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THE ABSORPTION PROPERTIES OF Cu-Zn FERRITE/RUBBER COMPOSITE MICROWAVE ABSORBER WITH PZT ADDITIVE

KWANG-HO SHIN* . GEON SA-GONG

Department of Electrical Engineering, Dong-A University
840 Hadan-dong, Saha-gu, Pusan, 604-714KOREA

Abstract: The absorption properties of Cu-Zn ferrite/rubber composite microwave absorbers with PZT(Lead Zirconate Titanate) additive were evaluated. The composite specimens have prepared by molding and curing the mixture of matrix rubber and Cu-Zn ferrite powders which are synthesized by the coprecipitation method using $FeCl_3 \cdot 6H_2O$, $CuCl_2 \cdot 2H_2O$ and $ZnCl_2$ as a starting raw materials. PZT is used as another filler particles to adjust the material constants of Cu-Zn ferrite/rubber composite specimens. we have found that the material constants of specimens could be controlled by various PZT mixing ratio. On the Cu-Zn ferrite/rubber composite specimens with PZT 10[wt%] additive, the reflection losses were larger than 30[dB] in the frequency range from 2.72 to 4.4[GHz] by adjusting the thickness.

I. INTRODUCTION

An electromagnetic wave absorber is generally used to reduce the reflection from large-scale structures that cause serious problems such as ghost images on TV and RADAR displays etc. In order to design a good absorbing system, it is very important to not only determine the characteristics of the parameters of an absorbing specimen itself, but fabricate a good absorbing materials.

The fundamental materials for microwave absorber applications are magnetic, dielectric and conducting materials. Above all, the ferrite, a kind of magnetic materials, has been widely used as microwave absorber[1]. The ferrite microwave absorbers are classified into two types: those that utilize the sintered solid ferrite absorber in the frequency range of MHz, and the ferrite/rubber composite absorber in GHz frequency range[2,3].

The characteristics of microwave absorber can be evaluated by the reflection loss, matching frequency, matching thickness and band-width[4]. Its characteristics are closely related with the electromagnetic properties of materials, such as complex magnetic permeability, dielectric permittivity of specimens and frequency etc. Since the material constant is an intrinsic factor, it depends on chemical composition of ferrite, mixing ratio of ferrite filler to rubber matrix, and magnetic property of ferrite.

In order to obtain the required material constants for commercial applications of microwave oven, Cu-Zn ferrite powders used as a filler particle were synthesized by coprecipitation method[5] and PZT(Lead Zirconate Titanate), which is ferroelectric material, was added with various mixing ratio to Cu-Zn ferrite/rubber composite specimens to adjust the material constants of ferrite/rubber composite specimens[6], and the effect of PZT addition on microwave absorption property of Cu-Zn ferrite/rubber composite were studied.

II. EXPERIMENTALS

A. Sample Preparation

The Cu-Zn ferrite was prepared by coprecipitation method. The coprecipitates were synthesized by adding aqueous solution of $CuCl_2 \cdot 2H_2O$, $ZnCl_2$ and $FeCl_3$ $6H_2O$(of which the mole ratio is $Cu^{2+}:Zn^{2+}:Fe^{3+}=1:1:4$) to some NaOH solution at 70(°C). Afterward, H_2O_2 was dropped into coprecipitates with stirring, subsequently, some air were supplied by air compressor. The oxidized by-products were washed with some distilled water sufficiently and dried in drying oven at 70(°C) for 24 hours. The coprecipitates were calcined at 800℃ for 1 hour and characterized with regards on its magnetic properties. After such thermal treatment, we obtained the spinel phase ferrite used as a filler particle to prepare some composite specimens.

In preparing some specimens, PZT ($PbZrO_3$-$PbTiO_3$) maded by wet-dry combination method[7] was mixed with various weight ratio(PZT/ferrite) to ferrite powders. These mixtures were mixed again with silicon rubber matrix(powders/ rubber=4), and molded into toroidal shaped specimens and cured. Their dimensions are 3mmΦ in inner diameter, 7mmΦ in outer diameter, and 5mm in thickness.

Table 1 gives a designation of specimens with various PZT addition.

Table 1. Composition ratio of specimens

(wt%)

Specimens	Ferrite	PZT	Rubber
A	100	0	25
B	100	5	25
C	100	10	25
D	100	15	25
E	100	20	25
F	100	33.3	25

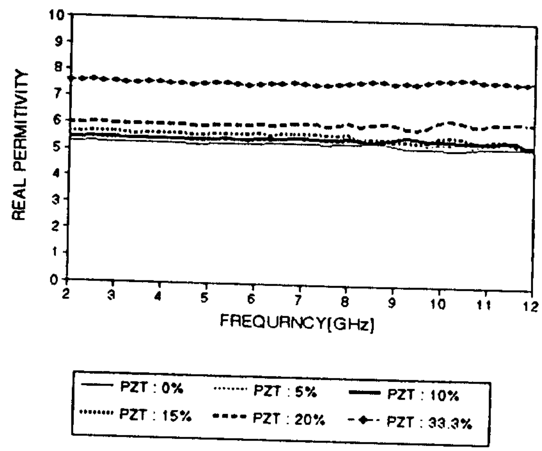
B. Measurements

Scattering parameters S_{ij} used as appropriate parameters for evaluating the absorption properties were measured by means of a network analyzer(HP8510B) with a co-axial type air line(inside, outside diameter: 3 and 7mm). The material constants, such as the complex dielectric permittivity and magnetic permeability, of composite specimens were directly calculated from the measured variables(s-parameter) over the frequency range from 2 to 12[GHz].

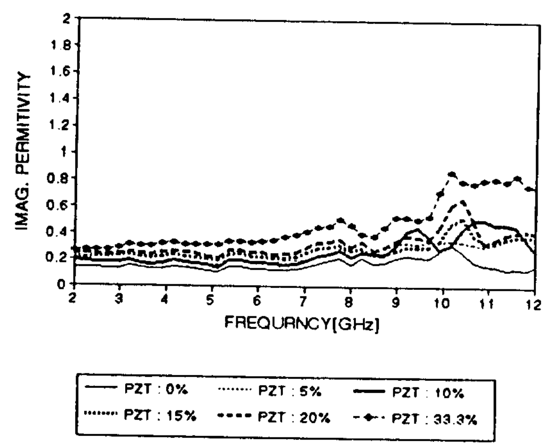
III. RESULTS AND DISCUSSION

Fig.1(a),(b),(c),(d) show the material constants of the specimens without and with various PZT mixing ratio(0~33.3wt%) as a function of frequency[2~12GHz]. Real parts(ε') of the dielectric permittivity of all specimens are increased exponetially with various PZT mixing ratio. While ε' values remain almost constant as frequency increases as shown in Fig.1(a). Imaginary parts(ε") of the permittivity of all specimens are increased linearly with increasing PZT mixing ratio in Fig.1(b). Especially, the values of ε" above the 8[GHz] were high and scattered. It is believed that the fluctuation of results might be caused by the error of measurements and dielectric dispersion of PZT filler[8,9].

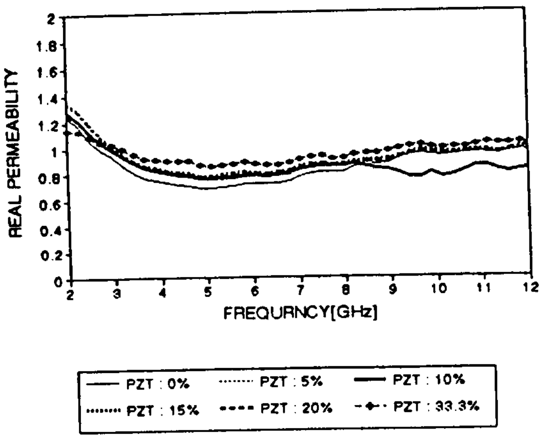
In general, real parts($\mu r'$) and imaginary parts($\mu r''$) of magnetic permeability above the magnetic resonance frequency decrease as frequency increases. The values of μ_r' and μ_r'' of specimens as shown in Fig.1(c),(d) are decreased in the frequency range of 2 to 12[GHz]. This fact can be explained by a consideration of the ferrite's magnetic resonance mechanism [10].



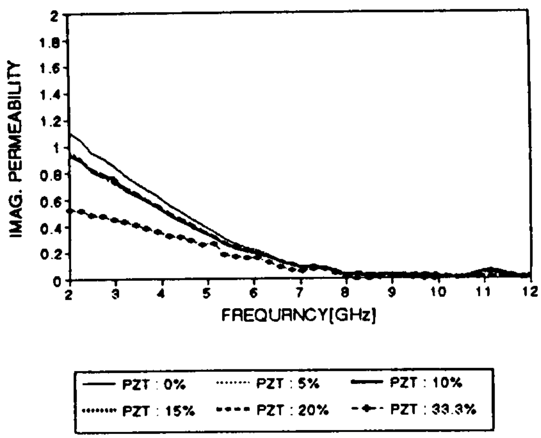
(a)ε' vs. frequency



(b)ε" vs. frequency



(c)μ′ vs. frequency



(d)μ″ vs. frequency

Fig.1. Frequency dependence of the Cu-Zn ferrite/rubber composite specimens with various PZT mixing ratio

The manetic and dielectric losses are given in table2. As you see, the magnetic losses are much larger than the dielectric losses. we can see that in most case microwave absorption is dominated remarkably by the manetic losses.

Table 2. Loss tangent of specimens

Sample	A	B	C	D	E	F
$\tan\delta_\varepsilon$	0.032	0.046	0.048	0.05	0.053	0.062
$\tan\delta_\mu$	0.333	0.285	0.293	0.268	0.277	0.168

It can be realized the relationship on the impedance matching map between zero-reflection condition and parameters, such as complex dielectric permittivity, magneric permeability, operating frequency and specimen thickness. The matching point is a point where zero-reflection condition is satisfied. For the matching condition in a given frequency, the specific material constants are needed. Thus, the parameters(such as real and imagenary parts of dielectric permittivity and magnetic permeability, frequency and thickness of specimens) have to go through the matching point on the impedance matching map.

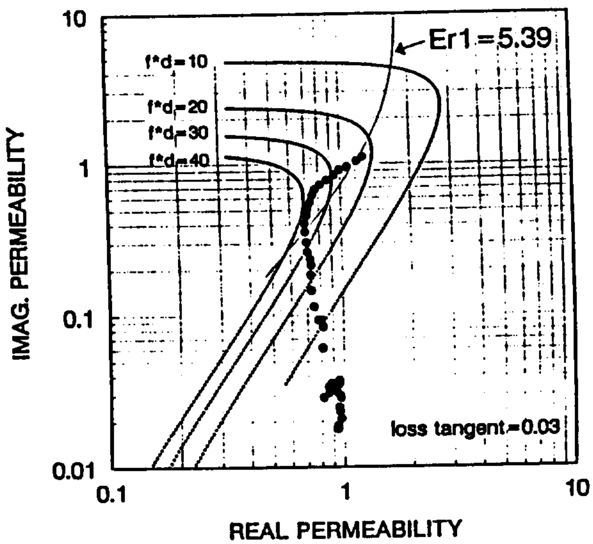


Fig.2. The complex permeability locus of composite specimen on impedence matching map(Specimen A)

Fig.2 shows the complex magnetic permeability locus of Cu-Zn ferrite/ rubber composite specimens without PZT on the impedance matching map while real part(ε′) of the complex dielectric permittivity is fixed at the value[ε_r': 5.39] obtained from Fig.1(a) and the dielectric loss factor is fixed at 0.03 obtained from the specimens.

It can be seen that the composite specimens have two points, so call matching point, where the complex permeability locus passes the point of real part of permittivity(ε_r':5.39). In Fig.2, the corresponding frequencies are 2.24 and 5.12[GHz], which are matching frequencies. We can also determine the matching thickness if the values of

$f_m \times d_m$ are known on the impedance matching map. As you see, the matching thicknesses result in turn 10.6 and 7.0(mm), respectively from the values of $f_m \times d_m$ are 23.7 and 35.8(GHz·mm).

In Fig.3, the complex magnetic permeability locus of Cu-Zn ferrite/ rubber composite specimens with 10wt% PZT addition on the impedance matching map while fixing the real part(ε':5.59) of the complex dielectric permittivities and the dielectric loss factor(0.048) obtained from the specimens. According to the above procedures, the matching frequencies obtained are 2.0 and 4.88[GHz], respectively. The reflection losses in these frequencies range could be obtained larger than the 20[dB] by adjusting the thickness(6.7-11.2mm).

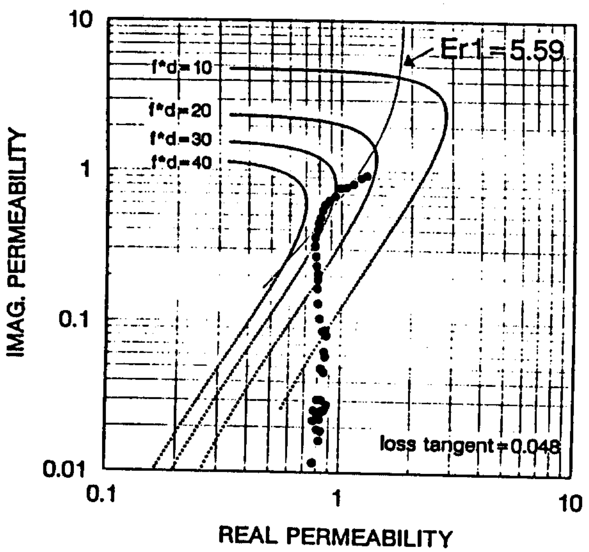


Fig.3. The complex permeability locus of composite specimen on impedence matching map(Specimen C)

Fig.4 shows 3-dimensional graph of the variation of reflection losses as a function of frequency and thickness for the composite specimen with 10wt% PZT additive. It was shown that the reflection losses were exceeded the 30[dB] in the frequency range of 2.48 to 4.4[GHz] by adjusting the thickness(7.3~10.2mm).

Table 3 summarizes the matching conditions of the specimens with various amounts of PZT addition in comparision with that of no PZT additive.

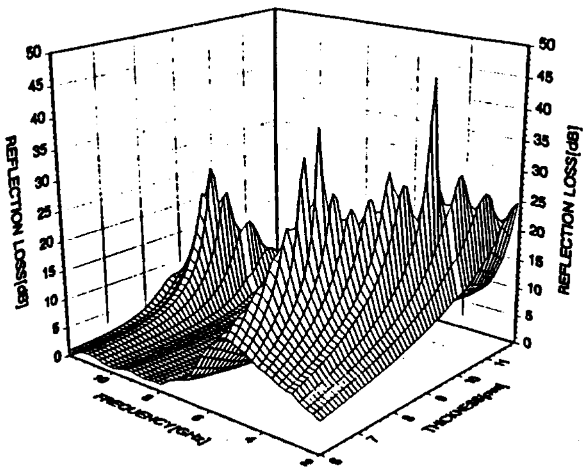


Fig.4. 3-dimensional graph of reflection loss as a function of frequency and thickness(Specimen C)

Table 3. Matching conditions of specimens

Sample	A	B	C	D	E
f_{m1}[GHz]	2.24	2.72	2.72	2.72	2.48
d_{m1}[mm]	10.6	9.7	9.7	9.4	9.8
f_{m2}[GHz]	5.12	4.4	4.16	4.4	4.64
d_{m2}[mm]	7.0	7.4	7.6	7.2	6.8

IV. CONCLUSION

The material constants of Cu-Zn ferrite/rubber composite specimens can be controlled by adding some amount of PZT(0-33.3wt%) and hence resulting real parts of dielectric permittivity are changed from 5.4 to 7.6 The Cu-Zn ferrite/rubber composite specimen with 10wt% PZT additive is shown that the reflection loss was larger than the 30[dB] in the frequency range of 2.72-4.4(GHz) by adjusting the thickness. The results would be applied for commercial microwave oven(operation frequency:2.45GHz) in S-band frequency region, and improvement of the absorption property of some kinds of ferrite/rubber composite absorbers since the material constants of the specimen are linearly shifted by controlling the PZT additon in Cu-Zn ferrite/rubber composite absorbers.

V. REFERENCES

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