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Development of Electromagnetic Wave Absorbers with Alnico Magnets

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We suggest a cast Alnico magnet as a new EM wave absorber. The proposed Alnico EM wave absorber shows advanced EM wave absorption properties of 24 dB at 15 GHz, 24 dB at 8.1 GHz, and 24 dB at 5.1 GHz for thicknesses of 1 mm, 2 mm, and 3 mm respectively. We also investigated the effects of the carbon and the Alnico contents and of the thickness dependence on the EM wave absorption properties.

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I. INTRODUCTION

EM (electromagnetic) wave absorbers are used to protect EM machines, such as personal communication and wireless LAN systems, from unwanted EM wave radiation. Soft ferrites, such as Mn-Zn and Ni-Zn ferrites, are important materials as EM wave absorbers because of their high magnetic loss, which contributes to the EM wave absorption [1, 2]. However, the magnetic loss of soft ferrites decreases quickly in the GHz range, so it is impossible to expect EM wave absorbers made with soft ferrites to show great absorption properties at GHz frequencies. Satoshi *et al.* [3] and Verma *et al.* [4] investigated EM wave absorption on hard ferrite, such as Sr and Ba ferrites, because they show high magnetic loss in the GHz range and revealed that Ba and Sr ferrites are useful materials for EM wave absorbers in the GHz range.

When we consider the problem of the natural environment and resources, it is a good way to use recycled magnets. Already, we have studied the EM wave properties of EM wave absorbers prepared with recycled Mn-Zn and Ba ferrites [2, 5–7]. In the studies, we showed that recycled magnets could be useful materials for EM wave absorbers. In addition to developing advanced EM wave absorbers with well-known soft and hard magnetic materials, such as Mn-Zn, Ni-Zn, Ba, and Sr ferrites, it is important to develop new materials for EM wave absorbers.

In this manuscript, we suggest Alnico magnets for use as a new EM wave absorber. As we know, this is the first paper to show that a EM wave absorber prepared with Alnico magnets has EM wave absorption properties. In addition, we prepared sheet-type absorbers with recycled cast Alnico magnets for natural-resource and environmental problems.

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II. SAMPLE PREPARATION AND MEASUREMENTS

1. Sample Preparation

In this research, we used recycled cast Alnico magnets with magnetic properties of residual induction (Br) = 0.65 T, coercive force (H_c) = 45 kA/m, and maximum magnetic energy $(BH)_{max}$ = 11 kJ/m^3 as a starting material. The magnets were smashed with a hammer, pulverized with a vibration mill, and mixed with silicon binders and/or carbon by using an open roller. The open roller's surface temperature was uniform during sample preparation because the surface temperature

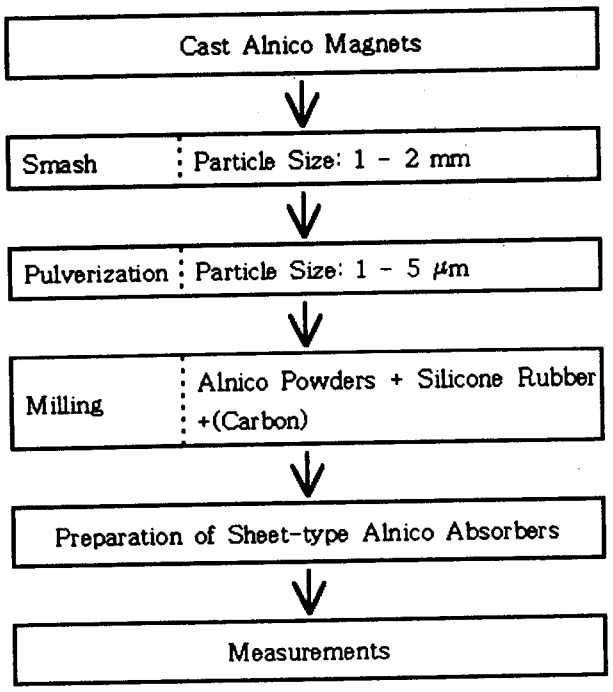

Fig. 1. Preparation of sheet-type Alnico absorbers.

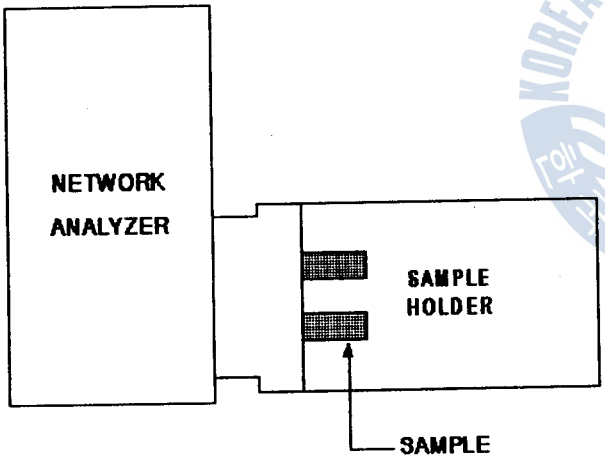

Fig. 2. Measurement system for the reflection coefficient.

affects the EM wave properties of sheet type absorbers [5]. The detailed preparation conditions for Alnico magnet absorbers are listed in Fig. 1.

2. Sample Measurements

For the investigation of the EM wave absorption properties of the samples, the prepared sheet-type absorbers were punched into a toroidal shape with an inner diameter of 3.05 mm and outer an diameter of 6.95 mm. The absorption properties of the samples were investigated with a HP-8753D network analyser. Figures 2 and 3 are

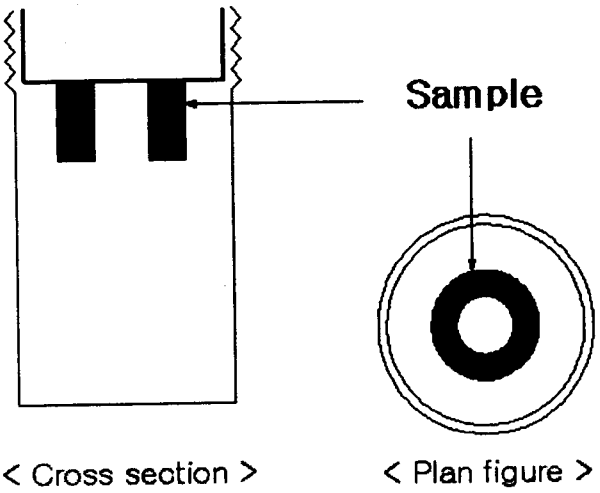

Fig. 3. Sample holder.

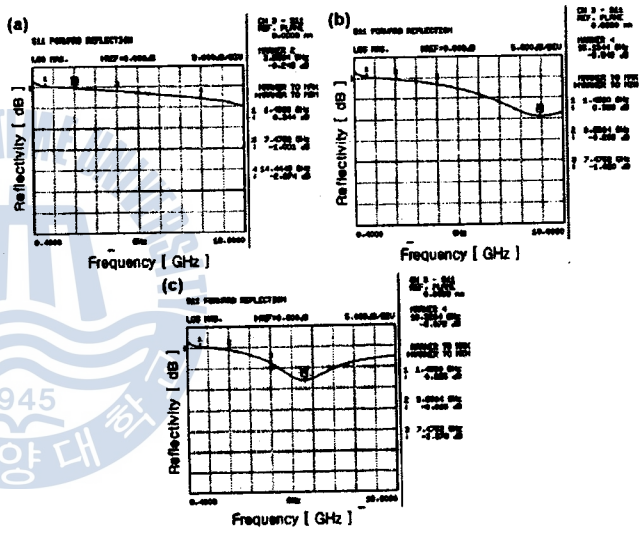

Fig. 4. Reflectivity as a function of frequency for samples with a composition of Alnico : Silicone binder = 50 : 50 wt.% and the thickness of (a) 1 mm, (b) 2 mm, and (c) 3 mm.

diagrams of the measurement system used for the reflection coefficient and the sample holder, respectively.

III. RESULTS AND DISCUSSION

1. EM Wave Absorption Properties of Alnico Magnet Absorbers

Figure 4 shows the reflectivity as a function of frequency for samples with a composition of Alnico : Silicone binder = 50 : 50 wt.%. From Fig. 4, we know that a sheet-type absorber prepared with recycled cast Alnico magnets has EM wave absorption properties in the GHz range. This says that the recycled cast Alnico magnets

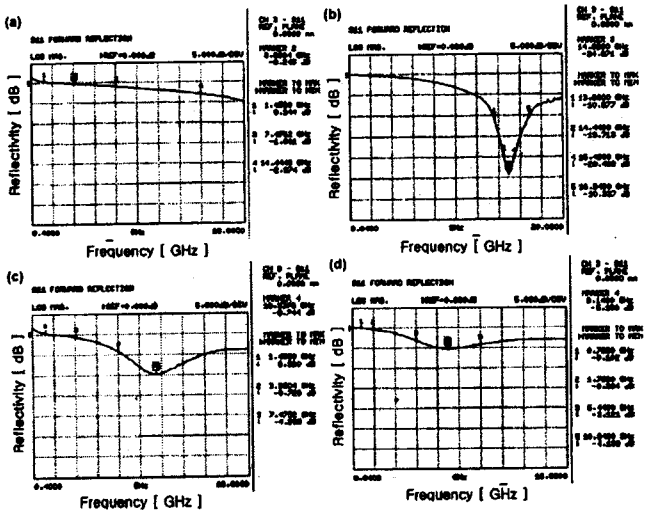

Fig. 5. Reflectivity as a function of frequency for 1-mm samples with compositions of (a) Alnico : Silicone binder : Carbon = 50 : 50 : 0 wt.%, (b) Alnico : Silicone binder : Carbon = 50 : 46 : 4 wt.%, (c) Alnico : Silicone binder : Carbon = 50 : 42 : 8 wt.%, and (d) Alnico : Silicone binder : Carbon = 50 : 38 : 12 wt.%.

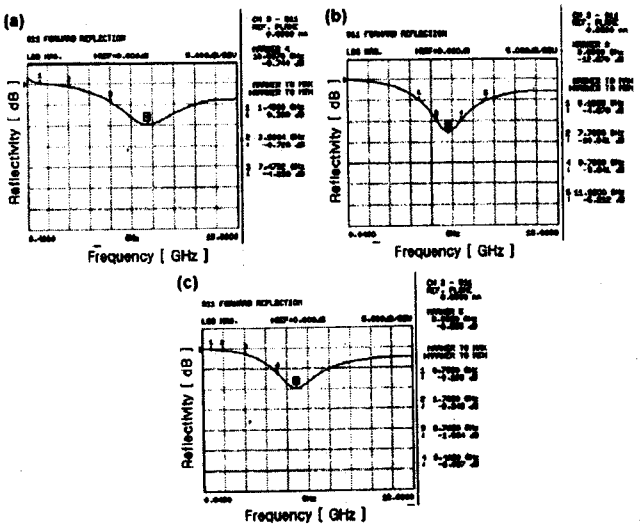

Fig. 6. Reflectivity as a function of frequency for 1-mm samples with the composition of (a) Alnico : Silicone binder : Carbon = 50 : 42 : 8 wt.%, (b) Alnico : Silicone binder : Carbon = 58 : 34 : 8 wt.%, and (c) Alnico : Silicone binder : Carbon = 60 : 32 : 8 wt.%.

are useful materials for EM wave absorbers in the GHz range.

2. Dependence of the EM Wave Absorption Properties on the Carbon Content

For many EM wave absorbers, such as Mn-Zn ferrite absorbers, Ni-Zn ferrites absorbers, and Ba ferrite absorbers, many researchers have revealed that carbon is a very useful material for increasing the EM wave absorption properties [1–4,8]. Thus, we investigated the effect of carbon in Alnico magnet absorbers on the EM wave absorbtion properties. Figure 5 shows the reflectivity as a function of frequency for samples with thickness of 1 mm. Naito and Mithumoto showed that adding carbon in soft magnetic materials was highly effective in reducing their thickness and improving their EM wave absorption properties [8]. We confirmed that carbon also affects the EM wave absorption properties in Alnico EM wave absorbers. As Fig. 5 shows an absorber with the composition of Alnico : Silicone binder : Carbon = 50 : 46 : 4 wt.% shows an advanced EM wave absorption property of 24 dB at 15 GHz.

3. Dependence of the EM Wave Absorption Properties on the Alnico Content

Figure 6 shows the reflectivity as a function of frequency for samples with thickness of 1 mm. As Fig. 6 shows, the matching frequency shifts toward lower frequency with increasing Alnico content, and the sample with a composition of Alnico : Silicon binder : Carbon = 58 : 34 : 8 wt.% shows an advanced reflectivity of 12.7 dB at 9.7 GHz. This means that we can control the matching frequency and the reflectivity by varying the content of Alnico in an Alnico EM wave absorber.

4. Dependence of the EM Wave Absorption Properties on the Sample Thickness

Figure 7 shows that the matching frequency decreases with increasing sample thickness. This phenomenon is consistent with the equation

$$d = \frac{c}{2\pi\mu_r f},$$

where c, d, and f are the velocity of light, the sample thickness, and the matching frequency, respectively [9]. This equation says that the matching frequency shifts toward lower frequency with increasing sample thickness. Figure 7 shows that the newly suggested Alnico-magnet EM wave absorbers have advanced EM wave absorption properties in the C-band. We can conclude that the proposed Alnico EM wave absorbers are useful for the C-band.

IV. CONCLUSIONS

We developed a new EM wave absorber with a cast Alnico magnet. This is the first research paper to show

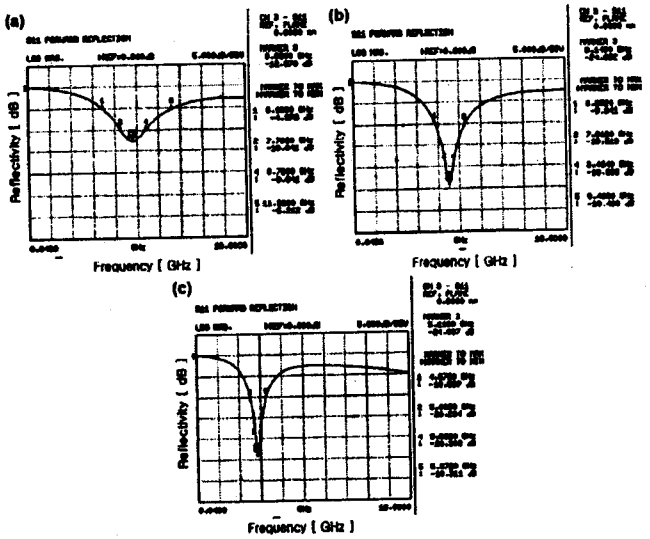

Fig. 7. Reflectivity as a function of frequency for samples with a composition of Alnico : Silicone binder : Carbon = 58 : 34 : 8 wt.%. (a) 1 mm, (b) 2 mm, (c) 3 mm

that Alnico-magnet EM wave absorbers have advanced EM wave absorption properties. The developed Alnico EM wave absorbers are useful for preventing unwanted EM wave in the C-band. The proposed Alnico EM wave absorber shows EM wave absorption properties of 24 dB at 15 GHz, 24 dB at 8.1 GHz, and 24 dB at 5.1 GHz for thicknesses of 1 mm, 2 mm, and 3 mm respectively. We also investigated the effects of the carbon and the Alnico contents and of the thickness on the EM wave absorption properties. We confirmed that a certain content of carbon improves the EM wave absorption properties and that the matching frequency shifts toward lower frequency with increasing sample thickness. Also, Alnico content affects the matching frequency.

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