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Electromagnetic Wave Absorption Characteristics of Charcoal Powder and Unsaturated Polyester Resin Composite

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The electromagnetic wave absorption properties of the composites which were made by mixing the powder of the charcoal heated at 923-1123 K (650-850 °C) and unsaturated polyester resin, were measured in the frequency range of 0.5-3.0GHz by a network analyzer.

The peak frequency of the absorption decreased with increasing the heated temperature of the charcoal, namely, 2.96GHz for the charcoal heated at 923 K and 1.49GHz for that at 1123 K, respectively.

Key words: charcoal, unsaturated polyester resin, composite, electromagnetic wave absorption

1. INTRODUCTION

Converting wood wastes to charcoal instead of incinerating them is important to conserve global environment. Charcoal has superior properties such as gas absorbing [1], humidity regulating [2], [3], and electromagnetic shielding properties [1]. It is used in many kinds of fields, but is rarely used as electromagnetic wave absorbers. The purpose of this study is to develop the superior electromagnetic wave absorbers, which consist of charcoal heated at various temperatures and unsaturated polyester resin.

2. EXPERIMENTAL

2.1 Original charcoal

The charcoal chips of Akamatsu (P. thunbergii) were made at 873K, and ball milled to powders with the diameters of less than 30 μm.

2.2 Heat-treatment of the charcoal

The charcoal powder was put into a melting pot and heated in an oven for 4 hours at various temperatures 923 K, 1023K and 1123K. The medians of diameters of these powders were equally around 7.5-11.0 μm.

Table 1 Mixing ratio of the charcoal powder and resin

heated temperature	content of the charcoal powder (weight percent)	content of the unsaturated polyester resin
non heated (control)	5	95
	25	75
	40	60
923 K	5	95
	20	80
	30	70
1023 K	5	95
	15	85
	20	80
1123 K	5	95
	10	90
	15	85

2.3 Fabrication of composite absorbers

Composite absorbers were made by mixing the charcoal powder and unsaturated polyester resin with mixing ratio shown in **Table 1**. The binder was unsaturated polyester resin containing 35 weight percent styrene monomer and 1 weight percent cobalt naphthenate solution. The composites were kept for 2 hours in atmosphere to degas. Methyl-Ethyl-Ketone-Peroxide was mixed 1 percent in resin. They were

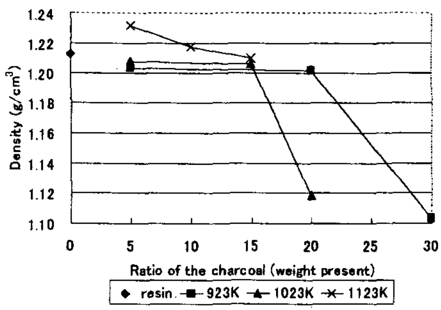


Fig 1 The density of the resin and composites

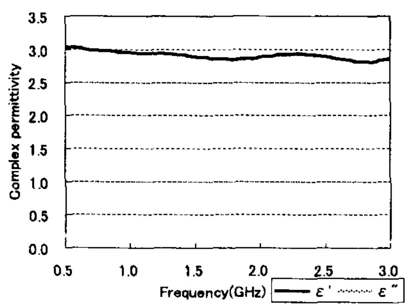
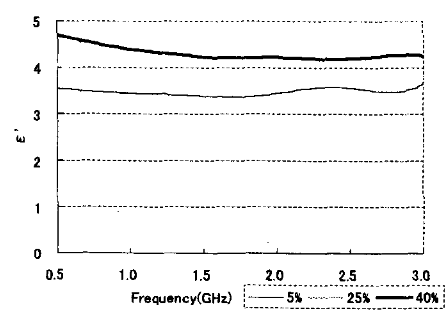
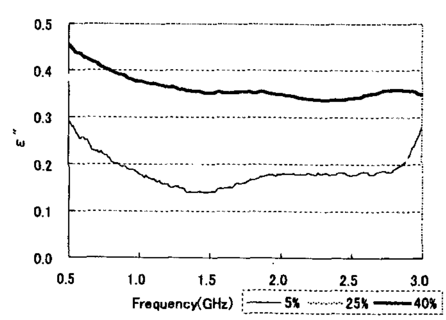


Fig.2 Complex permittivity of the unsaturated polyester resin.



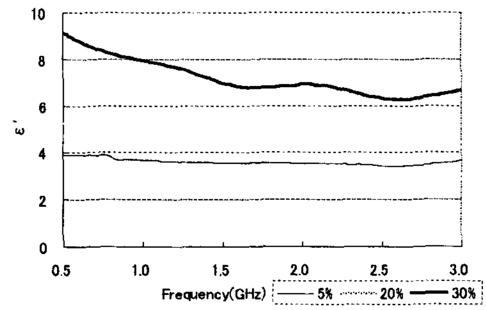
(a)



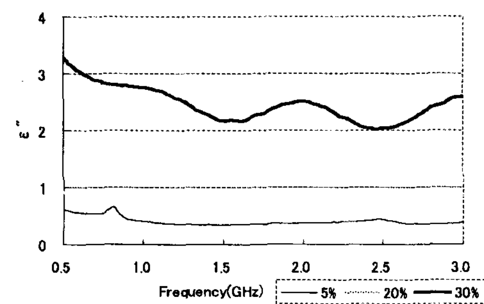
(b)

Fig.3 Frequency dependence of (a)real part (b)imaginary part of the permittivity for the various composites made of the untreated charcoal.

cured at room temperature for 16 hours, and heat-cured in an oven at 353K for 16 hours.



(a)



(b)

Fig.4 Frequency dependence of (a)real part (b)imaginary part of the permittivity for the various composites made of the charcoal heated at 923K.

2.3 Specimen measurement

Reflective coefficients S of the cylindrical shape specimens (inner diameter 8.9mm, outer diameter 19.9mm) were measured in the frequency range of 0.5-3.0GHz by a vector network analyzer made by Hewlett Packard Co. Ltd. (HP8753E). The complex permittivity ε_r (ε' - jε'') were derived from S. In the case of a metal-back single layer absorber, the impedance Z_{in} at the front end of the absorber is expressed using the ε_r by

$$Z_{in} = \frac{Z_0}{\sqrt{\varepsilon_r}}\tanh(j\frac{2\pi d}{\lambda}\sqrt{\varepsilon_r}), \qquad (1)$$

where Z_0 is the free space impedance, d is the thickness and λ is the electromagnetic wave length in free space.

3. RESULTS AND DISCUSSION

Figure 1 shows the affection of the charcoal ratio to the composites density. The density of the resin was 1.21 g/cm^3. The composites had the density of 1.20-1.23 g/cm^3. The high mixing ratio samples had the low density. As the reason of this, it was thought that the viscosity of the resin increased with increasing

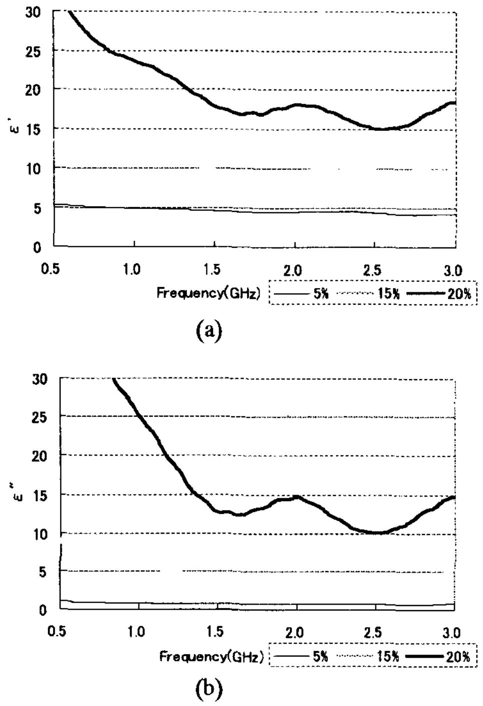


Fig.5 Frequency dependence of (a)real part (b)imaginary part of the permittivity for the various composites made of the charcoal heated at 1023K.

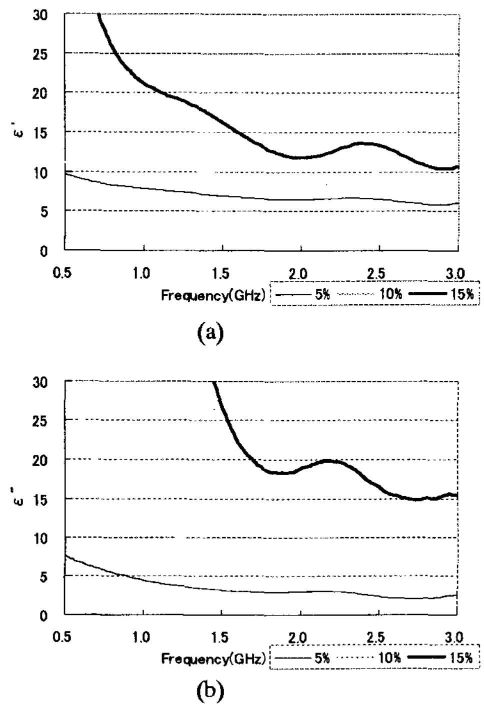


Fig.6 Frequency dependence of (a)real part (b)imaginary part of the permittivity for the various composites made of the charcoal heated at 1123K.

the ratio of the charcoal, therefore they had many bubbles.

Figure 2 shows the frequency dependence of the complex permittivity ε_r for the unsaturated polyester resin. The real part ε_r' of ε_r kept about constant value of 2.8-3.0. The imaginary part ε_r'' of ε_r kept about constant value of 0.1-0.2. **Figure 3** shows the frequency dependence of the ε_r for the various composites made of the untreated charcoal and resin. The ε_r' and ε_r'' increased with increasing content of the charcoal. Since the values of ε_r'' of composites were less than 0.45, they had few electromagnetic absorbing property. **Figure 4** shows the frequency dependence of the ε_r for the various composites made of the charcoal heated at 923 K and resin. The values of ε_r' and ε_r'' increased with increasing content of the charcoal. The ε_r' for the high mixing ratio sample decreased in the lower frequency region with increasing the frequency. **Figure 5** shows the frequency dependence of the ε_r for the various composites made of the charcoal heated at 1023 K and resin. The values of the ε_r' and ε_r'' increased with increasing content of the charcoal. The ε_r' for the high mixing ratio samples decreased in the lower frequency region with increasing the frequency. **Figure 6** shows the frequency dependence of the ε_r for the various composites of the charcoal heated at 1123 K and resin. The values of the ε_r' and ε_r'' increased with increasing content of the charcoal. In the case of the same content of the charcoal, the values of the ε_r' and ε_r'' increased with increasing heated temperature of the charcoal. Generally the value of the electric resistance of the charcoal decreases with increasing the heated temperature of the charcoal [4]. In the same way, the values of the ε_r' and ε_r'' increased with decreasing the heated temperature of the charcoal. In the case of the same temperature, the ε_r' and ε_r'' increased with increasing content of the charcoal.

Figure 7 shows the frequency dependence of the return loss at the matching thickness for the various composites made of the charcoal heated at 923K. The maximum return loss was 12dB for the composite containing 20 weight percent the charcoal. The matching thickness was 36mm and the peak frequency of the absorption was 2.96GHz. **Figure 8** shows the frequency dependence of the return loss at the matching thickness for the various composites made of the charcoal heated at 1023K. The maximum return loss

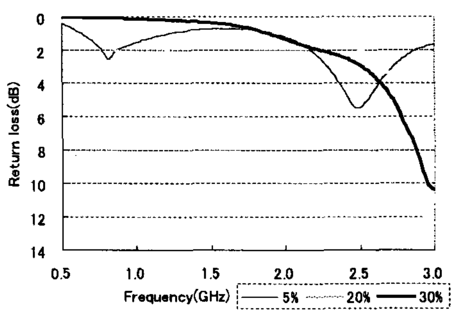


Fig.7 Simulated return loss for the various composites made of the charcoal heated at 923K.

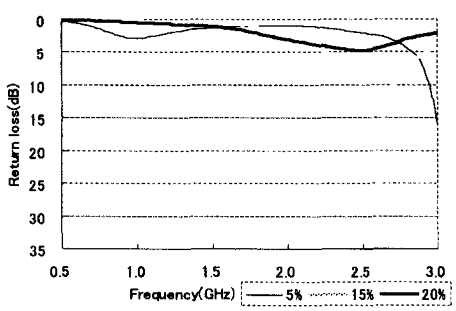


Fig.8 Simulated return loss for the various composites made of the charcoal heated at 1023K.

was 31dB for the composite containing 15 weight percent the charcoal. The matching thickness was 9mm and the peak frequency of the absorption was 2.60GHz. **Figure 9** shows the frequency dependence of the return loss at matching thickness for the composite made of the charcoal heated at 1123K. The maximum return loss was 33dB for the composite containing 5 weight percent the charcoal. The matching thickness was 20mm and the peak frequency of the absorption was 1.49GHz. The matching composition of the charcoal decreased with increasing the heated temperature of the charcoal. The minimum matching thickness was 9mm for the composite using the charcoal heated at 1023K. The peak frequency of the absorption decreased with increasing the heated temperature of the charcoal. **Figure 10** show the non reflection line and ε_r for the composite at the matching frequency. The ε_r at 2.60GHz for the composite containing the charcoal heated at 1023K, and the ε_r at 1.49GHz for the composite containing the charcoal heated at 1123K, ment the non reflection line. But, the ε_r for the composite the charcoal heated at 923K, did not meet the line. Therefore the maximum return loss for the composite using the charcoal heated at

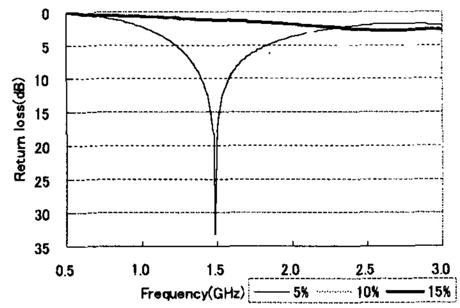


Fig.9 Simulated return loss for the various composites made of the charcoal heated at 1123K

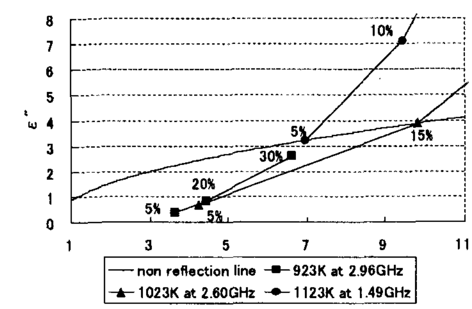


Fig.10 Non reflection line and ε_r for the composites

923K was smaller than that of the others. The ε_r for the composite containing 15 weight percent the charcoal heated at 1023K, and 5 weight percent the charcoal heated at 1123K laid near the line than the others. Therefore the maximum return loss for other composites was smaller than that of these composites. The absorber, which had optionally matching frequency in the range from 1.49 to 2.96 GHz, might be able to be fabricated by using the charcoal, heated at 923-1123K,with mixing ratio 5-20 weight percent.

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