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Fabrication of Woodceramics Separator for Disk Type Polymer Electrolyte Fuel Cell

Hirotaka Shimizu, Yuuki Kaihara, Hiroyuki Mito, Nobuhiro Watanabe, Kazuhiko Kakishita, Toshikazu Suda and Toshihiro Okabe*
Polytechnic University, 4-1-1 Hashimotodai, Sagamihara 229-1196, Japan
Fax: 81-42-763-9150, e-mail: shimizu@uitec.ac.jp
* Aomori Industrial Research Center, 4-11-6 Daini-tonyamachi, Aomori 030-0113, Japan
Fax: 81-17-739-9613, e-mail: okabe@aomori-tech.go.jp

In the present research, the woodceramics separator for a disk type polymer electrolyte fuel cell (PEFC) was fabricated to develop a new application of woodceramics. The woodceramics could be suitable for the material because the separator of the disk type PEFC required not only high conductivity but also high gas permeability. A cotton paper was adopted as a raw material. It was confirmed that the disk type PEFC using the woodceramics separator generated an electric power. It was, furthermore, found that the output characteristics of the PEFC were influenced by the degree of impregnation for phenolic resin used in the fabrication process of the separator. It was also pointed out that the optimum degree of impregnation was about 28 wt%.
Key words: woodceramics, polymer electrolyte fuel cell (PEFC), separator, phenolic resin, impregnation

1. INTRODUCTION

Recently, the woodceramics has got into the spotlight as an ecological and low-cost material because can be fabricated from a ligneous waste such as waste paper[1]. On the other hand, fuel cell is drawing an attention as an ecological power generation method. Polymer electrolyte fuel cell (PEFC) operates with lower temperature than the other types of fuel cells[2] and, furthermore, realizes weight saving and miniaturization. The research and development on the application of the PEFC has especially become active rapidly in wide fields.

An application of the woodceramics as the conductive component to the PEFC has been investigated as reported in Refs. [3]-[5]. Namely, the woodceramics electrode was fabricated and tested for the electrical characteristics as the electrode. It was found that the woodceramics electrode successfully generated an electric power.

In the present research, the woodceramics separator for a disk type PEFC was fabricated to develop a new application of woodceramics. The disk type PEFC is categorized into a "passive" type PEFC with no fans or blowers to provide air (oxygen), and has simple structure,[6][7]. Generally, the capacity of the disk type PEFC is up to several hundred watts[2]. The separator of the disk type PEFC required high gas permeability as well as high conductivity. Hence, the woodceramics could be suitable for the material of the separator. The application of the woodceramics into the separator could realize an ecological and low-cost PEFC. A cotton paper was used as the raw material in this research. It was confirmed that the disk type PEFC with woodceramics separator generated an electric power. Generally, the woodceramics is fabricated by carbonizing of the wood pulp or woody material impregnated with phenolic resin in which the pulp changes into glassy carbon. The influence of the degree of impregnation for phenolic resin on the output characteristics of the PEFC with the woodceramics separator was examined. It was found that the optimum degree of impregnation existed.

2. DISK TYPE PEFC WITH WOODCERAMICS SEPARATOR

Figure 1 and 2 represent the photograph and schematic diagram of the disk type PEFC (length of 57 mm, width of 28 mm, weight of 37 g), respectively. As schematically illustrated in Fig. 2, the PEFC consists of a membrane electrode assembly (MEA), a separator, collect electrodes, end palates and some gaskets. These parts are mechanically fixed together. The hydrogen feed is down a central tube and the hydrogen is supplied to the anode on the upside of the MEA. The hydrogen supply is dead-ended (no circulation or venting) although the PEFC has a manual purging system. A

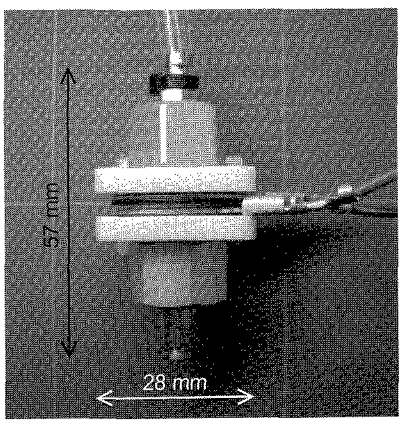

Fig. 1. Photograph of disk type PEFC.

relatively thick gas diffusion layer is underneath the MEA. This part is called "separator" in the disk type PEFC. Air (oxygen) diffuses in and water diffuses out through the separator. In general, a porous material is used for the separator so that the gases can go in and out. The electric current flows to the collect electrode through the separator. The separator should also be electrically conductive. Hence, the woodceramics can be suitable for the material of the separator.

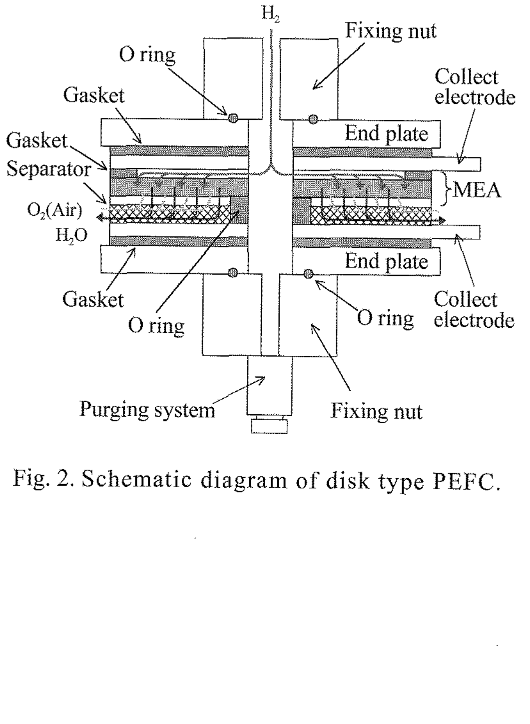

Fig. 2. Schematic diagram of disk type PEFC.

3. EXPERIMENTAL PROCEDURE

3.1 Fabrication of Woodceramics Separator

Figure 3 demonstrates the schematic diagram illustrating the fabrication process for the woodceramics separator. A cotton paper (thickness of 0.9 mm) was adopted as the raw material, and was immersed into a methanol solution of phenolic resin (Bellpearl, Air Water Bellpearl Inc.) for about 48 hours. The impregnation degree K for phenolic resin into a cotton paper was changed by controlling the concentration for methanol solution, and the range of K covered 9.9 wt% to 43.0 wt%. After that, the paper immersed into the solution was vacuum-dried at a temperature of 150 ℃ for 15 minutes, and was carbonized in vacuum. The specimens were then carbonized by a process that the cotton papers were heated to a temperature of 300 ℃ at the rate of 1 ℃/min, and maintained at 300 ℃ for 3 hours. Next in the carbonizing process, the specimens were heated to 600 ℃ at the rate of 1 ℃/min, and maintained at 600 ℃ for 3 hours as shown in Fig. 4(a). After carbonizing process, the specimens were annealed by a process that heated the specimens to a temperature of 900 ℃ at 10 ℃/min in vacuum, and was maintained at 900 ℃ for 3 hours as shown in Fig. 4(b). For water-repellent treatment, the woodceramics was immersed into a diluted suspension of fluorinated ethylene polyethylene resin (Teflon FEP, DuPont), and was heat-treated at 300 ℃ for 30 minutes. Finally, woodceramics was cut into a size of 398 mm^2 (outer diameter: 26 mm, inner diameter: 13 mm) to fit the PEFC as shown in Fig. 5. The left and right photograph in Fig. 5 show the raw material (cotton paper) and woodceramics separator (K=41.0 wt%), respectively.

Figure 6 shows the typical characteristics of the thickness of the separator as a function of impregnation degree K. It was found that the value of thickness of the separator increased with the value of K.

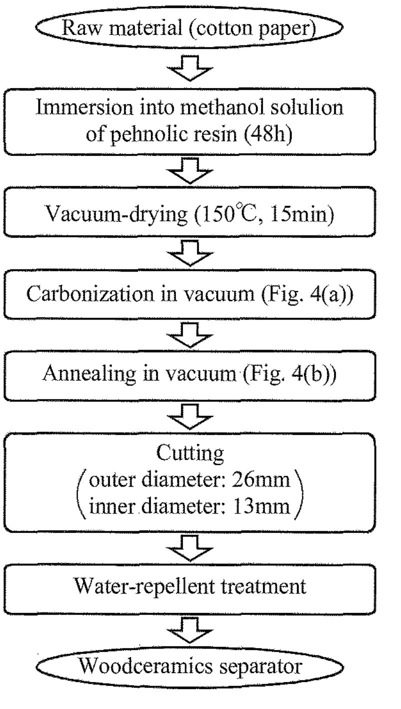

Fig. 3. Schematic diagram illustrating fabrication process of woodceramics separator.

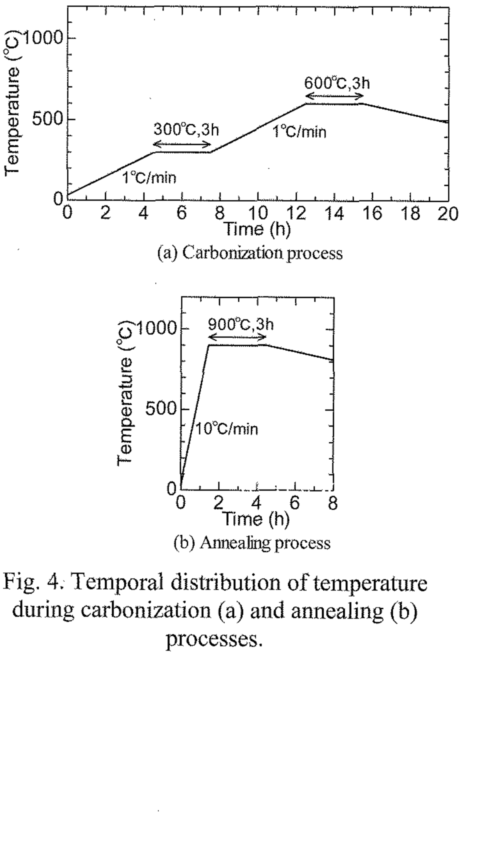

Fig. 4. Temporal distribution of temperature during carbonization (a) and annealing (b) processes.

3.2 Measurement of Output Characteristics

The voltage-current characteristics of the PEFC with woodceramics separator were measured. Figure 7 illustrates the experimental set-up. The hydrogen was supplied from a hydrogen-storing alloy (MS Canister, JSW). The purity and pressure of hydrogen were more than 99.99 % and about 0.1 MPa, respectively. Adjusting the output current from the PEFC by an electronic load device, we measured the output voltage was measured. The output power from the PEFC was obtained from the product of the output current and voltage. The experiment was carried out at room temperature.

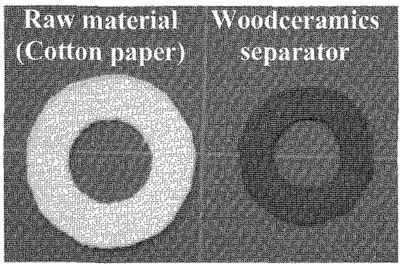

Fig. 5. Photograph of cotton paper (left) and woodceramics separator (right).

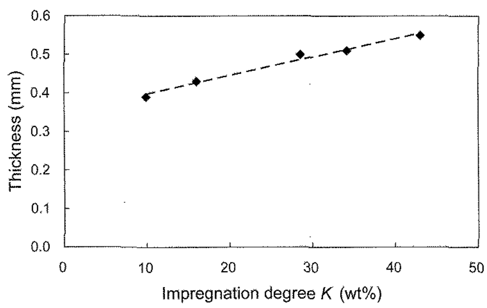

Fig. 6. Typical characteristics of thickness of woodceramics separator as a function of impregnation degree K.

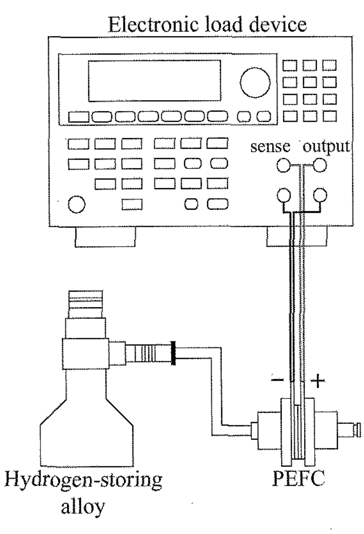

Fig. 7. Experimental set-up for voltage-current characteristics of disk type PEFC.

4. RESULTS AND DISCUSSION

Figure 8 shows the measured voltage-current characteristics. The results for the separator with different K's were indicated together. From this figure, it is confirmed that an electric power was generated by the PEFC with woodceramics separator. All the voltages decreased with an increase in the current. The voltage for K=28.5 wt% was highest in all the conditions although the voltage for K=43.0 wt% was highest under the condition of the current of less than 0.1 A.

Figure 9 describes the output power as a function of the current. As seen in this figure, the power-current characteristic of the PEFC has the maximum value. In this paper, the maximum value of the power is called "maximum power". In case of K=28.5 wt%, the maximum power was largest and the value was 0.103 W.

Figure 10 indicates the relationship between the maximum power and the degree K of impregnation. As seen in this figure, the optimum degree of impregnation under which the maximum power is largest exists. The output power depends on the electric conductivity and gas permeability of the separator. The electric conductivity increases with K although the gas permeability decreases[4]. When K is too large, the generated power may be low because of the bad gas

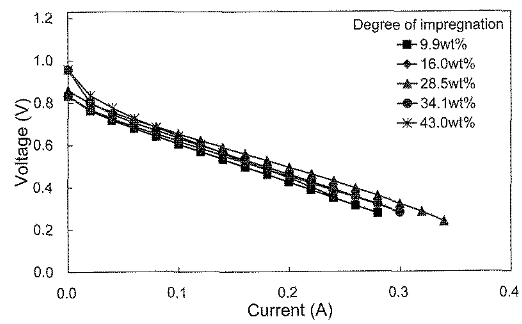

Fig. 8. Voltage-current characteristics of PEFC with woodceramics separator

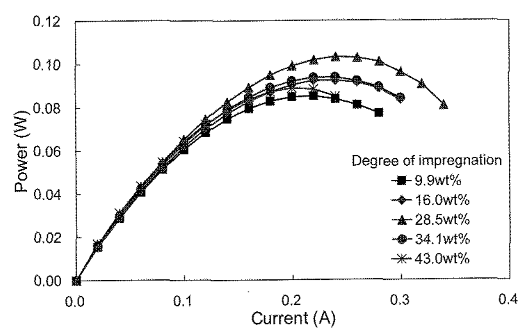

Fig. 9. Power-current characteristics of PEFC with woodceramics separator.

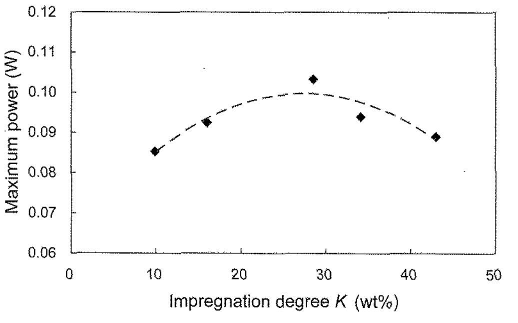

Fig. 10. Maximum power as a function of degree *K* of impregnation.

permeability. If the separator with too low *K* was used, the conductivity is low. Furthermore, reduction of mechanical strength may also be affected[5]. The woodceramics is reinforced by the phenolic resin. Since the mechanical strength may be weak in case of low *K*, the porous in the separator might be destroyed when it is mechanically incorporated into the PEFC. As a result, the gas permeability may become worse. From Fig. 10, the optimum degree of impregnation may be about 28 wt%.

To understand the output characteristics of the PEFC with the woodceramics separator in detail, the influence of the operating temperature of the PEFC and the purity of the provided hydrogen on the output characteristics should be examined. The inner resistance should also be estimated. These characteristics are also important to improve the performance of the PEFC.

5. CONCLUSIONS

The separator for a disk type PEFC was fabricated with woodceramics. A cotton paper was adopted as the raw material. The electric power generation by the PEFC using the woodceramics was observed. The maximum output power has the peak value at a certain degree of impregnation of phenolic resin. It was found that the value may be about 28 wt%.

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