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Electrical characteristics of acid- and alkali- treated Woodceramics

Hiroyuki Mito, Kazuhiko Kakishita, Toshikazu Suda and Masato Murakami*
Polytechnic University, Kanagawa
Fax: +81-427-63-9168, e-mail: h-mito@uitec.ac.jp
* Shibaura Institute of Technology, Tokyo
Fax: 81-03-5859-8117, e-mail: masatomu@sic.shibaura-it.ac.jp

Waste paper of postcards was used for the fabrication of woodceramics (WP-WCMs). To improve the humidity sensitivity, WP-WCMs were treated with H_2SO_4 or KOH after sintering or annealing, and their electrical impedance and humidity sensitivity were measured. Despite the decrease of impedance, the humidity sensitivity increased for WP-WCMs treated with KOH after annealing. The humidity sensitivity enhanced with the increase of KOH solution concentration. In other treatments both the humidity sensitivity and the impedance decreased. Consequently, in order to enhance the humidity sensitivity of WP-WCMs, the treatment with KOH after annealing is effective in improvement of humidity sensitivity.
Key words: Woodceramics, Humidity sencer, Waste paper, Postcards

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 [1-10]. In general, WCMs are fabricated by sintering woody materials impregnated with phenolic resin to form glassy carbon which reinforces the fibrous structure of wood. It is known that WCMs can be fabricated from waste wood, waste paper, saw dust and so on; hence WCMs are environmentally conscious materials (ecomaterials) designed for minimizing the environmental impacts. The WCMs have the prominent characteristics such as lightweight, hardness, corrosion resistance and heat resistance.

In addition, WCMs have the porous structure caused by the woody fiber. 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, so that WCMs has been studied as a humidity sensor [3-9] and an ammonia sensor [10]. From the viewpoint of using WCMs as a sensor commercially, waste paper of postcards (WP-WCMs hereafter) is better raw material than medium density fiber board for the fabrication of WCMs and, in fact, reproducible results of the impedance and the better humidity sensitivity have been obtained. In this paper, WP-WCMs have been fabricated from waste paper of postcard and have been immerse in the acid or alkali

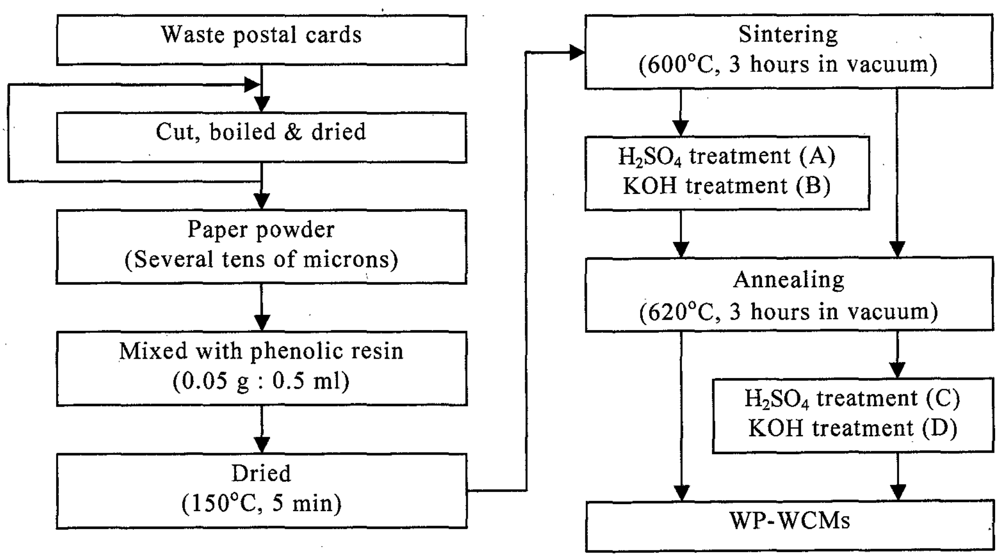

Fig. 1 Fabrication process for WP-WCMs

solution to improve the humidity sensitivity. The humidity sensitivity for WP-WCMs treated by various solution has been measured and the improvement of sensitivity is discussed.

2. EXPERIMENTAL

Fabrication process for WP-WCMs is shown in Fig.1. The waste paper was cut, boiled and dried and these processes were repeated several times. Then the paper was passed through a sieve with 53 μm apertures to make the paper powder with the size of several tens of microns in diameter. The diameter of paper powder was confirmed by scanning electron microscope. The paper powder and the phenolic resin solution (Bellpearl, Air Water Belllpearl Inc.) were mixed by the ratio of 0.05 g and 0.5 ml. The solution of phenolic resin was produced by dissolving powder phenolic resin into methanol with the concentration of phenolic resin 40%. Mixtures were pressed at room temperature to form disks with the size of 19.5ϕ x 5 mm thick. After drying at 150°C for 5 min, the disks were sintered at 600°C for 3 hours forming WP-WCMs. After sintering, they were subjected to annealing at 620°C for 3 hours to control the electrical impedance. The some WP-WCMs were immersed in the acid or alkali solution before or after annealing. In this work, KOH solution and H_2SO_4 solution were used as alkali and acid solution, respectively. The concentration of solution was varied from 10% to 50%. Treatment time and temperature were 5 min and room temperature, respectively.

Electrodes were formed on WP-WCMs surface by conductive adhesive. The space between the electrodes was 8 mm. Measurement of the humidity dependence of WCMs impedance was performed in the environmental testing equipment (PL-2KP, Espec Inc.). Measurement temperature was fixed at 30°C as the humidity was changed from 30 to 80%RH. The electrical impedance was measured by applying a constant AC voltage of 5 V at a frequency of 100 Hz between the two electrodes at equilibrium condition after changing the humidity.

3. RESULTS AND DISCUSSION

Figure 2 shows impedance dependence of humidity sensitivity (HS). HS is defined by

$$HS = \frac{(Z_{30\%} - Z_{80\%})}{Z_{30\%}} \quad (1)$$

where Z30% and Z80% are impedances at humidity of 30%RH and 80%RH, respectively. For the WP-WCMs treated by H_2SO_4 before annealing (sample A described in Fig.1), the impedance and humidity sensitivity unchanged. For the WP-WCMs treated with H_2SO_4 after annealing (sample B) and treated with KOH before annealing (sample C), the impedance and humidity sensitivity drastically decreased. The impedance of sample B and C became insensitive to humidity. On the contrary, for WP-WCMs treated with KOH after annealing (sample D), although the impedance slightly decreased, the sensitivity enhanced. The change of impedance and humidity sensitivity were listed in Table 1.

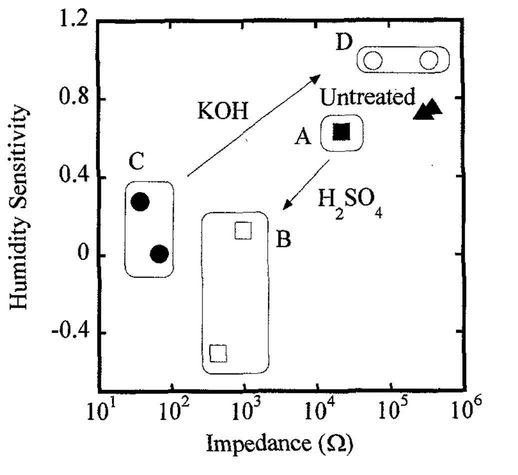

Fig.2 Impedance dependence of humidity sensitivity. Treatment of sample A, B, C and D were described in Fig1.

Figure 3 shows humidity dependence of impedance for WP-WCMs immersed in H_2SO_4 after annealing. The solution concentration was varied from 10% to 50%. In this figure, the impedance was normalized by the impedance at humidity of 30%RH. Although the impedance for untreated WP-WCMs decreased with increase of humidity, those for the WP-WCMs immersed in 10% and 30% H_2SO_4 increased or unchanged with increase of humidity. In the case of the treatment by 50% H_2SO_4, however the ability as humidity sensor was regained, its sensitivity was less than that for untreated

	H_2SO_4		KOH	
	Before annealing (A)	After annealing (B)	Before annealing (C)	After annealing (D)
Impedance	→	↘	↘	↘
Humidity sensitivity	→	↘	↘	↗

Table1 Change of impedance and humidity sensitivity

WP-WCMs. Thus, it is suggested that H_2SO_4 treatment for WP-WCMs causes degradation of humidity sensitivity.

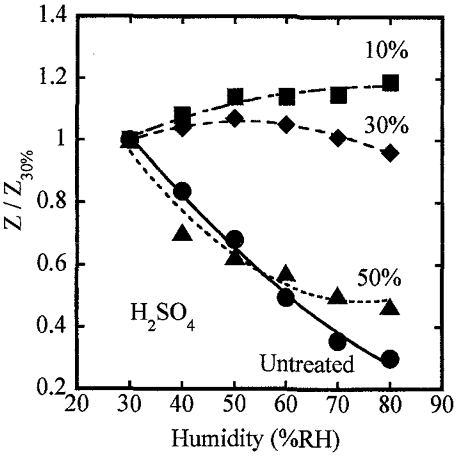

Fig.3 Humidity dependence of impedance for WP-WCMs immerse in H_2SO_4 after annealing. The solution concentration was varied from 10% to 50%.

Figure 4 shows humidity dependence of impedance for WP-WCMs immersed in KOH with the concentration 10% to 50% after annealing. Amount of impedance change increased from 40%RH to 80%RH when KOH concentration increased to 50%. It suggests that humidity sensitivity for WP-WCMs was enhanced by KOH treatment.

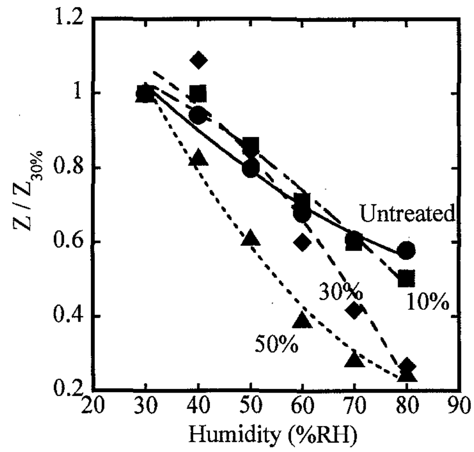

Fig.4 Humidity dependence of impedance for WP-WCMs immerse in KOH with the concentration 10% to 50% after annealing.

Figure 5 exhibits relationship between humidity sensitivity and the impedance for WP-WCMs treated with H_2SO_4, and KOH. Impedance of WP-WCMs treated with H_2SO_4 decreased substantially with increase of solution concentration. The humidity sensitivity had a minimum for WP-WCMs treated with H_2SO_4 solution with concentration of 10%. On the other hand, humidity sensitivity of WP-WCMs treated with KOH can be raised

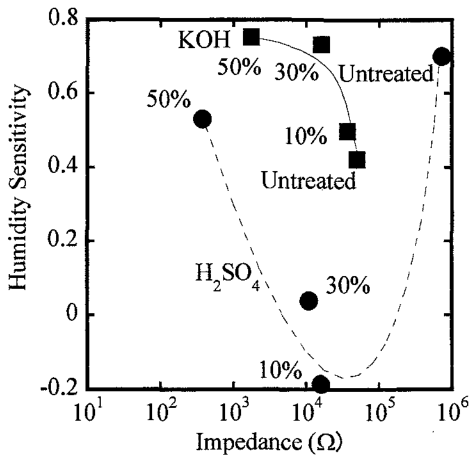

Fig.5 Relationship between humidity sensitivity and impedance for WP-WCMs treated with H_2SO_4 and KOH.

without impedance change. Consequently, the humidity sensitivity for WP-WCMs can be improved without changing impedance by the treatment with KOH. The reason for the improvement is probably the increase of hydrophilic grope such as OH grope and carboxylic grope at the WCMs surface due to KOH treatment.

4. CONCLUSION

WP-WCMs fabricated from waste paper of postcard were treated in KOH and H_2SO_4 and their humidity sensitivity were estimated. Although the humidity sensitivity for WP-WCMs immersed in H_2SO_4 degraded, it for WP-WCMs immersed in KOH was improved without impedance change. Consequently, the treatment used alkali solution is effective in improvemnt of humidity sensitivity.

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