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Application of Woodceramics for VOC Sensor

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Woodceramics was fabricated from cotton paper (CP-WCMs) as a VOC (volatile organic compounds) sensor. CP-WCMs fabricated from the cotton paper consists mainly of carbon and the impurities are very few, so that cotton paper is suitable for WCMs raw material due to its homogeneity and the purity. The impedance response of CP-WCMs when exposed to butyl acetate gas (one of VOC) was measured. The impedance of CP-WCMs decreased with the increase of butyl acetate gas concentration. Consequently, CP-WCMs seems to be suitable for butyl acetate gas sensor.

Key words: woodceramics, VOC, VOC sensor, gas sensor

1. INTRODUCTION

Woodceramics (WCMs) are new functional carbon materials and have recently shown a strong promise of constituting the next generation as industrial materials [1-10]. WCMs are fabricated by sintering woody materials impregnated with phenolic resin to form glassy carbon which reinforces the fibrous structure of wood. WCMs particularly have the porous structure caused by woody fiber, so that WCMs has been developed as a gas sensor. The electrical impedance of WCMs decreases with humidity resulting from the supply of electrons and/or ions by the adsorption of water molecules on WCMs porous surface [3-9]. Similar to water molecules, the impedance change occurs by adsorbing ammonia gas on the WCMs surface [10].

There is a great demand of a compact and easy to use volatile organic compounds (VOC) sensor in the coating industry. Similar to water molecules and ammonia gas, it is believed that the impedance change of WCMs occurs by adsorbing VOC on the WCMs surface. In this paper, WCMs was fabricated from cotton paper (CP-WCMs) as a VOC sensor. The detection gas used here was butyl acetate gas that was one of the VOC. The impedance response of CP-WCMs with butyl acetate gas was measured and the application for a VOC sensor is discussed.

2. EXPERIMENTAL

Fabrication process for CP-WCMs is shown in Fig.1. The cotton paper was transformed to paper powder using electric blender. The paper powder was rinsed with acetone solution. The paper powder 0.05 g were mixed with 40% phenolic resin solution (Bellpearl, Air Water Inc.) 0.5 ml, and then were hardened to the disk shape with the size of 19.5ϕ x 5 mm thick. The disk was dried at 100°C for 20 minutes and then sintered at 300°C for 3 hours and 620°C for 4 hours in vacuum to make CP-WCMs. The composition of CP-WCMs was analyzed using fluorescent X-ray analysis. Electrodes were formed on CP-WCMs surface by a conductive adhesive. The space between electrodes was 8 mm. The measurement apparatus for the electrical impedance response to butyl acetate gas is shown in Fig 2.

The CP-WCMs was put in the well-stoppered container A and it was set in container B. The container B was filled with butyl acetate gas by vaporizing of liquid solution. After the container A was opened, the electrical impedance response was measured by applying a constant AC voltage of 5 V at a frequency of 110 Hz. The gas concentration was measured with gas detector tube at the first and last time of impedance measurement. The gas concentration was varied with various amount of vaporized liquid solution.

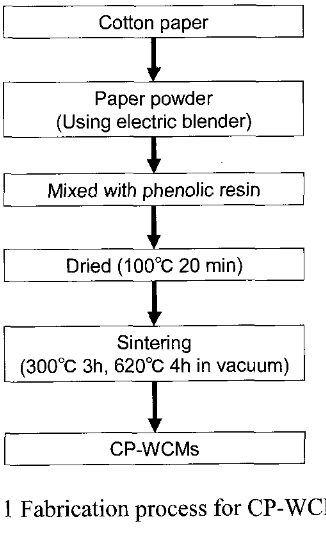

Fig. 1 Fabrication process for CP-WCMs

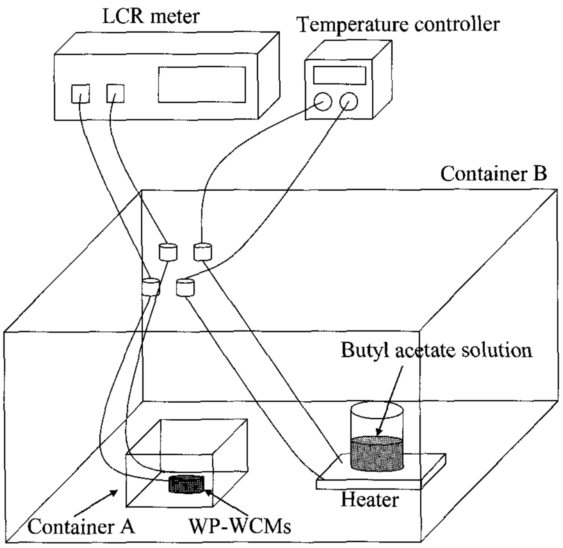

Fig. 2 The measurement apparatus for the electrical impedance response to butyl acetate gas

3. RESULTS AND DISCUSSION

The composition of CP-WCMs obtained using fluorescent X-ray analysis is shown in Table.1. In this table the data of MDF and WP are described as WCMs made from medium density fiber board (MDF) and waste paper (WP), respectively. MDF-WCMs and WP-WCMs contain a slight amount of impurities, such as aluminum, silicon and so on, originated with raw materials. On the other hand, CP-WCMs consists mainly of carbon: the impurities are very few. This result suggests that cotton paper is suitable for WCMs raw material due to its homogeneity and purity as a gas sensor.

Figure 3 shows the impedance response of CP-WCMs without butyl acetate gas. The working temperature of CP-WCMs was 100°C. The longitudinal axis of figure is normalized by the impedance before the container A is opened. Although the butyl acetate gas was not put in to container B, the impedance increased as time passed. It is well known that the impedance of WCMs decreases with humidity resulting from the adsorption of water molecules on WCMs porous surface.

Thus the increase of impedance may be attributed to the evaporation of water from inside CP-WCMs. In order to eliminate the impedance increase resulting from water evaporation, the samples were annealed at 150°C for 10 min in air before the measurement. After the annealing, the impedance response was measured at various WCMs temperatures, from 100°C to room temperature. Figure 4 shows the impedance response of CP-WCMs with and without butyl acetate gas. The temperature of CP-WCMs was maintained at 40°C during the measurement. Without butyl acetate gas, the impedance increased immediately after the beginning of the measurement and then became constant.

This result indicates that the impedance change due to water evaporation is eliminated by the pre-annealing at 150°C. At the beginning of the measurement, the container A is opened so that the surface temperature of CP-WCMs may instantaneously decrease, causing the impedance increase. In fact, the impedance changed only by opening and closing the container A.

When exposed to the butyl acetate gas, the impedance decreased after the short increase (region A) of impedance due to surface temperature change. Then, it had a minimum (region B) and increased again (region C). The minimum impedance value decreased with increasing the butyl acetate gas concentration. This result indicates that the impedance of CP-WCMs decreased due to the absorption of butyl acetate gas on the surface. The gas concentration inside the container was monitored by gas detector tube at the first and the last of impedance measurement. It was found that the gas concentration was decreased during the measurement probably due to the adsorption of the gas by CP-WCMs. It is well known that WCMs is highly capable adsorbing agent.

Figure 5 shows the gas concentration dependence of impedance in region B and C. The circle and triangle denote the impedance at region B (minimum value) and the average impedance at region C, respectively. The impedance monotonically decreased with the gas concentration and then saturated. The increase of impedance in region C is probably caused by the decrease of gas concentration due to the absorption on the CP-WCMs surface. Consequently, these results suggest that CP-WCMs is suitable for butyl acetate gas sensor.

Table.1 Chemical composition of MDF-WCMs, WP-WCMs and CP-WCMs

Composition	C	O	Na	Ca	K	Mg	Si
MDF-WCMs (wt%)	94	5.4	0.30	0.11	0.075	0.051	0.024
	Cl	P	Mn	Al	S	Fe	
	0.023	0.014	0.013	0.012	—	—	

Composition	C	Al	Si	Ca	P	K	
WP-WCMs (wt%)	≅ 99.9	0.063	0.045	0.013	—	—	
CP-WCMs (wt%)	≅ 100	—	—	—	—	—	

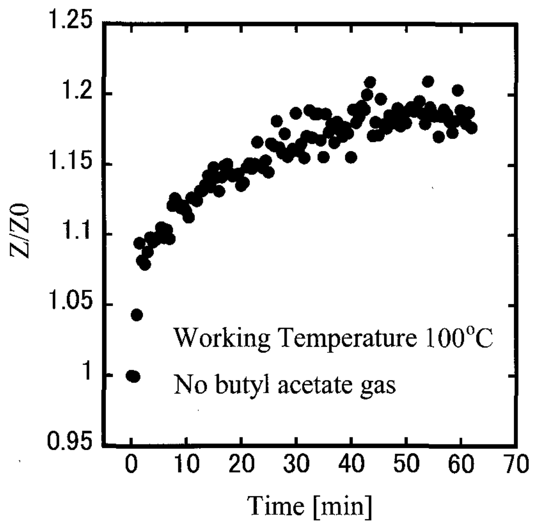

Fig. 3 Impedance response of CP-WCMs without butyl acetate gas

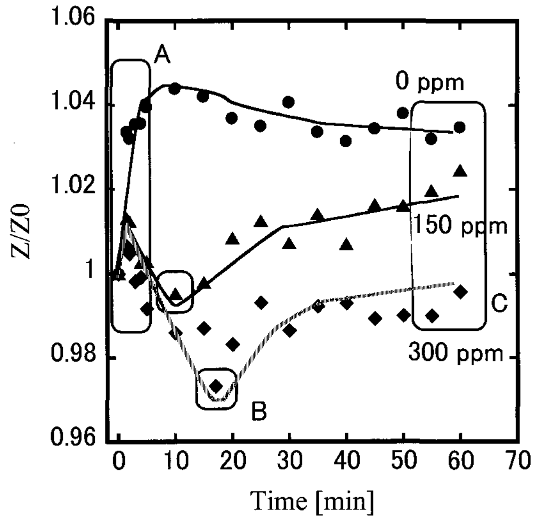

Fig. 4 Impedance response of CP-WCMs with and without butyl acetate gas

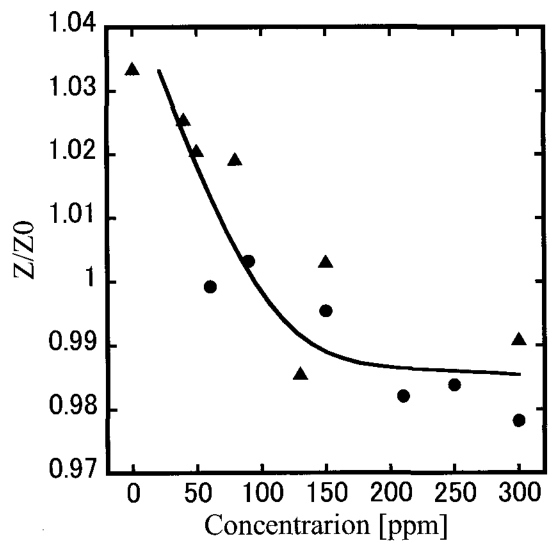

Fig. 5 Gas concentration dependence of impedance in region B and C

4. CONCLUSION

WCMs was fabricated from cotton paper as a butyl acetate gas sensor. The impedance response of CP-WCMs when exposed to butyl acetate gas was measured. CP-WCMs fabricated from cotton paper consists mainly of carbon and the impurities are very few, so that cotton paper is suitable for WCMs raw material due to its homogeneity and the purity. It is found that annealing CP-WCMs in air before the measurement is necessary, in order to eliminate the impedance increase resulting from water evaporation. The impedance of CP-WCMs changes due to the absorption of butyl acetate gas on the surface. The minimum value and the saturated value of impedance decrease with the increase of butyl acetate gas concentration. When CP-WCMs is used as butyl acetate gas sensor in the field, the decrease of gas concentration due to the gas absorption on the surface of CP-WCMs is negligible: so that the impedance may saturate during the measurement. Consequently, CP-WCMs is suitable for butyl acetate gas sensor.

References

[1] T. Okabe, K. Saito and K. Hokkirigawa, J. Porous Mat., 2, 207-213 (1996).
[2] T. Okabe, K. Saito, M. Fushitani and M. Otsuka, J. Porous Mat., 2, 223-228 (1996).
[3] T. Suda and K. Kakishita, Trans. Mat. Res. Soc. Japan, 24(3), 305-309(1999).
[4] K. Kakishita, T.Suda and H. Irisawa, Trans. Mat. Res. Soc. Japan, 25(3), 705-708(2000).
[5] K. Kakishita and T. Suda, Trans. Mat. Res. Soc. Japan, 26(3), 875-877(2001).
[6] K. Kakishita and T. Suda, Trans. Mat. Res. Soc. Japan, 26(3), 883-886(2001).
[7] T. Suda, N. Kondo, T. Okabe and K. Saito, J. Porous Mat., 6, 255 - 258 (1999).
[8] K. Kakishita and T. Suda, Trans. Mat. Res. Soc. Japan, 27(3), 657-660(2002).
[9] K. Kakishita, S. Asai and T. Suda, Trans. Mat. Res. Soc. Japan, 28(4), 1049-1051(2003).
[10] K. Kakishita, and T. Suda, Trans. Mat. Res. Soc. Japan, 29(5), 2427-2430(2004).

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