FUEL SUPPLY METHODS FOR A ZIGZAG-TYPE DMFC

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Abstract: We proposed a new direct methanol fuel cell with a zigzag-folded membrane electrode assembly. The fuel cell can achieve high output voltage though easy in-series connection. The problem of fuel supply is one of the cause of decreasing output voltage in zigzag-type DMFC. In soak-up fuel supply method, the 4-mm-thick filter paper was sufficient to supply fuel to the cell in 1 hour operation. To curb the decrease in output, the soak-up capillary action fuel supply method was change to the immersion fuel supply method. In immersion fuel supply method, 10-mm-width cathode was sufficient to supply air entire the cell.

Keywords: Zigzag structure, Fuel supply, Soak-up, Immersion

INTRODUCTION

Recently, the rapid advancement of wireless data communication and electronic circuit design technologies has resulted in a great diversity of functions for personal portable electronic devices. The corresponding electricity requirements for such devices have also increased. However the performance capabilities of conventional lithium-ion batteries are unlikely to keep pace with the increasing power requirements. A new high-energy direct methanol fuel cell (DMFC) is one of the most promising electrical power sources.[1]

A DMFC, for which the theoretical energy density is 10 or more times greater than that of current lithium cells, is expected for use in mobile devices.[1] In order to increase the output voltage of the DMFC, a novel zigzag-type structure has been proposed.[2] This structure can readily be converted to a stack structure, and is known to achieve high-output voltage through a facile in-series connection. Figure 1 shows a schematic diagram of a zigzag-type DMFC.

Figure 2 shows the fabrication process for the zigzag-type DMFC, which is described as follows:

(1) Separate anode and cathode electrodes are attached to a membrane. Current collectors are subsequently placed as shown in Fig. 2(a), and the membrane electrode assembly (MEA) sheet is then folded.

(2) An insulating film is then placed over the first cathode. The current collectors are then folded back over the insulating film.

(3) The sheet is then folded back over the current collector, and the current collector is folded back over the sheet.

(4) Steps (b) and (c) are repeated as necessary.

Repeating steps (b) and (c) provides a zigzag-type DMFC that is able to achieve high-output voltage by a simple connection in series.

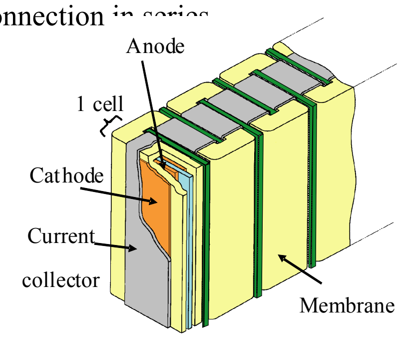

Fig. 1. Schematic diagram of a zigzag-type DMFC.

Achievement of high power density is required in order to utilize the zigzag-type DMFC for mobile devices. However, a lower power density has been reported for the zigzag-type DMFC than that of a conventional stack-type DMFC.[2] Herein, we describe the output power characteristics of a zigzag-type DMFC with varying fuel and air supply.

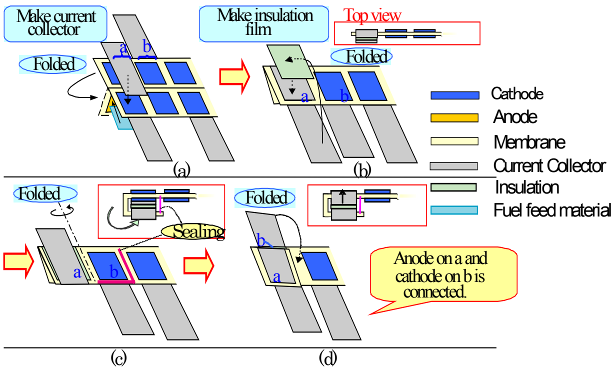

Fig. 2. Fabrication process for a zigzag-type DMFC.

EXPERIMENTAL CONDITION

The fuel and oxidant feed methods for anodes and cathodes in a zigzag-folded DMFC differ from those of conventional cells. The liquid methanol fuel between the anodes is soaked up and fed to the anodes using filter paper, and air is fed to the cathodes through spaces in the insulation film. The fuel supply method does not provide sufficient methanol to the entire area of the anodes. Figure 3 shows the output-voltage characteristics for plate-type and zigzag-type DMFCs.

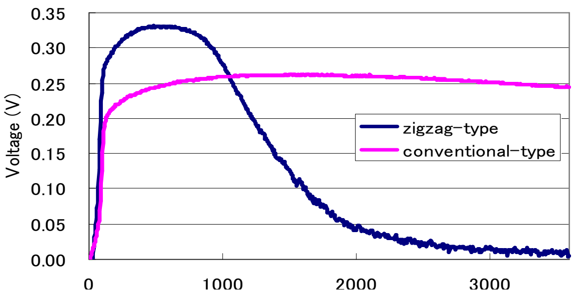

Fig. 3. Output voltage characteristics for plate-type and zigzag-type DMFCs.

The output voltage of the zigzag-type DMFC decreases after 1000 s. The decrease is caused by a lack of methanol supply to the surface of the cell. A different fuel supplier geometry and method of fuel supply were considered in this investigation.

The prototype cell had two electrodes on a Nafion117 membrane.[3] The anode and cathode consisted of a Pt-Ru electrocatalyst supported on carbon cloth and a Pt electrocatalyst (3.0 mg/cm^2) supported on carbon cloth, respectively. The areas of the electrodes and the membrane were 16 and 50 cm^2, respectively. In the soak-up experiment aluminum foil was used as a current collector, because of its manufacturing process. Gold-coated titanium mesh with an aperture ratio of 75% was used as a current collector, exclude soak-up experiment. The concentration of methanol used was 2 M. Measurements were conducted at room temperature (*ca.* 20 °C), and were recorded using data logger software MX100 (Yokogawa).[4]

In order to supply methanol to the entire area of the anode, fuel supplier filter papers with various thickness (0.4, 1, 2, and 4 mm) were investigated. Figure 4 shows the experimental setup to examine the effect of filter paper thickness on fuel supply to the anode.

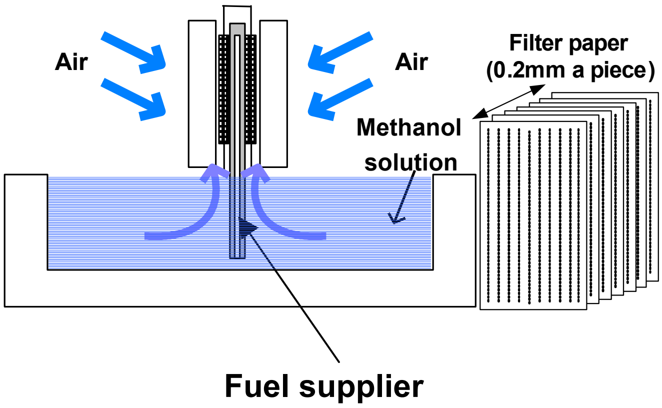

Fig. 4. Experimental set-up for the thickness of filter paper.

The method of fuel supply was changed in order to gain higher output voltage. Rather than supplying the fuel using capillary action, an attempt was made to supply the fuel by immersing the cell into the methanol solution. The DMFC structure used for this supply method is an inside-out conventional zigzag-type DMFC, as shown in Fig. 5. In order to supply air to the area of the cathode, the width of the cathode was varied at 4, 6, 8 and 10 mm.

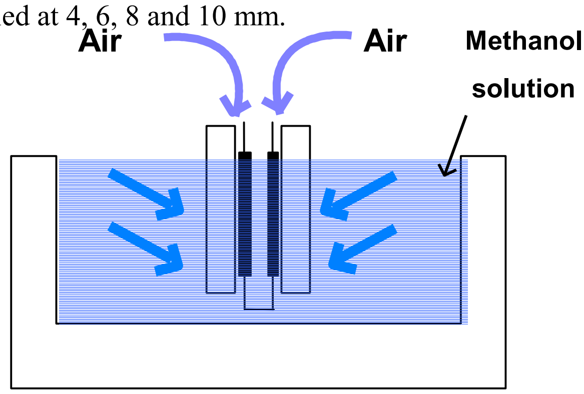

Fig. 5. Experimental set-up for the immersion fuel supply method.

To provide adequate air supply, the current collector was divided into three pieces, top, middle and bottom, to confirm air supply to the entire cathode area. The cathode thicknesses used were the same as those used in the former experiment; 4, 6, 8 and 10 mm. Figure 6 shows the state of the experiment.

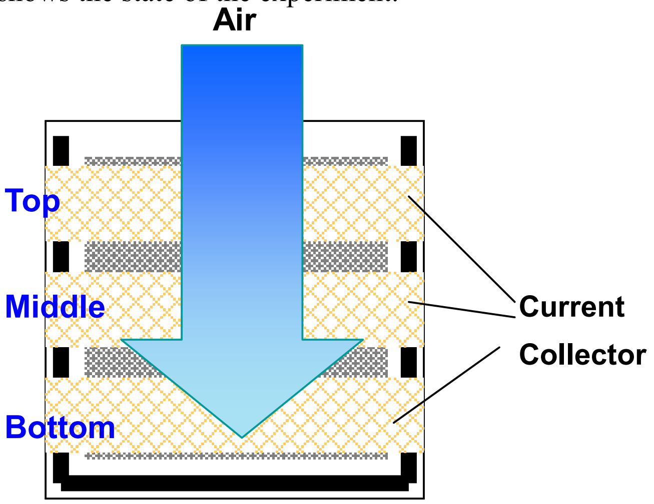

Fig. 6. Experimental set-up for air supply to the entire cathode area.

RESULTS AND DISCUSSION

Figure 7 shows the output-voltage characteristics for each filter paper thickness. The output voltage showed increased stability for the thicker filter paper fuel suppliers. With respect to 1 hour of operation, the 4-mm-thick filter paper was sufficient to supply fuel to the cell, and compared to the 1-mm-thick filter paper, the output voltage after 1 hour was approximately twice as large. After the fuel in the filter paper is used for electricity generation, there are no capillary forces acting on the fuel supplier, especially at the upper region, if the fuel supplier thickness is low. However, the cell is practically used only at the bottom.

To curb the decrease in output, the soak-up capillary action fuel supply method was change to the immersion fuel supply method. Figure 8 shows a comparison of the output voltage for both methods. This result is 4-mm-thick filter paper in soak-up method and 4mm cathode width in immersion method. Output voltage of soak-up fuel supply method is different from Fig.7. This is due to difference of current collector. For the soak-up method, no significant decrease in output was observed over 1 hour of operation. Therefore, the period of operation was doubled to 2 hours. The output-voltage for the immersion supply method was very low compared with the soak-up supply method, but was more stable over the longer operation period. This result suggests that the immersion supply method fuel supply is suitable; however, the output voltage was very low due to insufficient air supply.

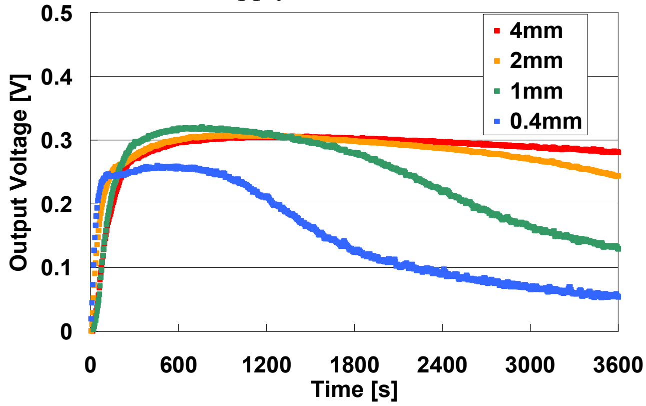

Fig. 7. Operation time vs. output-voltage characteristics for different filter paper thickness.

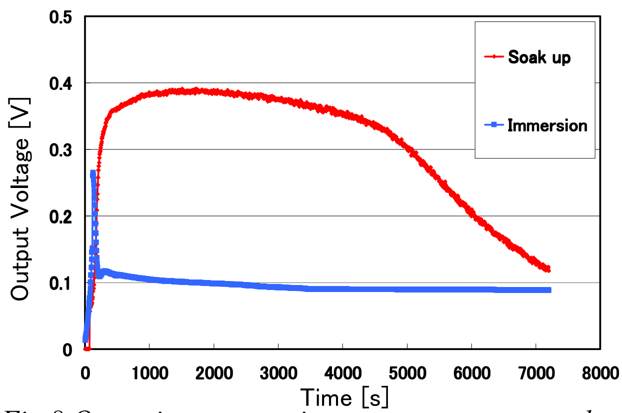

Fig.8.Operation time vs. output-voltage characteristics for soak-up and immersion fuel supply methods.

This result revealed the necessity to examine the air supply. Figure 9 shows the output-voltage characteristics for each width of the cathode. As the cathode air intake is expanded, the output voltage increases. A cathode width of 4 mm (same size as the soak-up supply method) was not enough for sufficient supply of air to the cell. Therefore, in order to increases the output-voltage, the width of the cathode air intake must be increased.

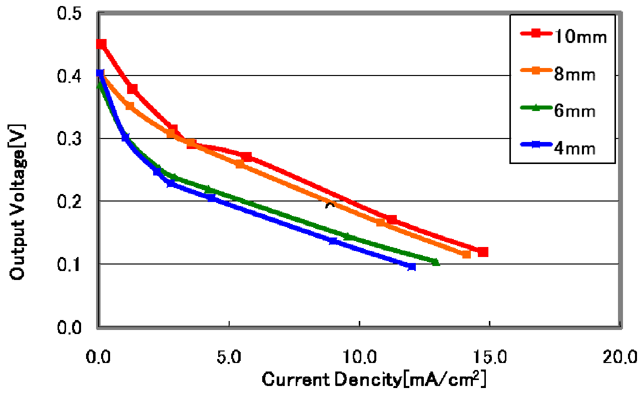

Fig.9. Current density vs. output-voltage characteristics for each cathode width.

The air supply to the bottom of the cell was examined. Figure 10 shows the output-voltage for each part of the cell with cathode widths of 6 and 10 mm. There was no significant difference between the top and middle of the 6- and 10-mm width cathodes. However, the output-voltage of the 6-mm-width cathode is very low at the bottom part compared with that for the 10-mm cathode. This indicates that only the top and middle part of the cell is used for the 6-mm cathode. However, a cathode with a 10 mm width is sufficient to maximize use of the entire cathode area.

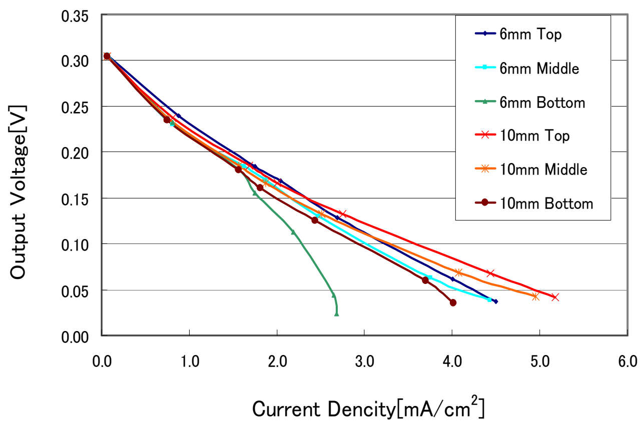

Fig. 10. Current density vs. output-voltage for each segment of the cathode.

SUMMARY

Fuel supply methods for a zigzag-type DMFC were investigated. For the soak-up fuel supply method, a 4 mm thick filter paper fuel supplier was sufficient for fuel supply over an operation period of 1 hour.

For the immersion fuel supply method, the output-voltage was more stable than that for the soak-up method; however, the output-voltage was lower. This was due to the narrow cathode air intake, which does not allow the air to arrive at the bottom of the cell. A cathode width of 10 mm was sufficient for the delivery of air to the bottom of the cell, which enabled use of the entire cathode area.

In using the soak-up supply method, consistency of the filter paper capillary force over time must be checked. If the capillary force decreases, then a substitute material will be required for the soak-up fuel supply method. In addition, active air supply will be necessary to improve the output density in the future, because the output density is still low.

ACKNOWLEDGEMENT

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