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Develpoment of Woodceramics (II)
- Examination of the Electromagnetic Shielding Characteristics -

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Woodceramics is the porous carbon material which is obtained from wood by impregnating phenol resin and then carbonaizing in vacuum. The authors investigated the effectiveness of Woodceramics porous carbon material as an electromagnetic shielding material. It was found that the volume resistivity changed broadly from 10 Ω·cm to 10^{-2} Ω·cm according to the increase in the burning temperature of Woodceramics. In tests focused on the shielding effect against electromagnetic waves with frequencies ranging from 100 kHz to 1 GHz, an electric shielding effect was observed with samples carbonized at 650 °C, a magnetic shielding effect was observed with samples burned at 700 °C or more and a wide range of attenuation, more than 40 dB, was observed with samples burned at 900 °C or more.

1. INTRODUCTION

With the rapid development an dissemination of computer equipment in recent years, the generation of electromagnetic waves has become a problem which must be coped with. Throughout the world, laws are being introduced to limit or prevent the generation of electromagnetic waves.

The measures against electromagnetic noise should be considered from both sides, that is, measure to cope with noise generated by electromagnetic equipment and measures to cope with noise entering the equipment. One possible method in both cases is the development of electromagnetic shielding materials.

At present, materials used for electromagnetic shielding include metals, compound materials composed of conductive matter such as powdered metal in plastic, plastic-plated metal, etc. Though these materials show excellent shielding effects, they all suffer from the handicap of being heavy.

This report focuses on the results of a study of the possibility of using Woodceramics, a porous, light weight material, for electromagnetic shielding.

2. EXPERIMENTAL METHOD

2.1. Specimen

The material used in the experiments was medium density fiberboard (MDF) made from Pinus Radiata, a coniferous wood, 12 mm thick, having a specific gravity of 0.72 and a water content of 8% (Brand name of MDF is "Noda High Best Wood S"). Concerning the properties of the phenol resin used in impregnation, refer to Table 1 (Brand name of resin is "PX-1600," manufactured by Honen Corp.).

2.2. Manufacture of Woodceramics and form of specimens

A total of 108 pieces of MDF board having dimensions of 75 mm x 75 mm x 12 mm were placed in an impregnating tank with phenol resin an decompressed while being exposed to ultrasonic vibration for two hours.

At the completion of the two hour period, the vibration was stopped, the tank pressure returned to normal and the material left to stand for twenty two hours. The impregnated MDF board samples where then placed in a dryer and exposed to 70 °C for five hours followed by exposure to 135 °C for two hours. By this method, almost the same weight of phenol resin as the weight of the MDF board (dry weight) was impregnated uniformly into the samples.

The MDF board samples impregnated with resin were heated in a non-oxygenated environment with the temperature increasing at a rate of 5°C per minute to the designated burning temperature value (400 , 450 , 500 , 550 , 600 , 650 , 700 , 750 , 800 , 850 , 900°, 950 , 1,000 , 1,050 , 1,100 , 2,000 , 2,450 , 2,800 °C)) for three hours, then allowed to cool naturally. Six pieces of the Woodceramics for each designated burning temperature value were provided; three were cut to dimensions of 50 mm x 50 mm x 5mm for measurement of electromagnetic shielding characteristics.

The equipment used for impregnation and burning was the same as used in previous tests [1].

2.3 Measured volume resistivity characteristics

The volume resistivity was measured by the four-point probe method [2-5], as shown in Fig. 1. The tester, a Hioki Milli-ohm High Tester, Model 3224, was used to measure the surface resistance R of the specimens with volume resistivity electrode sensors. The distance between neighboring electrodes S1, S2 and S3 was 0.5 cm and the terminal load of the sensors was 100 gf. The surface resistivity R was fed to a computer using a GB-IB interface and the volume resistivity calculated according to the following formula (1)[6].

$$r = 2\pi \ KSR = 2\pi \ KS \ V/I \ (\Omega \cdot cm) \quad \text{............... (1)}$$

I: measurement current (fixed current) (A)
R: measurement resistance (Ω)
V: Voltage calculated from I and R (V)
S: Distance between electrodes (cm)
K: Coefficient from ratio of distance between electrodes and thickness of specimen

It has already been determined by L.B. Valdes that resistance R depends on the thickness of the specimen. According to the formula, the coefficient K for the measurements in this experiment (thickness of specimen, 1 cm ; distance between electrodes, 0.5 cm) therefore is 1.1.

2.4. Measured electromagnetic shielding characteristics

Measurement of the electromagnetic wave shielding characteristics was performed using an Anritsu MA8602B shield measuring system. In the strictest sense this system cannot separately measure the electronic shielding effect and the magnetic shielding effect. However, is a small dipole type transmitting-receiving antenna is used and output proportional to the amplitude of the mainly electronic field can be obtained, the electric shielding effectiveness can be assumed and when the transmitting-receiving antenna is a small loop antenna and output proportional to the amplitude of the mainly magnetic field can be obtained, the magnetic shielding effectiveness can be assumed. The measuring system is shown in Fig. 2.

The effectiveness of the shielding can be determined by the reflection of the incidence surface of the specimen or by absorption loss within the specimen. In this report,

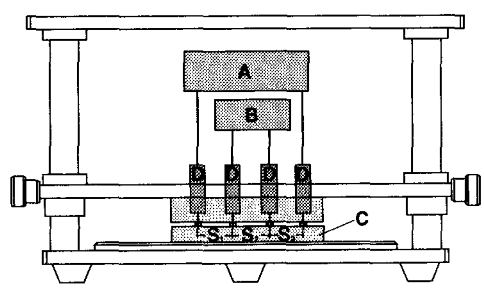

Fig.1 The measurment module of the volume resistivity.

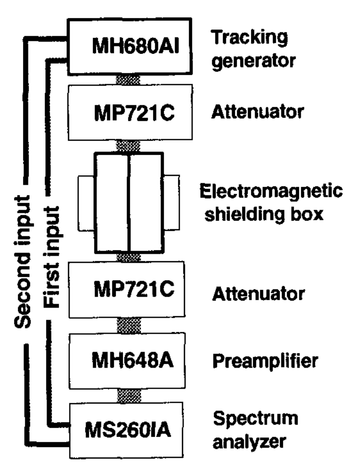

Fig.2 The measurment system of electromagnetic shielding effectiveness.

the difference in the level of the wave when the specimen was in the tester and not in the tester, in other words, the insertion loss level, was considered to be the shelter volume or shield effect volume. If the receiving level when the specimen is not present is E_1 and when present is E_2, the shield effectiveness SE (dB) is given by the following formula (2)[7].

$$SE = 20 \log_{10}(E_1/E_2) \quad (dB) \qquad (2)$$

According to formula (2), the electric field and magnetic field characteristics of Woodceramics burned at 400 °C-1,100 °C is in the range of 100 KHz to 1,000MHz.

3. RESULTS AND DISCUSSION

3.1. Volume resistivity

Figure 3 shows the relationship between burning temperature and volume resistivity of Woodceramics. Resistivity changed from approximately 10^{10} Ω•cm to 10^{-3}Ω•cm according to changes in the burning temperature. This means that it is very possible to create Woodceramics of the desired volume resistivity by strictly controlling the burning temperatures.

3.2. Electromagnetic shielding characteristics

The electromagnetic shield effectiveness results for Woodceramics burned at 650 °C- 950 °C are shown in Fig. 4 and at 1,000 °C- 1,100 °C are shown in Fig. 5. The shield effectiveness was not expected at lower temperatures of 400 °C- 600 °C but gradually appeared above the 600 °C level. The measured shield effectiveness showed the maximum volume in the frequency range of 100 to 500MHz in the 100 to 1,000 MHz range.

The magnetic shield effectiveness was also measured for specimens burned at 650 °C- 1,100 °C. Figure 6 and Fig. 7 present the measurement results. The maximum shield effectiveness frequencies of specimens burned at various temperatures appeared in the higher frequencies compared to the electric shield effectiveness.

Figure 8 shows the relationship between volume resistivity and attenuation in the electric shielding. Among the measured frequencies, the shield effectiveness oat 100, 300 and 1,000 MHz was shown. There is a tendency when comparing burning temperatures, that the smaller the volume resistivity, the larger the shielding effectiveness. In the respective frequencies, when the volume resistivity becomes less than 0.050 Ω•cm (at a burning temperature of 700 °C or more), the shield volume suddenly decreases and when it is 0.012 Ω•cm, the maximum shield volume of 49 dB is shown at 0.012 Ω•cm.

Figure 9 shows the relationship between volume resistivity and attenuation in the magnetic shielding. Compared to the electronic shielding shown in Figure 8, magnetic shielding values shown in Fig. 9 are of a larger volume at higher frequencies as shown by 1,000MHz, 300 MHz and 100 MHz. As with the values in Fig. 9, when the volume resistivity becomes less than 0.012 Ω•cm, the shielding volume suddenly increases, showing the maximum of 46 dB at 1,000 MHz. As previously

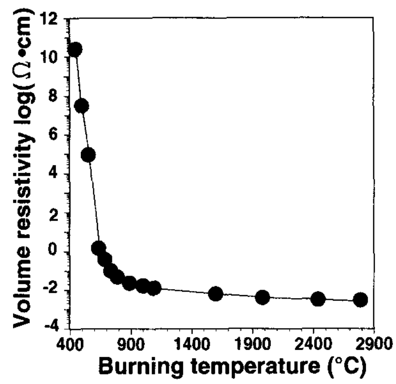

Fig.3 The relatinships between burning temperatures and volume resistivities.

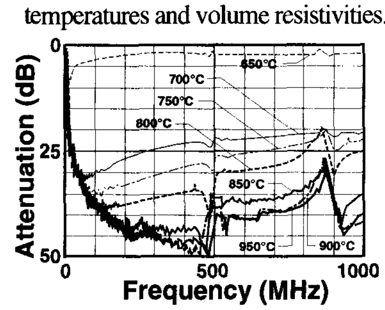

Fig.4 The electric shielding effectiveness of Woodceramics burned at 650-950°C.

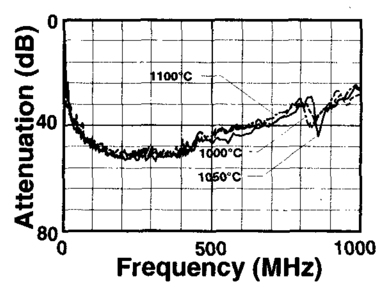

Fig.5 The electric shielding effectiveness of Woodceramics burned at 1000-1100°C.

stated, the relationship between the value of the volume resistivity and the shield effectiveness of material burned at a temperature of 700 °C or more which showed the most remarkable shield effect was checked and it was determined that conductivity increased in this range where aromatic chain structures were formed and carbonization developed. From this experiment, it has become clear that the shielding material should be burned at temperatures above 700 °C according to the required shielding volume. The results show the relationship between volume resistivity and electromagnetic shield effectiveness. However, in order to confirm the application characteristics of Woodceramics as an absorption material, it will be necessary to study it over a wide microwave range and a wide range of shield characteristics or measure the conductive rate of a complex number as the Woodceramics is a porous conductive material (in the high frequency range, unlike with other conductive material such as metal, which has a complex conductive character which simply goes down in inverse proportion to the frequency, Woodceramics shows a sudden drop).

4. CONCLUSION

Investigation of the potential of Woodceramics porous carbon material as an electromagnetic shield material was carried out and the following was determined.

1) The volume resistivity changed widely from approximately. $10^{10}\,\Omega$•cm to $10^{-3}\Omega$•cm according to the increase in burning temperature from 400 °C to 2,800 °C.
2) As for the electronic shield effect, it gradually appeared at a burning temperature of 600 °C and increased according to the rise in burning temperature.
3) As for the magnetic shield effect, it gradually appeared at a burning temperature of 700 °C and increased according to the rise in burning temperature.

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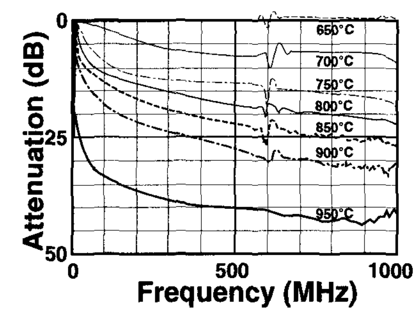

Fig.6 The electric shielding effectiveness of Woodceramics burned at 650-950°C.

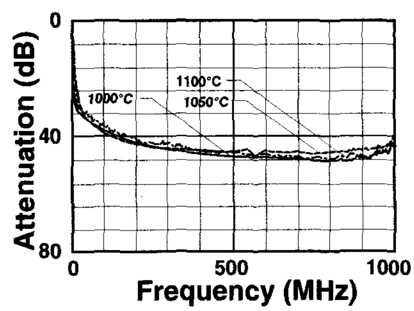

Fig.7 The electric shielding effectiveness of Woodceramics burned at 1000-1100 °C.

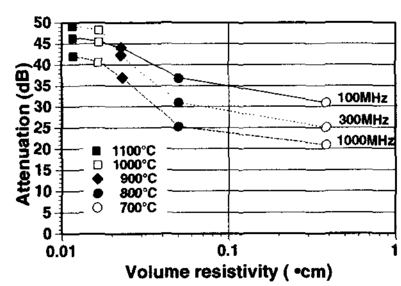

Fig.8 The relationships between volume resistivities and attenuation in the electric shielding.

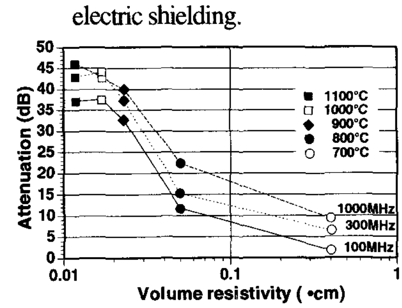

Fig.9 The relationships between volume resistivities and attenuation in the magnetic shielding.