Journal of Korean Magnetics Society, Volume 5, Number 5, October 1995

THE CONTROL OF PERMITTIVITY IN THE Ni-Zn FERRITE ABSORBER

S.B.Cho and J.H.Oh
Department of Ceramic Engineering, Inha University, Inchon 402-751, Korea

Abstract-The variation of magnetic permeability and dielectric constant and their relationship with microwave absorbing properties are investigated in sintered Ni-Zn ferrite. Toroid specimens of $(Ni_{0.5}Zn_{0.5}O)_{1-y}(Fe_2O_3)_{1+y}$ ferrites are prepared by conventional ceramic processing technique. The large change in magnetic permeability is observed by the variation of excess Fe_2O_3 in the Ni-Zn ferrites. The more the iron-excess from y=0.04 to y=0.12, the lower value of both μ_r' and μ_r'' is observed. However dielectric permittivity increases with the increase of the excess Fe_2O_3. The control of permittivity is realized by nitrogen sintering atmosphere and excess Fe_2O_3, respectively.

I.INTRODUCTION

The spinel ferrites have been utilized for many years as absorbers of various forms, such as absorbing rubber materials, sintered plate, or paints[1]. The sintered plate of Ni-Zn ferrite is widely used as an electromagnetic wave absorber used in VHF/UHF region. Microwave absorbing properties of the ferrite tile including the plate thickness and the zero-reflection frequency are determined by its magnetic permeability (μ_r) and dielectric constant (ε_r) as well [2,3]. Many studies were carried out to investigate the microstructure or chemistry dependence of magnetic permeability for producing a well-controlled ferrite absorber [4,5].

In the present study, we investigated the variation of material constants and the microwave absorbing properties with varing excess Fe_2O_3 and sintering atmosphere, respectively. The primary effect of the excess Fe_2O_3 is to increase the dielectric constant, while magnetic permeability is decreased with increasing excess Fe_2O_3. The primary effect of nitrogen-sintering was to increase the dielectric constant, however the magnetic permeability has nearly the same value as that of air-treated specimen. The results suggested that matching frequency and matching thickness could be controlled by the variation of excess Fe_2O_3 and sintering atmosphere in the Ni-Zn ferrite, respectively.

II. EXPERIMENTALS

Sample with composition $(Ni_{0.5}Zn_{0.5}O)_{1-y}(Fe_2O_3)_{1+y}$,where y=0, y=0.04, y=0.08, y=0.12, are prepared by conventional ceramic processes. The raw materials (NiO, ZnO, and Fe_2O_3) were mixed in a ball-mill and calcined at 900 ℃ for 2 hrs. The powders added 3 wt.% polyvinyl alcohol were pressed into toroidal samples, 9 mm in out-diameter and 3 mm in in-diameter. The samples were sintered at 1250 ℃ for 2 hrs in air, oxygen, and nitrogen atmosphere. Finally, the sintered specimens were machined precisely for a close fitting into the coaxial cable used for the electromagnetic measurements. The complex permeability and permittivity were determined by using HP 8720B network analyser. Measurement were made in the 0.13 - 1.00 GHz frequencies. The scattering function S_{11} and S_{21}, corresponding to the reflection and transmission, of a TEM(transverse electric and magnetic wave) were measured on the surface of the sample in a coaxial line. The complex permeability and permittivity were calculated from the measurements in the case of the short-circuit and of the open-circuit[6].

III.RESULTS

To select the basic composition from Ni-Zn ferrite system the measurements of the material constants were carried out. $Ni_{0.5}Zn_{0.5}Fe_2O_4$ was chosen as a basic composition, showing a high μ_r''value. This results agree with Hahn's study[7].

Fig.1 shows the complex permeability ($\mu_r'-j\mu_r''$) and dielectric constant ($\varepsilon_r'-j\varepsilon_r''$) spectra observed in$(Ni_{0.5}Zn_{0.5}O)_{1-y}(Fe_2O_3)_{1+y}$ samples sintered in air. The magnetic permeability exhibits the typical high-lossy spectrum; μ_r'' is much higher than μ_r' and both are decreasing functions of the frequency. A noticeable change in magnetic permeability is observed with the variation of Fe_2O_3 contents. The more the iron-excess from y=0 to x=0.12, the lower value of both μ_r' and μ_r'' is resulted. However, the value of ε_r' is significantly increase with increasing excess Fe_2O_3 in ferrites. The imaginary part of permittivity(ε_r'') is omitted in Fig.1 because of its small value.

Fig.2 shows the microwave reflectance calculated

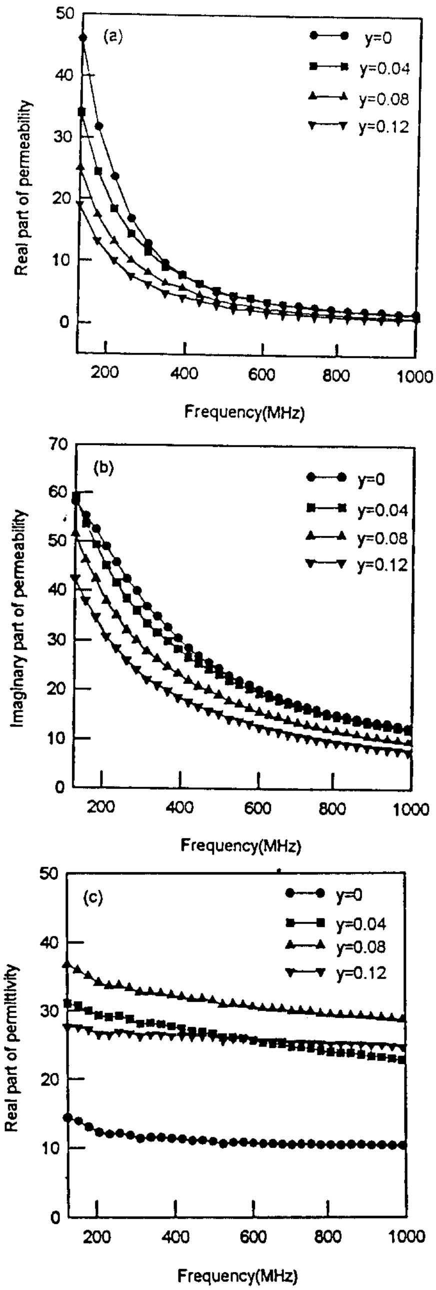


Fig.1. Material constants vs frequency spectra observed in $(Ni_{0.5}Zn_{0.5}O)_{1-Y}(fE_2O_3)_{1+Y}$ sintered specimens; (a) μ_r' vs frequency (b) μ_r'' vs frequency (c) e_r' vs frequency.

from the measured μ_r and ε_r. The calculation procedure was described in the previous paper[ ]. The directly measured reflection loss is in good agreement with the calculated value as demonstrated in the specimen of y=0. A specified frequency with minimum reflection loss moves to lower frequency as the excess Fe_2O_3 increases (600 MHz at y=0, 235 MHz at y=0.12) and the corresponding absorber thickness increases (4 mm at y=0, 7.3 mm at y=0.12).

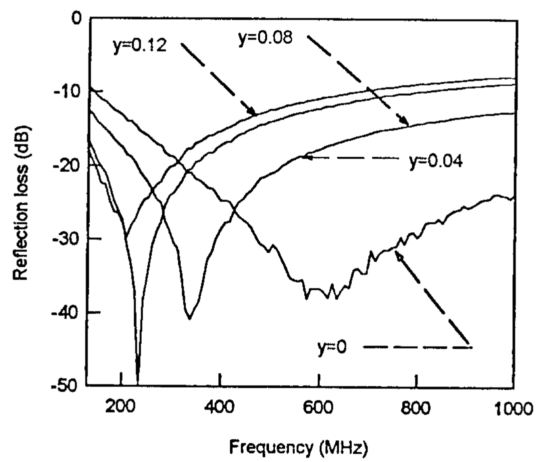


Fig.2. Microwave absorption of $(Ni_{0.5}Zn_{0.5}O)_{1-y}(Fe_2O_3)_{1+y}$ sintered specimens with maximum attenuation.

Fig.3 shows the material constants spectra observed in $Ni_{0.5}Zn_{0.5}Fe_2O_4$ sintered specimens for different sintering atmosphere. The most drastic change in material constants, when sintered in nitrogen, is the increase in dielectric constant. Approximately twice larger ε_r' is observed in the nitrogen-sintered ferrite as compared to that of air-treated specimen as demonstrated in Fig. 3(c). However, the magnetic permeability (both μ' and μ'') has nearly the same dispersion as that of air-treated samples (Fig. 3(a) and 3(b)).

Comparing the material constants for oxygen-sintered ferrite in Fig.3 with that for y=0 in Fig.2, the material constants has nearly the same dispersion as that of air-treated specimen. We can expected that oxygen atmosphere is not effected to control of material constants.

IV.DISCUSSION

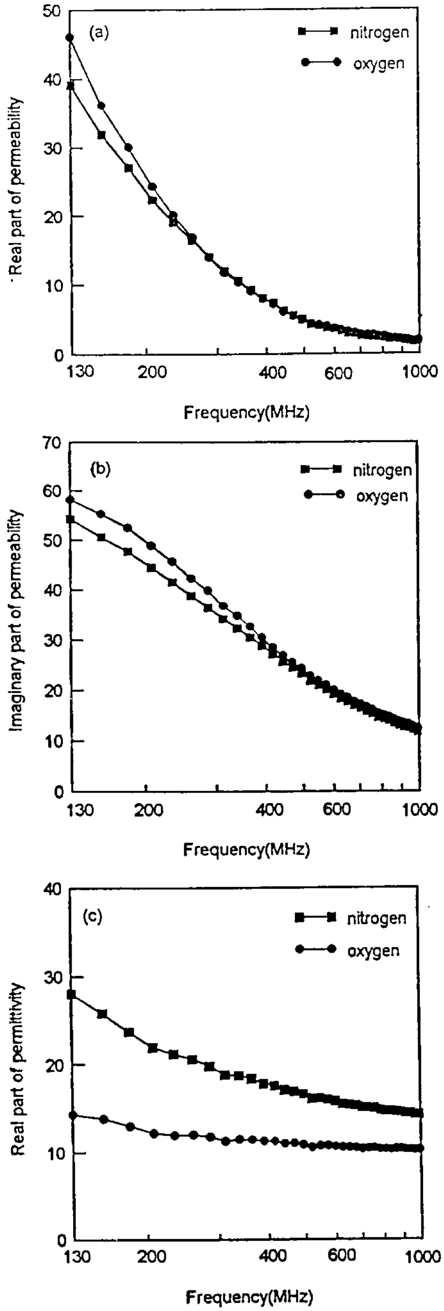


Fig.3. Material constants vs frequency spectra observed in $Ni_{0.5}Zn_{0.5}Fe_2O_4$ sintered specimens for different sintering atmosphere.

For a microwave absorbing layer terminated by a conductor, a zero-reflection condition is obtained by a proper combination of magnetic permeability and dielectric constant, which is given by

$$\sqrt{(\mu/\varepsilon)}\tanh[j(2\pi d/\lambda)\sqrt{(\mu\varepsilon)}] = 1 \qquad (1)$$

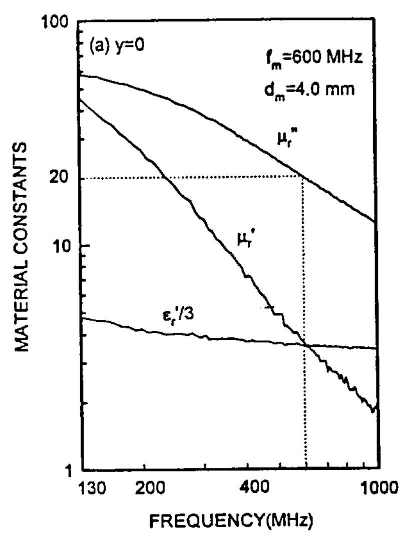
where, d is absorber thickness and λ is wavelength. For an absorber with high magnetic loss ($\mu''>\mu'$) and low dielectric loss tangent, the parameter requirements for zero-reflection can be approximated by the simple relationships [2,3].

$$d/\lambda = 1/2\pi\mu'' \qquad (2a)$$

$$\varepsilon' = 3\mu' \qquad (2b)$$

The first relationship determines the absorber thickness (d) in terms of the radiation wavelength and only the imaginary part of permeability at the frequency. The second relationship determines a specified frequency for zero-reflection which involves the real part of permeability and dielectric constant. The validity of these relationships was given by Musal and Hahn [2] in their work on ferrite absorber.

In the present study of Ni-Zn ferrites, the equation (2) can also be effectively used in determining the microwave absorbing properties.



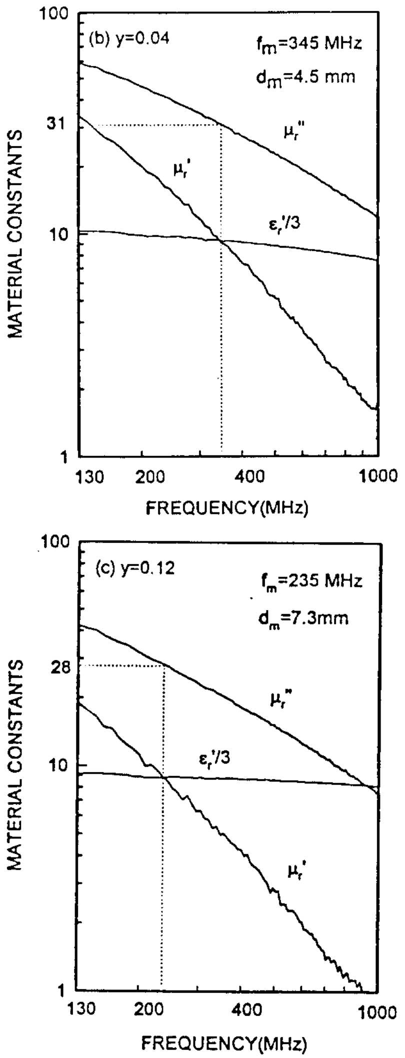


Fig.4. Theoretical estimation of zero-reflection frequency and absorber thickness in the $(Ni_{0.5}Zn_{0.5}O)_{1-Y}(Fe_2O_3)_{1+y}$ sintered specimens.

Fig.4 shows one illustration of determining the absorber thickness and zero-reflection freqeuncy. For $Ni_{0.5}Zn_{0.5}Fe_2O_4$ sample prepared in air, equation (2) is satisfied at a frequency of 600 MHz, and where the required thickness is 4 mm. This prediction is in good agreement with the result of reflection loss shown in Fig.2.

The lower zero-reflection frequency and the thicker absorber thickness with increasing excess Fe_2O_3 in ferrite can be explained in Fig.4. An

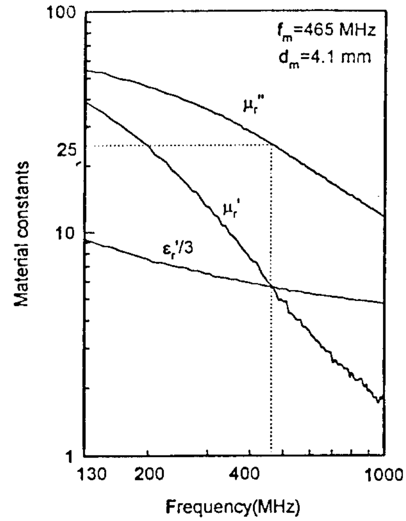


Fig.5. Theoretical estimation of zero-reflection frequency and absorber thickness in the $Ni_{0.5}Zn_{0.5}Fe_2O_{4y}$ sintered specimen for nitrogen atmosphere.

increase of Fe^{+2} content, by increasing Fe_2O_3, will constitute the electron conduction and then increase the dielectric constants. The larger thickness with increasing excess Fe_2O_3 in ferrite is basically attributed to lower value of μ_r'' as shown in Fig.4. The primary effect of the excess Fe_2O_3 is to increase dielectric constants.

Fig.5 explains the impedance matching frequency shifts to lower frequency with the increase in dielectric constant, which is realized in the nitrogen-sintered ferrites. As demonstrated in Fig.3, the nitrogen-sintering gives a result of high ε_r' about twice larger than that of air-treated sample, while the magnetic permeability (both μ' and μ'') remains almost the same. This high dielectric constant is basically attributed to the enhanced electrical conduction with the increase in ferrous ion (Fe^{+2}) content. As shown in Fig.5, the increase in ε_r' makes the equation 2(b) be satisfied at a lower frequency of 461 MHz, and where the absorber thickness is 4.1 mm. This results shows that impedance matching frequency could be controlled by the variation of excess Fe_2O_3 and nitrogen sintered in Ni-Zn ferrite.

V.CONCLUSION

The impedance matching frequency shifts to a lower frequency with increasing excess Fe_2O_3 in Ni-Zn ferrite, while the larger thickness with increasing excess Fe_2O_3 in ferrite is basically attributed to lower value of μ_r''. The primary purpose of the nitrogen-sintering was to increase the dielectric constant. Approximately twice larger ε_r' was observed in the nitrogen-sintered ferrite as compared to that of air-treated specimen. The control of the permittivity is realized by the nitrogen sintering atmosphere and excess Fe_2O_3 in Ni-Zn ferrite, respectively.

REFERENCES

[1] G.J.Yin and S.B.Liao,"Permeability spectra of Co substitued Ni ferrites," IEEE Trans.on Mag., vol27, pp5459-5461(1991).

[2] H.M.Musal,Jr. and H.T.Hahn, "Thin-layer electromagnetic absorber design," IEEE Trans. on Mag., vol.25, pp.3851-3853(1989).

[3] K.Akita, "Countermeasures against TV ghost inteference using ferrite," in FERRITES: Proceedings of the International Conference, Japan, September 1980, pp.885-889.

[4] H.T.Hahn, "The substitution of cobalt for nickel in stoichiometric nickel-zinc ferrite," J.Appl.Phys., vol.69, pp.6192-6194(1991).

[5] H.T.Hahn, "The variation of permeability with ferrite tile density," J.Appl.Phys., vol.69, pp.6195-6197(1991).

[6] W.B.Weir,"Automatic measurement of complex dielectric constants and permeability at microwave frequencies," Proc. IEEE, vol62, pp33-36(1974).

[7] H.T.Hahn, R.W.Cahill and H.M.Musal,Jr., "Magnetic loss in the nickel-zinc-iron system," J.Appl.Phys., vol.64, pp5650-5652(1989).