The Magnetic Properties and Microwave Absorbing Characteristics of Ni-Zn Ferrite

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Abstract---The relations between magnetic properties and microwave absorbing characteristics of Ni-Zn ferrites were examined. As the initial permeability of Ni-Zn ferrite material increased, the microwave absorbing performance of ferrite absorber was improved in the MHz region. From the results of these experiments, we could develop the ferrite absorber having superior microwave absorbing performance in the 10MHz-400MHz region.

I. INTRODUCTION

Microwave absorbing characteristics such as the matching frequency, matching thickness, and band-width are influenced by the magnetic properties and resonance phenomena of ferrite material [1]. Thus, in order to develop high performance ferrite absorber, it is important to investigate the relationship between the magnetic properties and microwave absorbing characteristics of ferrite absorber. But little work has been done on this relationship of ferrite material.

The purpose of this study was to investigate the effect of the magnetic properties such as initial permeability(μ_i), saturation magnetization (σ_s) and coercive force(H_c) on the microwave absorbing characteristics of Ni-Zn ferrites.

II. EXPERIMENTAL

Ni-Zn ferrites were prepared by conventional ceramic process. Raw materials(NiO,ZnO and α -Fe₂O₃) were mixed, calcined, milled, axially pressed and then sintered at 1150°C for 2 hours in the air. The initial permeability and other magnetic properties of toroidally shaped specimens were measured by an impedance analyzer (Hewlett-Packard, HP-4194) and a B-H analyzer(Iwatsu, SY-8232), respectively. The scattering parameters(S_{11}, S_{21}) of toroidally shaped ferrite(outer dia.=7.0 mm, inner dia.=3.0 mm) were measured by a Network analyzer (Hewlett-Packard, HP-8753) in the frequency range 300 kHz~1 GHz. The complex permeability and permittivity were determined from the scattering parameters [2].

Also, the saturation magnetization(σ_s) of Ni-Zn ferrites was measured by VSM(LDJ 9101).

III. RESULTS AND DISCUSSION

III-1) The Magnetic Properties of Ni-Zn ferrites

The frequency dependence of the initial permeability (μ_i) is shown in Fig.1.

Fig.1 The frequency dependence of μ_i .

As can be seen in Fig.1, μ_i increases but the frequency dependence of μ_i becomes worse with decreasing the Ni/Zn ratio.

Fig.2 represents the variation of maximum flux density(B_m), saturation magnetization(σ_s) and coercive force(H_c) with Ni/Zn ratio.

As shown in Fig.2, the B_m , H_c and σ_s increase with increasing Ni/Zn ratio. This behavior is probably due to the increased A-B exchange interaction with increasing Ni/Zn ratio in the case of Ni-Zn spinel ferrite [3].

We manufactured the ferrite absorbers of these Ni-Zn ferrites having different magnetic properties and examined the microwave absorbing characteristics of ferrite absorber.

Fig.2 The variation of B_m , σ_s and H_c with Ni/Zn ratio.

Magnetic properties of Ni-Zn ferrites developed in this study were represented in Table I.

Table I. The Magnetic Characteristics of Ni-Zn Ferrites (freq. : 100 kHz, H_m : 800 A/m).

Material	Ni/Zn ratio	μ_i (100kHz)	B_m (mT)	H_c (A/m)	σ_s (emu/g)
S-1	2.58	89	354	135	72
S-2	0.53	323	302	28	63
S-3	0.39	971	259	16	53
S-4	0.35	2074	250	12	46
S-5	0.33	3122	218	8	42

III-2) The Complex Permeability and Microwave Absorbing Characteristics.

In order to investigate the relation between magnetic properties and microwave absorbing characteristics, the complex permeability of Ni-Zn ferrites was examined in the frequency range of 300kHz-1GHz. The frequency dependence of complex permeability of Ni-Zn ferrites is shown in Fig.3. As shown in Fig.3, the resonance phenomena are observed. In Ni-Zn ferrites, these resonance phenomena occurred in this frequency range are believed to be due to spin rotational resonance [4].

It is also found that the resonance frequency is shifted toward lower frequency with decreasing Ni/Zn ratio.

For spin rotation, general model is the Snoek one [5] which predicts the resonance frequency given by

$$f_r = (\gamma/2\pi) H_a \quad (1)$$

Fig.3 The frequency dependence of complex permeability of Ni-Zn ferrites.

where γ is gyromagnetic ratio, H_a is the anisotropy field and f_r is the spin rotational resonance frequency of material. Equation (1) indicates that the spin rotational resonance frequency depends on the anisotropy field.

From the results of Table I, it could be known that the coercive force (H_c) of S-1 material (Ni/Zn=2.58) and S-5 material (Ni/Zn=0.33) was 135 A/m, 8 A/m respectively. Thus, decreasing the spin rotational resonance frequency with decreasing Ni/Zn ratio indicates that the anisotropy becomes smaller as the Ni/Zn ratio decreases.

Fig.4 shows the structure of flat and grid absorber [6] manufactured in this study.

Fig.4 The structure of flat and grid absorber.

(a) : flat absorber (b) : grid absorber
(d : Absorber thickness)

For microwave absorbing layer backed by a metal plate, the normalized input impedance (Z_{in}) at the absorber surface is given by [7]

$$Z_{in} = 1 = \sqrt{\mu_r / \epsilon_r} \tanh[j(2\pi/c)\sqrt{\mu_r \epsilon_r} f d] \quad (2)$$

where μ_r is the complex permeability($\mu_r' - j\mu_r''$), ϵ_r is the complex permittivity($\epsilon_r' - j\epsilon_r''$), c is the velocity of light, f is the frequency, and d is the thickness of absorber. This equation is called the zero reflection condition for an absorber. And the frequency and thickness that satisfy eq.(2) are called impedance matching frequency and matching thickness of absorber.

The reflection loss(dB) is function of Z_{in} , and the reflection loss of the microwave absorber can be calculated at given f and d using equation (3):

$$\text{dB} = 20 \log |(Z_{in}-1)/(Z_{in}+1)| \quad (3)$$

The reflectivity characteristics of grid structure are calculated for normal incidence of plane wave by using the spatial network method [6]. In this calculation procedure, the electromagnetic field is expressed in the equivalent circuit of the three-dimensional lattice work [8].

The calculated microwave absorbing results with thickness variation are represented in Fig.5 and Table II.

Fig.5 The reflection loss of flat and grid absorber
(a) : flat absorber (b) : grid absorber
(d : Absorber thickness)

From the results of Fig.5 and Table II, it can be found that the microwave absorbing frequency range of ferrite absorber is moving to lower frequency band according to increasing initial permeability.

With decreasing Ni/Zn ratio, the matching frequency(f_m) and band-width(≥ -20 dB) of flat

Table II. The Microwave Absorbing Characteristics of Ni-Zn Ferrites.

[Flat Absorber]			
Material	Matching Freq.(MHz)	Matching Thickness(mm)	Band-width (≥ -20 dB)
S-1	910	3.5	750~1,470 MHz
S-2	350	5.0	190~710 MHz
S-3	188	6.2	54~470 MHz
S-4	143	7.0	39~410 MHz
S-5	110	7.5	28~300 MHz

[Grid Absorber]			
Material	Matching Freq.(MHz)	Matching Thickness(mm)	Band-width (≥ -20 dB)
S-1	980	10	870~1,900 MHz
S-2	500	15	200~1,300MHz
S-3	310	18	65~920 MHz
S-4	250	19	45~700 MHz
S-5	180	22	20~520 MHz

and grid absorber are shifted toward lower frequency, whereas the matching thickness(dm) increase. Therefore, in order to control the microwave absorbing characteristics, it is important to control the magnetic properties such as μ_i , B_m , σ_s , H_c and f_r of ferrite material.

IV. CONCLUSION

We focused on the effect of magnetic properties on the microwave absorbing characteristics of ferrite absorber.

The matching frequency(f_m) of ferrite absorber was proportional to its coercive force(H_c) and saturation magnetization(σ_s) in the Ni-Zn ferrite.

It was also seen that the microwave absorbing performance was improved in the MHz region as the initial permeability increased.

From these experiments, it can be concluded that the microwave absorbing characteristics of ferrite absorber are controlled by adjusting the magnetic properties of ferrite material.

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