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Performance Characteristics of Polymer Electrolyte Fuel Cell with Woodceramics Electrodes

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We have proposed an application of woodceramics sheet to electrode for Polymer Electrolyte Fuel Cell (PEFC). The performance of the PEFC with woodceramics electrodes was experimentally investigated. The woodceramics electrode was made from a paper filter. It was confirmed that the amount of impurities in the woodceramics electrode was very small. The generated power of the PEFC with woodceramics electrodes was almost same as that of the PEFC with carbon paper electrodes. To estimate the influence of the degree *K* of impregnation of phenolic resin in the woodceramics electrode, we made several woodceramics electrodes with different *K*. The generated power of the electrode with *K* of 28.2 % was 0.34 mW/cm^2. It was highest among the electrodes made in this experiment. In case of the electrode with too large *K*, the output power may be low because of bad gas permeability. On the other hand, If the electrode has too small *K*, the output power may also be low. That is because the mechanical strength may decrease with a decrease in *K*. This means that there may be the optimum *K* from the viewpoint of the output power.
Key words: woodceramics, PEFC, electrode, phenolic resin, impregnation.

1. INTRODUCTION

Recently, woodceramics has become of interest as an ecological and low-cost material[1]. That is because the woodceramics is made from ligneous waste such as waste paper. We have proposed the application of the woodceramics to Polymer Electrolyte Fuel Cell (PEFC)[2]. The woodceramics can be applied to the electrode and/or the separator for the PEFC as an electrically-conductive material.

In this paper, the performance of the PEFC with the electrodes made from woodceramics sheet was investigated. A filter paper was adopted as the raw material for the woodceramics sheet. Estimating the chemical composition contained in the woodceramics electrode using X-ray fluorescence analysis, we confirmed that the amount of impurities in the electrode was small. The voltage-current density characteristics of the PEFC with the woodceramics electrode were measured. In the experiment, the performance of the PEFC with carbon paper electrodes for comparison. The carbon paper is one of the most popular materials for PEFC electrode. Furthermore, the some woodceramics electrodes with different degree *K* of impregnation of phenolic resin were tested to investigate the influence of *K* on the performance of the PEFC.

2. PEFC WITH WOODCERAMICS ELECTRODE

A schematic construction of a typical PEFC is illustrated in Fig. 1[3]. A proton exchange membrane is sandwiched by electrodes having catalyst layer. The electrode is thin and porous so that both the electrolyte from one side and the gas from the other side can penetrate. We made these electrodes from the woodceramics sheet. The membrane and electrodes are united by hot-press and membrane electrode assembly (MEA) is formed. The MEA is fixed by separators. As shown in Fig. 1, the separator had grooves and the gas was provided through those.

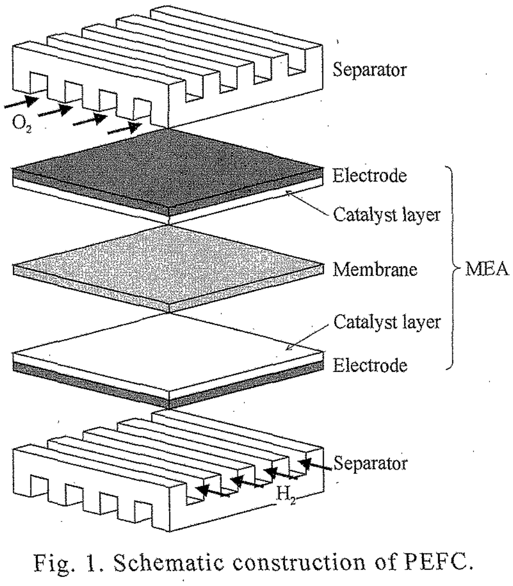


Fig. 1. Schematic construction of PEFC.

3. MANUFACTURING PROCEDURE OF MEA

The woodceramics sheet was made from a filter paper. The mass, thickness and retained particle diameter were 9 mg/cm^2, 0.02 cm and 6 μm, respectively. We made some woodceramics sheets with different degree *K* of impregnation of phenolic resin to investigate the influence on the power generating performance. The annealing temperature and time were 900 ℃ and 3 hours[2][4].

Figure 2 shows an outline of manufacturing procedure of the MEA. First, a water-repellent treatment was given the woodceramics sheet. The woodceramics sheet was immersed into a diluted suspension of FEP. After that, we heat-treated it at 300 ℃ for 30 minutes. The chemical compositions of the woodceramics electrode after the water-repellent treatment were measured by fluorescent X-ray analysis. Figure 3 indicates the result for the sample whose *K* was 52.5 %. Carbon was proved to be the main component of the woodceramics electrode and the weight percentage was 88 wt%. Fluorine was also detected (the weight percentage was 8.5 wt%). It seemed to be due to the water-repellent. It was found that the amount of impurities in the woodceramics electrode was very small.

Secondly, the woodceramics electrode was cut into a size of 4.8 cm^2 (2.2 cm×2.2 cm). We made catalyst paste by mixing carbon support (VulcanXC72R) with platinum and the electrolyte (Nafion) solution. The catalyst paste was applied to the woodceramics electrode so that the amount of platinum was 1 mg/cm^2. The MEA was manufactured by sandwiching a proton exchange membrane (Nafion115) between the electrodes and hot-pressing that at 130 ℃. The hot-pressing pressure was 50 kgf/cm^2. Figure 4 indicates the MEA manufactured with the woodceramics electrodes.

4. PERFORMANCE OF PEFC WITH WOODCERAMICS ELECTRODES

4.1 Experimental Procedure

We measured the voltage-current density characteristics of the PEFC with woodceramics electrodes. In the experiment, the cell temperature and dew-point temperature were adjusted to 70 ℃. Hydrogen and Oxygen volumetric flow rates were 300 mL/min and 150 mL/min. The gas pressure was atmospheric one.

4.2 Voltage-Current Density Characteristics

Figure 5 shows the measured voltage-current density characteristics. The results for the electrode with different *K*'s were indicated together. The open circuit voltages for the woodceramics electrodes of *K*=0 %, 28.2 % and 42.0 % were 0.78 V, 0.93 V and 0.93 V, respectively. All the voltages decreased with an increase in the current density. The voltage for *K*=28.2 % is almost same as that for *K*=42.0 % under the condition that the current density is less than about 0.5 A/cm^2. For the current density of more than 0.5 A/cm^2, the voltage for *K*=28.2 % is higher than that for *K*=42.0 %. On the other hand, the voltage for *K*=0 % (not given any water-repellent treatment) declined sharply with the current density. Figure 5 also shows the characteristics for the electrode with carbon paper which is a popular material for the electrode of PEFC. The voltage for the woodceramics electrodes of *K*=28.2 % and 42.0 % were almost same as that with carbon paper.

4.3 Power Density-Current Density Characteristics

Figure 6 shows the power density as a function of the current density. This figure indicates the results for

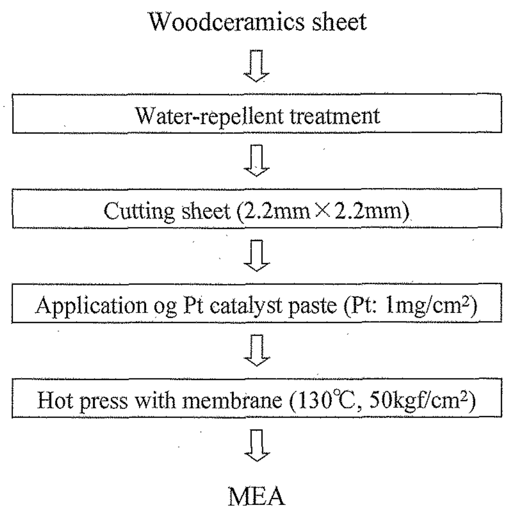


Fig. 2. Manufacturing procedure of MEA.

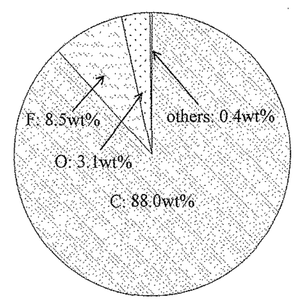


Fig. 3. Chemical compositions in woodceramics sheet (degree *K* of impregnation: 52.5 %)

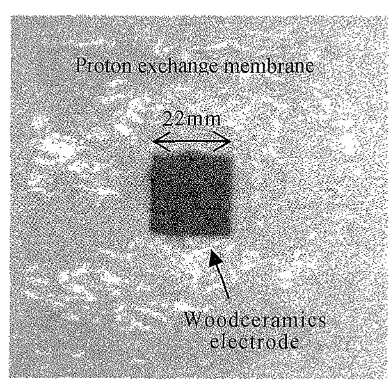


Fig. 4. Photograph of MEA manufactured.

K=0 %, 28.2 % and 42.0 % together with that of carbon paper. As seen from this figure, the power density-current density characteristic of the PEFC has the maximum value. Figure 7 indicates the maximum power density for each K. The maximum power density of K=28.2 % was 0.34 W/cm^2 and was highest of the three. This value corresponded to 88 % of that of the carbon paper. The maximum power density of K=42.0 % was 0.29 W/cm^2 and was 76 % of that of the carbon paper. The maximum power density of K=0 % was 0.005 W/cm^2. It was confirmed that the woodceramics electrode of K=0 % hardly generates the electric power.

5. Discussion

As shown in Fig. 7, the optimum degree K of impregnation of phenolic resin may exist where the maximum power density is highest. The generated power depends on the electric resistivity and gas permeability of the electrode. The gas permeability increases with the bulk density. We have estimated the influence of K on the electric resistivity and bulk density[4]. Figure 8 indicates the electric resistivity and bulk density as a function of K. As shown in Fig. 8, the electric resistivity decreases with an increase in K although the bulk density rises. When K is too large, the generated power may be low because of the bad gas permeability. If we use the electrode with too low K, the resistivity is high. As a result, the generated power may decrease. However, the increase in the electric resistivity is inadequate to explain very low power density of the electrode with K=0 %. To discuss the reason for the reduction of generated power for low K, we observed the surface of the electrode by electron microscope. Figure 9 (a) and (b) are the microscope photograph of woodceramics electrode of K=0 % before and after hot-pressing for the MEA. It was found that the porous exists in the electrode before hot-pressing. On the other hand, the porous in the electrode after the hot-pressing was destroyed. We also confirmed that the porous was kept in the electrodes made under the conditions of K=28.2 % and 42.0 % after hot-pressing. The woodceramics is reinforced by impregnation of phenolic resin in the manufacturing process. Since the mechanical strength may be weak in case of K=0 %, the porous in the electrode might be destroyed. As a result, the gas permeability may become worse. Hence, the generated power may be low in the PEFC having electrodes with low K because of the bad gas permeability. This means

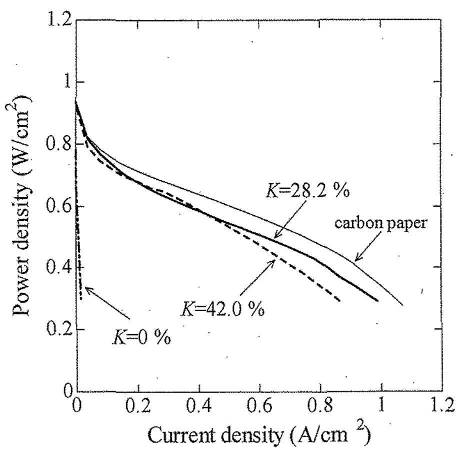


Fig. 5. Voltage-current density characteristics.

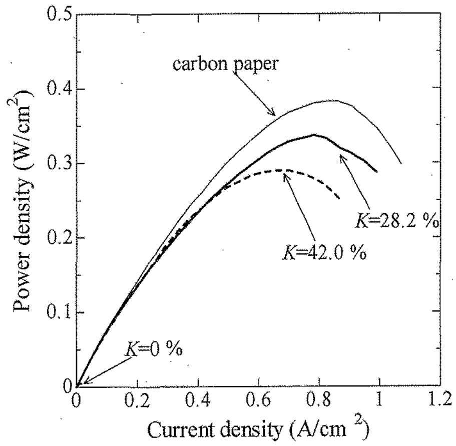


Fig. 6. Power density-current density characteristics.

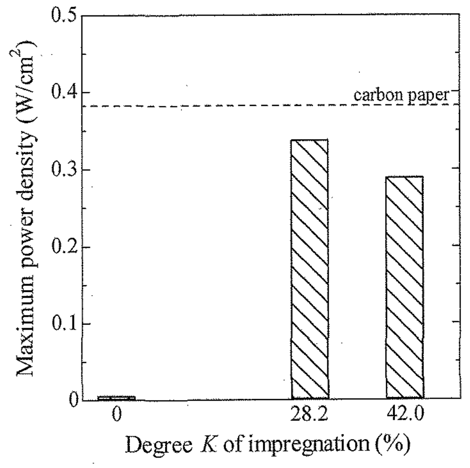


Fig. 7. Maximum power density as a function of degree K of impregnation.

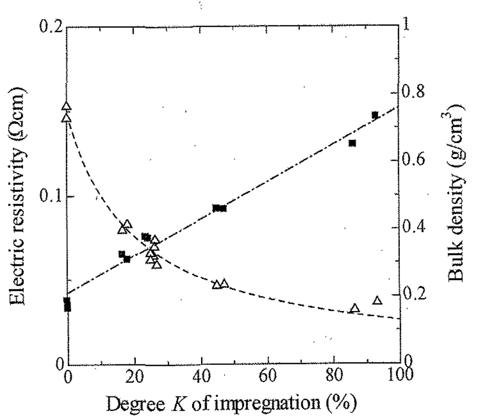
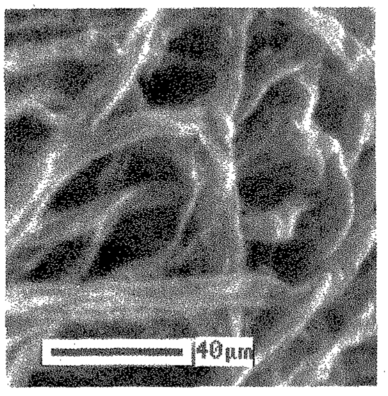
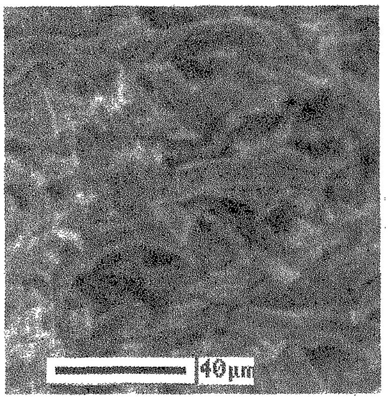


Fig. 8. Electric resistivity and bulk density as a function of degree K of impregnation.



(a) before hot-pressing



(b) after hot-pressing.

Fig. 9. Microphotograph of surface of electrode (K=0 %).

that the electrode must have sufficient mechanical strength for the pressure at hot-pressing .

6. CONCLUSIONS

We investigated the performance of the PEFC with woodceramics electrodes. The electrode was made from a filter paper. We confirmed that the PEFC generated the electric power and the magnitude was almost same as that of the PEFC with carbon paper electrodes. We also discussed the influence of the degree K of impregnation of phenolic resin. It was pointed out that there may be the optimum K from the viewpoint of the electric power generation. Furthermore, it was found that the electrode must have sufficient mechanical strength of electrode to keep the porous for gas permeability.

REFERENCES

[1] T. Okabe, K. Saito and K. Hokkirigawa, *Journal of Porous Materials*, **2**, pp.207-213 (1995).
[2] H. Shimizu, K. Hashimoto, N. Watanabe, K. Kakishita, T. Suda and T. Okabe, *Transactions of the Materials Research Society of Japan*, **31**, pp.941-944 (2006).
[3] J. Laminie and A. Dicks, "Fuel Cell Systems Explained Second Edition", John Wiley & Sons, England (2003) pp.66-119.
[4] H. Shimizu, K. Hashimoto, N. Watanabe, H. Mito, K. Kakishita, T. Suda and T. Okabe, *Transactions of the Materials Research Society of Japan*, **32** (2007) (to be published).

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