Humidity Dependence of Resistance for Woodceramics made of Wood Powder

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Wood powder with considerably uniform diameter has been used for fabrication of woodceramics. Density and form dependence of the woodceramics on humidity sensitivity has been investigated. The sensitivity to humidity increased with decreasing density of woodceramics before sintering and with increasing the thickness of woodceramics. It is suggested that the electrical resistance and the sensitivity to humidity can be improved by controlling the density and the form of woodceramics for a humidity sensor.
Key words: woodceramics, humidity sensor, wood powder, density

1. INTRODUCTION

Woodceramics (WCMs hereafter) are the new functional carbon materials and have recently shown a strong promise of constituting the next generation of industrial materials [1-8]. WCMs are fabricated by sintering woody materials impregnated with phenolic resin to form glassy carbon which reinforces the fibrous structure of wood. It is well known that WCMs can be fabricated from waste wood, waste paper, saw dust and so on; thereby WCMs are environment conscious materials (ecomaterials) designed for minimizing the environmental impacts. The WCMs have the prominent characteristics of lightweight, hardness, corrosion resistance and heat resistance.

WCMs particularly have the porous structure caused by woody fiber, so that WCMs has been developed as a humidity sensor [3-8]. Although a large number of polymer sensors widely used, those are limited in usage at low temperature and tend to have mold grown on the sensor surface by prolonged use. Using WCMs has an advantage of being able to avoid the mold.

The electrical resistance of WCMs decreases with humidity resulting from the supply of electrons and/or ions with adsorption of water molecules on WCMs porous surface. In order to use a WCMs humidity sensor commercially, problem of reproducibility on individual material composition for humidity sensitivity have to be solved.

In this paper, WCMs have been fabricated from woody powder with considerably uniform diameter and humidity dependence of the resistance for WCMs has been measured. The density and form dependence on the sensitivity to humidity is discussed.

2. EXPERIMENTAL

Fabrication process for WCMs is shown in Fig. 1. Woody powder with the size of 5 - 10 μm in diameter and powder phenolic resin were mixed by the weight ratio 8.5 : 1.5. The mixture was pressed to form different density and thickness. The size of specimens used in this experiment was 13 x 11 mm^2. The density was varied from 0.248 to 0.478 g/cm^3 and the thickness was varied from 2.5 to 7.9 mm. After drying specimens at 135°C for 1 hour, liquefied

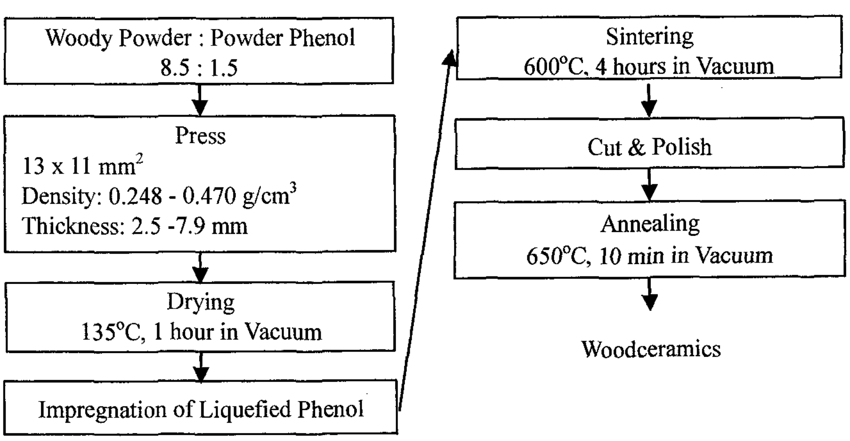

Fig.1 Fabrication process for woodceramics

Table 1 Chemical composition of WCMs made of wood powder.

Composition	C	Na	Si	K	Ca	Fe
Atomic Weight (%)	99	0.69	0.014	0..22	0.063	0.16

phenolic resin was impregnated using an ultrasonic impregnation system [2]. The specimens were sintered at 600°C for 3 hours to form WCMs. After the WCMs were cut and polished, they were annealed at 650°C during 10 min to remove mechanical stress. Chemical composition of WCMs was analyzed by fluorescence X-ray spectroscopy method using Rh tube operated at 50 kV and 50 mA.

Aluminum was evaporated on WCMs surface in vacuum as electrodes. Measurement of the humidity dependence on resistance of WCMs was performed in the environmental examination system. Measurement temperature was fixed at 30°C and the humidity was changed from 30 to 90%RH. The electrical resistance was measured by applying a constant AC voltage of 5 V at a frequency of 1 kHz between the two electrodes.

3. RESULTS AND DISCUSSION

Figure 2 shows the relationship between weight and electrical resistance for WCMs after sintering and the density before sintering. Both the weight and the resistance for WCMs after sintering increased with the increase in the density before sintering. The amount of liquefied phenol impregnated in WCMs changes with the density before sintering. Liquefied phenol contained in WCMs is carbonized by sintering and changed into glassy carbon which has low resistance. When the density is small, the impregnated amount of phenolic resin increases so that the resistance decreases.

Chemical composition of WCMs was analyzed by the fluorescence X-ray spectroscopy method, which is shown at Table 1. The result indicates that the main element of WCMs is carbon with very small amount of oxide such as sodium, silicon, potassium, calcium and iron, which is caused from wood powder.

Humidity dependence of electrical resistance for WCMs with different density is shown in Fig.3. The resistance is normalized by the resistance at humidity of 30%RH. It is obvious that the resistance on humidity decreases with the increase in density before sintering. Relationship between the sensitivity to humidity and the resistance at humidity of 30%RH is shown in Fig.4 (filled circle). The sensitivity is defined as the rate of resistance reduction subjected to

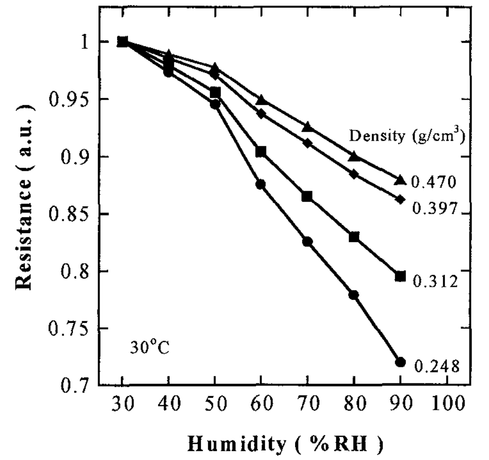

Fig.3 Humidity dependence of the electrical resistance for WCMs with different density.

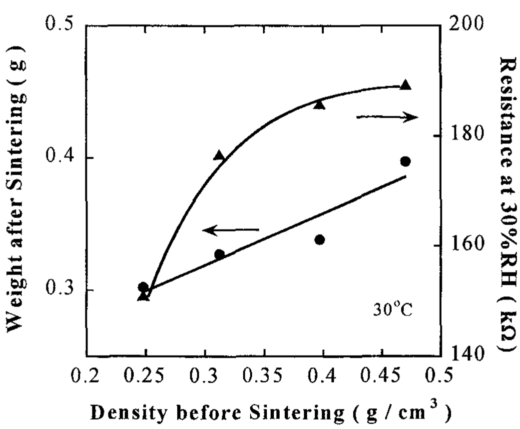

Fig.2 Relationship between the weight and the electrical resistance for WCMs after sintering and the density before sintering.

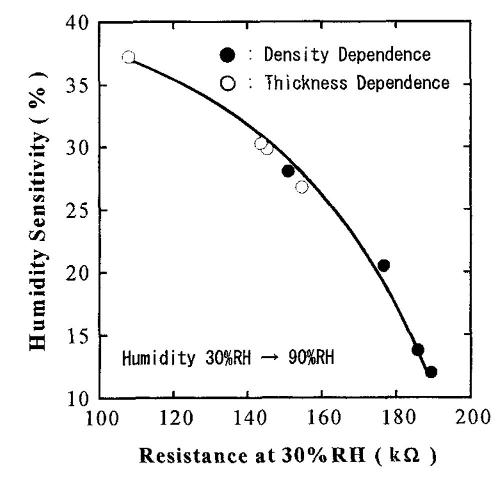

Fig.4 Relationship between the sensitivity to humidity and the resistance at humidity of 30%RH.

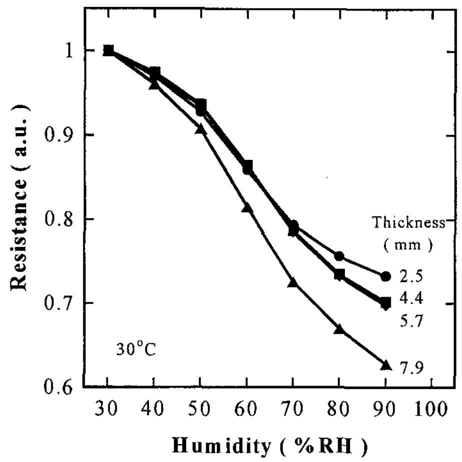

Fig.5 Humidity dependence of the resistance for WCMs with various thicknesses.

the humidity change from 30 to 90%RH. It is generally assumed that the amount of water molecule adsorption does not depend on the electrical resistance of the specimen, so that the sensitivity to humidity should increase with resistance. In fact, when the resistance is changed by doping various metals into WCMs, the sensitivity to humidity increase with the increase in resistance. In this experiment, the opposite results to the anticipation were obtained.

The amount of liquefied phenol impregnated in WCMs decreases with increasing the density before sintering. Considering water molecules adsorbed to OH basis resulted from phenolic resin, reduction of the amount of the liquefied phenol impregnated in WCMs causes the decrease of the adsorption sites of water molecules; as a result, the sensitivity becomes smaller as the density before sintering becomes larger.

The humidity dependence of the resistance for WCMs with various thicknesses is shown in Fig.5. Electrical resistance decreases with the increase in the thickness of WCMs. In addition, the relationship between the sensitivity to humidity and the resistance at humidity of 30%RH is shown in Fig.4 (open circle). The sensitivity to humidity becomes smaller as the thickness of WCMs becomes thinner, whereas the resistance becomes higher. Since the water molecules mainly adsorb on the WCMs surface, the ratio of surface area to volume might decrease and the sensitivity to humidity becomes smaller with decreasing thickness of WCMs.

4. CONCLUSION

Wood powder with considerably uniform diameter has been used for the fabrication of woodceramics. The density and form dependence of humidity sensitivity has been discussed. The sensitivity to humidity decreases with the increase in the density before sintering, because the density before sintering increases with decreasing the amount of liquefied phenol impregnated in WCMs. The sensitivity to humidity becomes smaller as the thickness of WCMs becomes thinner, whereas the resistance becomes higher. It is suggested that the electrical resistance and the sensitivity to humidity can be improved by controlling the density and form of WCMs for a humidity sensor.

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