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Microwave Absorbers Prepared with Alnico Magnets

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Abstract : *We suggest a cast Alnico magnet as a new microwave absorber. The proposed Alnico microwave absorber shows advanced microwave absorption properties of 24 dB at 13.3 GHz for the thicknesses of 1 mm. We also investigated the effects of the carbon, which affects strongly to microwave absorption in Alnico magnet microwave absorbers. Central frequency shifts toward lower frequency with increasing Alnico content which is related to the frequency to show* $\tan\delta > 1$. *Also, we investigated the sample thickness dependence on the microwave absorption properties.*

Key words : *Microwave absorber, Recycled Alnico magnet, Carbon content, Alnico content, Sample thickness, GHz range, Soft ferrite, Hard ferrite*

1. Introduction

Microwave absorbers are used to protect electromagnetic machines, such as personal communication systems and wireless LAN systems, from an unwanted microwave radiation. Soft ferrites, such as Mn-Zn and Ni-Zn ferrites, are important materials as microwave absorbers because of their high magnetic loss, which contributes to the microwave absorption (Song, 2003 ; Kim, 1997). However, the magnetic loss of soft ferrites decreases quickly in the GHz range, so it is impossible to expect microwave absorbers made with soft ferrites to show great absorption properties at GHz frequencies. Sugimoto et al. (Sugimoto, 1998) and Verma et al, (A. Verma, 2002) investigated microwave 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 microwave 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 microwave properties of microwave absorbers prepared with recycled Mn-Zn and Ba ferrites (Song, 2003 ; Kim, 2003 ; Moon, 2003 ; Choi, 2003). In the studies, we showed that recycled magnets could be useful materials for microwave absorbers. In addition to developing advanced microwave 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 microwave absorbers.

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

2. 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 (Hc)=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. Fig. 1 shows the scanning electron microscope(SEM) of pulverized Alnico magnets. The open roller's surface temperature was uniform during sample preparation because the surface temperature affects the microwave properties of sheet type absorbers (Kim, 2003). The detailed preparation process for Alnico magnet absorbers is listed in Fig. 2.

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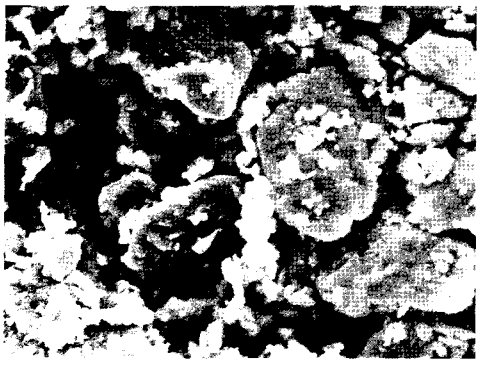


Fig. 1 SEM micrographs of pulverized Alnico magnets

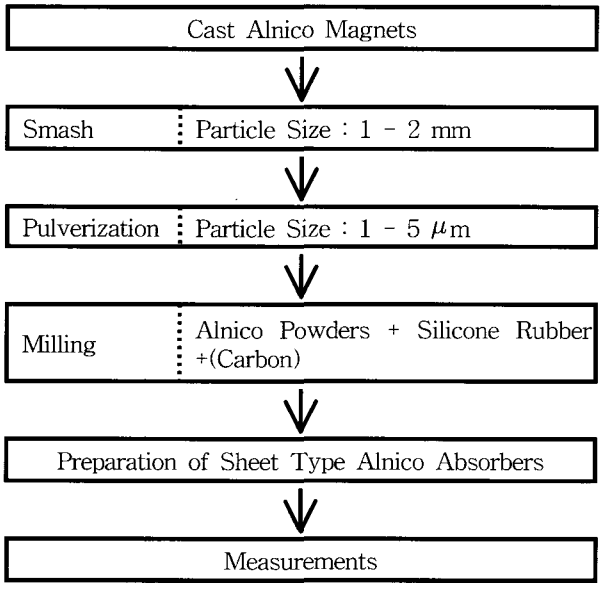


Fig. 2 Preparation of sheet-type Alnico microwave absorbers

2) Sample Measurements

For the investigation of the microwave 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 an outer diameter of 6.95 mm. The absorption properties of the samples were investigated with a HP-8753D network analyser. Fig. 3 and Fig. 4 are diagrams of the measurement system used for the reflection coefficient and the sample holder, respectively.

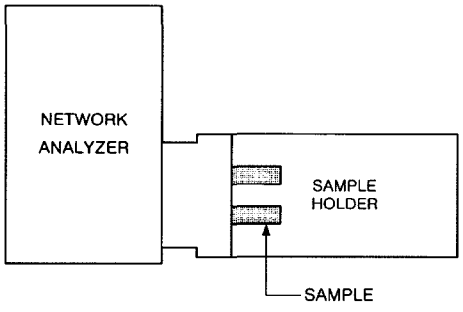


Fig. 3 Measurement system for the reflection coefficient

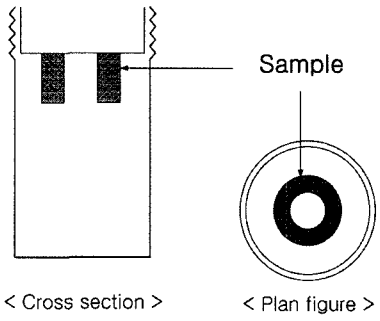


Fig. 4 Sample holder

3. Results and Discussion

1) Microwave Absorption Properties of Alnico magnets

We investigated the reflectivity of Alnico magnet microwave absorbers with different Alnico content and Fig. 5 shows the reflectivity as a function of frequency for the sample with thickness of 1 mm. From Fig. 5, we know that a sheet-type absorber prepared with recycled cast Alnico magnets has microwave absorption properties in the 5 ~ 14 GHz range. This says that the recycled cast Alnico magnets are useful materials for microwave absorbers in the GHz range. In Fig. 5, the central frequency shifts toward lower frequency with increasing Alnico content. In order to clarify the effects of Alnico contents, we investigated the permeability of the samples as a function of frequency.

The microwave absorption ability of ferrites relates with the magnetic loss $\tan\delta=(\mu''/\mu')$, and the magnetic loss is strong for $\tan\delta>1$ (Y. Hashimoto, 1983). In Fig. 6, the frequencies to satisfy the condition $\tan\delta>1$ shift toward lower frequency with increasing Alnico content which agrees with the results of Fig. 5. We concluded that the shift of central frequency toward lower frequency with increasing Alnico contents is related to the frequency to show $\tan\delta>1$.

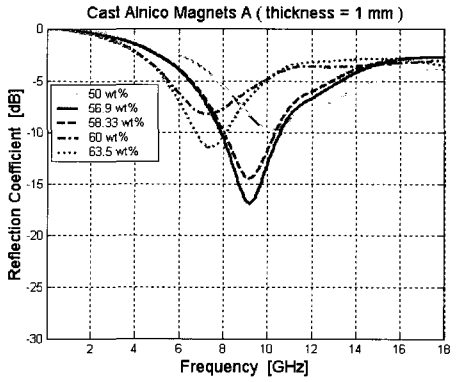
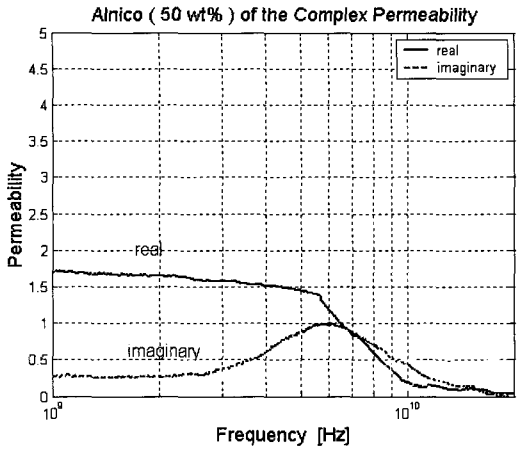
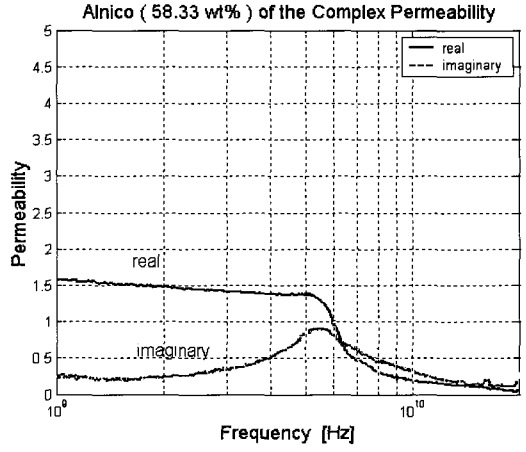


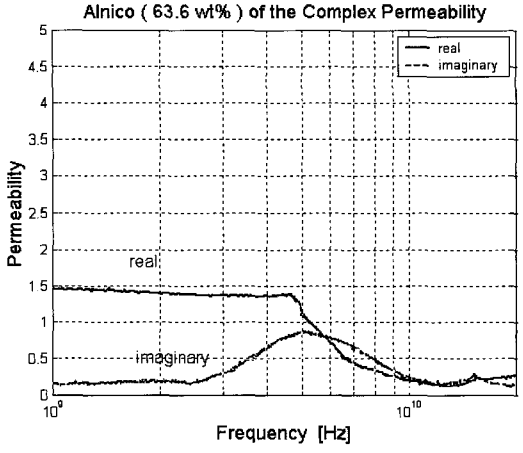
Fig. 5 Reflectivity as a function of frequency for samples with different Alnico content



(a) Alnico : 50 wt%



(b) Alnico : 58.3 wt%



(c) Alnico : 63.5 wt%

Fig. 6 permeability of samples with different Alnico contents as a function of frequency.

2) Dependence of the Microwave Absorption Properties on the Carbon Content

For many microwave 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 microwave absorption properties (Song, 2003 ; Satoshi Sugimoto, 1998 ; A. Verma, 2002). Matsuo et. al (Matsuo Yoshimura, 2002) showed that adding carbon in soft magnetic materials was highly effective in reducing their thickness and improving their microwave absorption properties. Thus, we investigated the effect of carbon in Alnico magnet absorbers on the microwave absorbtion properties. Fig. 7 shows the reflectivity as a function of frequency for samples with thickness of 1 mm. We confirmed that carbon also affects the microwave absorption properties in Alnico microwave absorbers. In Fig. 7, an absorber with the carbon content of 4 wt% shows an superior microwave absorption property of 24 dB at 13.3 GHz.

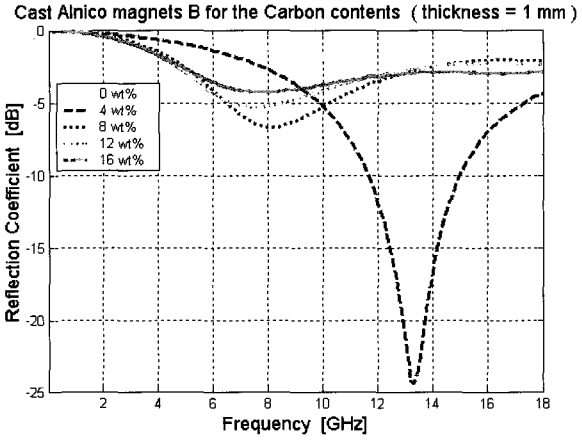


Fig. 7 Reflectivity as a function of frequency for 1 mm samples with different carbon contents.

3) Dependence of the Microwave Absorption Properties on the Sample Thickness

Fig. 8 shows that the central frequency decreases with increasing sample thickness. This phenomenon is consistent with the Eq. (1)

$$d = \frac{c}{2\pi\mu'' f} \tag{1}$$

where c, d, and f are the velocity of light, the sample thickness, and the matching frequency, respectively (Y. Naito, 1987). This equation says that the central frequency shifts toward lower frequency with increasing sample thickness. Fig. 8 shows that the newly suggested Alnico magnet microwave absorbers have advanced microwave absorption properties in the C and X-band. We can conclude that the proposed Alnico microwave absorbers are useful for the C and X-band.

4. Conclusions

We developed a new microwave absorber with a cast Alnico magnet. This is the first research paper to show that Alnico magnet microwave absorbers have advanced microwave absorption properties. The developed Alnico microwave absorbers are useful for preventing unwanted microwave in the C and X-band. The proposed Alnico microwave absorber shows microwave absorption properties of 24 dB at 13.3 GHz for thicknesses of 1 mm.

We also investigated the effects of the carbon and the Alnico contents and of the thickness on the microwave absorption properties. We confirmed that a certain content of carbon improves the microwave absorption properties and that the central frequency shifts toward lower frequency with increasing Alnico contents.

Acknowledgements

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References

[1] A. Verma, R. G. Mendiratta, T. C. Goel, and D. C. Dube(2002), "Microwave studies on strontium ferrite based absorber", J. Electroceramics 8(3): pp. 203-208.

[2] Dong-Han Choi, Dong il Kim, and Jae-Man Song(2003), "Dependence of electromagnetic wave absorption properties on binders", J. Korean Phys. Soc. 42(6): pp. 799-802.

[3] Dong Il Kim, Su Jung Kim, and Jae Man Song(2003), "Dependence on preparation temperature of the microwave absorption properties in absorbers for mobile phones", J. Korean Phys. Soc. 43(2): pp. 269-272.

[4] Dong Young Kim and Yeon Choon Chung(1997), "Electromagnetic wave absorbing characteristics of Ni-Zn ferrite gride absorber", IEEE Trans. EMC 39(4): pp. 356-361.

[5] Jae Man Song, Hyun Jin Yoon, Dong Il Kim, Su Jung Kim, Seung Min Ok, Bo Young Kim, and Ki Man Kim,(2003) "Dependence of electromagnetic wave absorption on ferrite particle size in sheet-type absorbers", J. Korean Phys. Soc. 42(5): pp. 671-675.

[6] Matsuo Yoshimura, Hashimoto Tanaka Ono Kimura, Suzuki Tanaka (2002), "Effect of carbon powder addition on wave return property of electromagnetic wave absorber by using recycling ferrite" J. of magnetics society of Japan 26(4): pp. 99490-496.

[7] Sang Hyun Moon, Seung Jae Shin, Jae Man Song, Dong Il Kim and Ki Man Kim(2003), "Development of composite Ba ferrite EM wave absorbers for GHz frequency" J. Korea Electromagnetic Engineering Soc. 14(12): pp. 1329-1334.

[8] Satoshi Sugimoto, Katsumi Okayama, Sin ichi Kondo, Hiroyasu Ota, Masafumi Kimura, Yoshiuki Yoshida, Hajime Nakamura, David Book, Toshi Kagotami, and Motofumi Homma (1998), "Ba M-type ferrite as an electromagnetic microwave absorber in the GHz range" Materials Trans. JIM 39(10): pp. 1080-1083.

[9] Y. Hashimoto(1983), "The application of ferrite as an absorber", Jpn. J. Appl. Phys. 6(3): pp. 175-175.

[10] Y. Naito, *"Electromagnetic Wave Absorbers"* (New Ohm, Tokyo, 1987), p. 86.

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