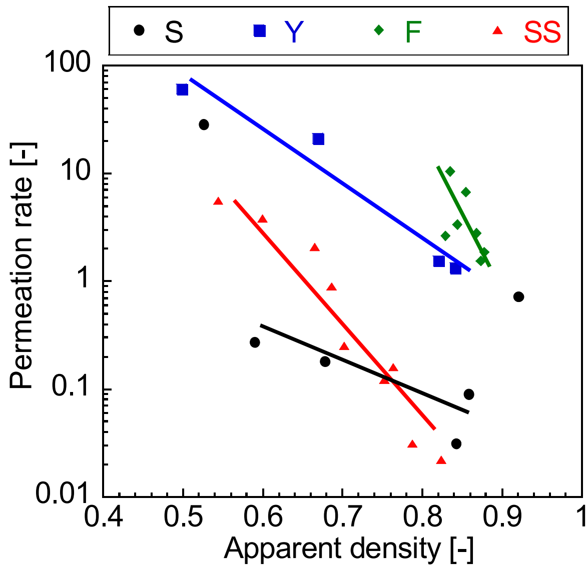


Fig.1 : Influence of the apparent density and types of PCPs on the methanol permeation rate.

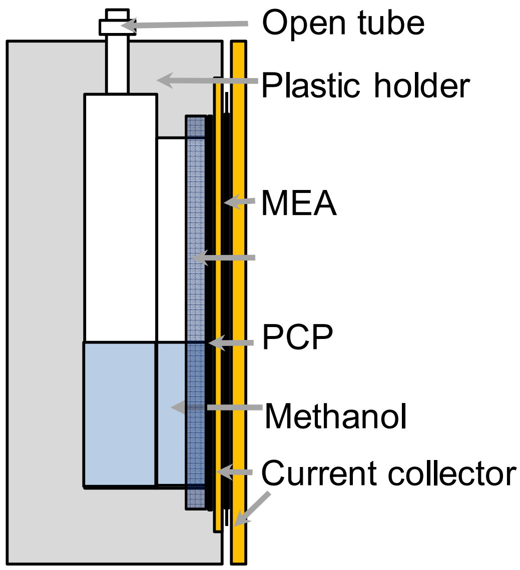


Fig.2 : Schematic diagram of experimental set-up of the single cell.

2.2 Membrane electrode assembly (MEA)

The MEA, which uses Pt and Pt-Ru black as the catalyst for the cathode and anode, respectively, was 15 mm in width and 55 mm in height, and it was prepared and fabricated in the same manner as described in our previous report [1]. The catalyst loading was 10-12mg/cm^2 in each electrode.

2.3 Experimental set up of single cell

Figure 2 shows the single cell with a PCP used in the experiment. In the anode compartment, a 12 cm^3 methanol reservoir and 55 mm in height was prepared. The MEA was sandwiched between two current collectors, which were made of stainless steel plates. The thickness of current collectors were 2 mm for cathode and 1mm for anode with open holes for the passage of fuel and oxidant. As a result of the vertical arrangement of the cell, methanol had to be distributed to whole area of electrode through PCP. It was expected that the fuel was supplied to anode irrespective of the head height of methanol by the capillary action of the porous structure of PCP. Under closed circuit conditions, the openings of anode current collector were filled with CO_2 gas which is produced by the anode reaction. Therefore, a layer of CO_2 gas was formed between the PCP and the anode, and the gas layer obstructs methanol transport from the reservoir to the anode.

3. RESULT AND DISCUSSION

3.1 Performance of the Vertical Arrangement.

Before we fabricate prototype of DMFC, to check the supplying fuel using neat methanol by PCP, i.e. effect of the head height of methanol on the cell performance, power generation characteristics were investigated in different methanol levels using the single cell. Fig.3 shows the variations in the power density at cell voltage of 0.25 V with neat methanol for methanol level from 5 mm to 55mm. Though power density was low initially, then it was over 30 mW/cm^2 and nearly constant irrespective of the methanol level. From this result, it was confirmed that the methanol could be distributed and supplied through PCP vertically arranged, and also the neat methanol can be directly used in the cell.

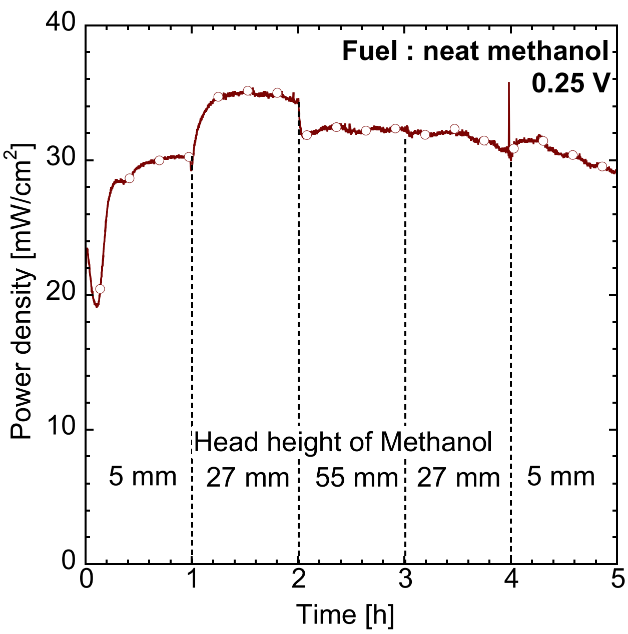


Fig.3 : Effect of methanol level on the power density profile at cell voltage of 0.25 V with neat methanol.

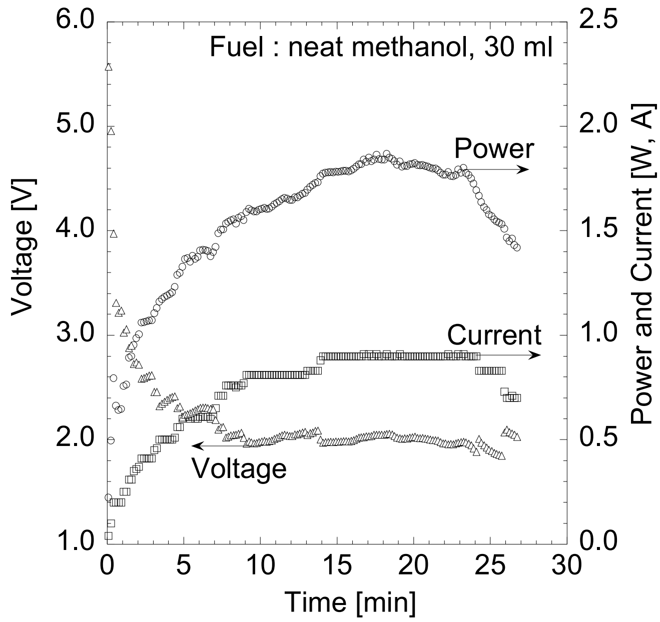
Fig.4 The prototype of passive DMFC.

3.2 Fabrication of a Prototype of Passive DMFC Stack

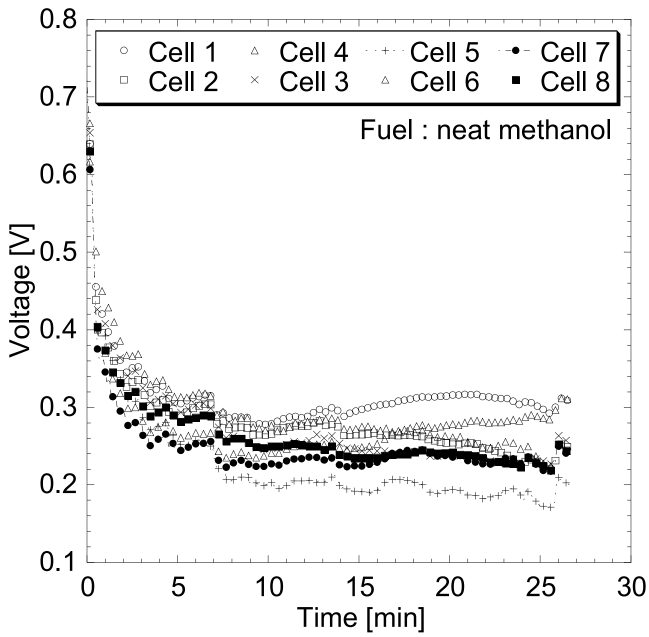
Based on the test results of the single cell with PCP, a prototype of DMFC with 2.0W rated power output was designed and fabricated. Fabricated prototype of DMFC was shown in Fig.4. It consisted of 8 cells which have the same configuration used in the single cell and 160 ml fuel reservoir which was shared by each cell in each backside. Its form was octagonal and total volume was 430 ml. This prototype was designed as a complete passive DMFC operated with the surrounding air at ambient conditions and with neat methanol.

3.3 Power Generation Characteristics of the Prototype of DMFC

To evaluate the basic properties of power generation of the DMFC prototype, performance was measured. Fig.4 shows power generation characteristics of the DMFC prototype operated with neat methanol. As shown in Fig.4 (a), power output increased with the increasing of current. When the current was set about 1 A, the power reached about 2 W. The maximum power output, 2W, was that expected for the prototype based on the single cell performance with 30 mW/cm^2. However, referring to the voltage profiles of single cells shown in Fig.4 (b), though voltage of each cell was almost the same by 7 minutes, and then it was distributed from 0.2 V (cell 5) to 0.3 V (cell 1). In stacking of fuel cell, it is important to make each cell performance uniform for advancing the power generation. This voltage difference among cells may be caused by a difference in resistivity of PCP for methanol transport. Although the prototype was fabricated using the same type of PCP, there may be a small difference in the structure and/or its distribution over the plate. Higher power output can be



(a) stack



(b) single cell

Fig.4 : Power generation characteristics of the DMFC prototype with neat methanol 30ml.

expected by making the single cell performance uniform.

4. CONCLUSION

Prototype of the small passive direct fuel cell (DMFC), which could use neat methanol and had simple fuel feeding system, was fabricated and its basic power-generation properties were experimentally investigated. First, in the single cell experiment, it was confirmed that the single cell was successfully operated with a power density over 30 mW/cm^2 using neat methanol irrespective of the head height of methanol in the reservoir. Based on the testing result from single cell, we fabricated a 2W prototype DMFC and it successfully operated with neat methanol and maximum power out put of 2.0 W.

Reference

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