

Analysis of EM wave absorber fabricated by using Sendust powder with different milling time

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Abstract

In this paper, we investigate EM wave absorbers using sphere Sendust powder and flake Sendust powder with CPE with different milling time. As a result, we know that there is a reduction of eddy current loss and the increase of space charge polarization which shifts frequency range to high frequency range and get wider frequency range when the milling time is increasing.

Keywords : EM wave absorber, milling time, eddy current loss, space charge polarization

1. Introduction

Recently, according to the advancement of electronic and communication technology, the control of EM wave environments becomes an important issue. Thus, the countermeasures against the electromagnetic interference (EMI) and the electromagnetic susceptibility (EMS) are severely required[1]. Countermeasure techniques for EMC problem adopt the various methods such as filtering, cabling, grounding, isolating and shielding, EM wave absorber is lately attracting public attention because it can essentially eliminate unnecessary EM wave.

In general, ferrites with spinel structures have been used widely as raw material of EM wave absorbers. The magnetic loss of soft ferrites decreases quickly in the GHz range, so EM wave absorbers prepared with soft ferrites have been used for frequencies below the GHz range[2]. And hard ferrites are used as EM wave absorbers in the GHz range because their magnetic loss increases at the natural resonance.

However, according to Snoek, polycrystal ferrites with spinel structures depend on Eq. (1).

$$S = \mu_i \cdot f_r = 6500(\text{MHz}) \quad (1)$$

In other words, S value multiplied frequency($f_{r(\text{Max})}$) that has the highest imaginary part of permeability(μ'') by initial permeability(μ_i) doesn't depend on composition ratio of ferrites and also can not exceed the defined value[3]. Namely, EM wave absorbers prepared with ferrites can not have high permeability in high frequency range as μ_i is proportioned the $1/f_{r(\text{Max})}$. Therefore, using of the existing ferrite EM wave absorbers is limited in high frequency ranges. To solve these matters, studies on soft magnetic metal kind of Fe are widely proceeding because its saturation magnetization is twice higher than the ferrite[4].

In general, when magnetic field of an alternating current $H = H_0 \cos \omega t$ (ω : angular frequency, t : time) is delivered on magnetic substance, energy loss occurring by H is shown Eq. (2).

$$p = \frac{1}{2} \omega \mu'' H_0^2 \quad (2)$$

Here, μ'' is imaginary part of the complex permeability of magnetic substance. In Eq. (2), to gain excellent energy loss, μ'' of magnetic substance has to be high at high frequency ranges. Hence, resonance frequency of the magnetic materials also has to be high at high frequency ranges to gain higher μ'' . For this reason, method such as heat treatment of the magnetic materials or control of its shape is being attempted[5].

In this paper, we analyzed the EM wave absorber which is fabricated by using sphere Sendust powder and flake Sendust powder. The flake Sendust is made by attrition milling.

2. Design of the EM wave absorber

EM wave absorber made of a conductor-backed single layer as shown in Fig. 1, the Return Loss (RL) can be obtained from the equivalent circuit as follows[6] and showed Eq. (3).

$$RL = -20 \log_{10} \left| \frac{z_{in} - 1}{z_{in} + 1} \right| \quad [dB] \quad (3)$$

Here, z_{in} is the normalized input impedance from the surface of absorber. The normalized input impedance is expressed as Eq. (4)[3][6].

$$z_{in} = \sqrt{\frac{\mu_r}{\varepsilon_r}} \tanh \left(j \frac{2\pi}{\lambda} \sqrt{\varepsilon_r \mu_r} d \right) \quad (4)$$

Here, λ is the wavelength, d is the thickness of the sample, ε_r is the complex relative permittivity, and μ_r is the complex relative permeability.

3. Preparation of samples

3.1 Absorbing materials

We used Sendust as the EM wave absorbing material. Sendust which is made of a brittle magnetic alloy of iron, silicon, and aluminum, is discovered by the Japanese in 1936 and is extensively used in cast and powder form. Sendust which is used in this paper is shown in table 1.

3.2 Processing of materials

We processed the thin plate-shape(Flake) Sendust powders, which can be manufactured with mechanical forging of spherical Sendust powders using attrition mill to get high value of magnetic permeability and dielectric permittivity.

3.1 Fabrication of the EM wave absorber samples

We used sphere Sendust powder and flake Sendust powder as the initial material in order to make the sheet-type EM wave absorber samples. Each Sendust powders are mixed with CPE as a binder, and a sheet type absorber samples are fabricated using an open roller. The open roller's surface temperature is controlled 70°C during sample preparation because the surface temperature affects the EM wave properties of sheet-type absorbers[7]. In order to investigate the characteristics with different absorbing material of samples, composition ratios of materials is fixed 60 : 40 wt.%. The fabricating process of an EM wave absorber is shown in Fig 2.

4. Simulated and measured result

4.1 Measurement system

For investigating of the EM wave absorption abilities of the samples, the prepared sheet-type absorbers are punched into a toroidal shape with an inner diameter of 3.05 mm and an outer diameter of 6.95 mm (GPC7 type). The absorption abilities of the samples are investigated by using HP 8753D network analyzer and gauged by measurement system as shown in Fig. 3. and Fig. 4 presents a photo of the sample holder and sheet-type sample and toroidal shape sample.

4.2 Analysis of the result

Fig. 5 shown the reflection coefficient against the frequency of the EM wave absorber samples and the thickness of the samples shown is 3 mm. A sample consisted of Sendust : CPE = 60 : 40 wt.%. In this figure, flake Sendust powder showed better absorption ability in high frequency range. Absorption ability for sphere Sendust powder is approximately 13 dB at 1.2 GHz and absorption ability for flake Sendust powder is approximately 22 dB at 2.8 GHz.

Fig. 6 shown the material property of sphere Sendust powder against the frequency of the EM wave absorber samples and the thickness of the sample is 3 mm. Fig. 7 shown the material property of flake Sendust powder against the frequency of the EM wave absorber samples and the thickness of the sample is 3 mm.

This phenomenon shows that flake Sendust powder which has higher complex relative permeability than sphere Sendust powder is suitable at high frequency range. In this case, we can expect that there is a reduction of eddy current loss(increase of permeability) and the increase of space charge polarization(increase of permittivity) when Sendust is flaked. Moreover, we find out that frequency range of using flake Sendust powder is wider.

5. Conclusion

In this paper, we investigate EM wave absorbers using sphere Sendust powder and flake Sendust powder in a magnetic material with CPE. These material properties are calculated from the S-parameter, and the absorption ability of the samples was measured by using network analyzer. We compared the absorption ability and the material property.

As a result, we know that there is a reduction of eddy current loss and the increase of space charge polarization which shifts frequency range to high frequency range(sphere Sendust powder : 13 dB at 1.2 GHz, flake Sendust powder : 22 dB at 2.8 GHz) and get wider frequency range. This fact might be helpful to design EM wave absorber thinner and smaller at high frequency range and should be investigated more.

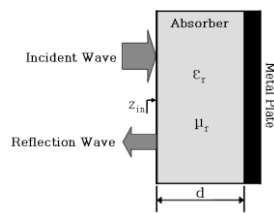


Figure 1: EM wave absorber

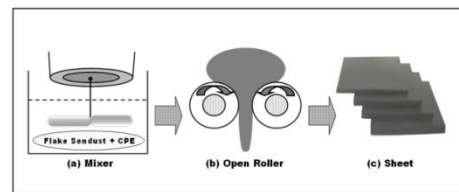


Figure 2: Fabricating process of the EM wave absorber samples

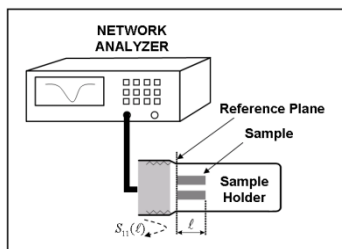


Figure 3: Measurement system



Figure 4: Sample and sample holders

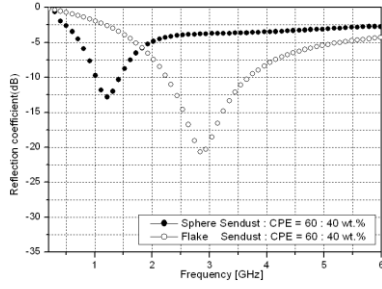


Figure 5: Reflection coefficient of samples

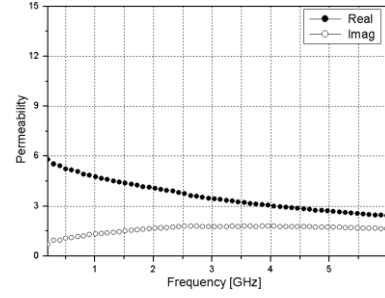


Figure 6: Material property of sphere Sendust powder

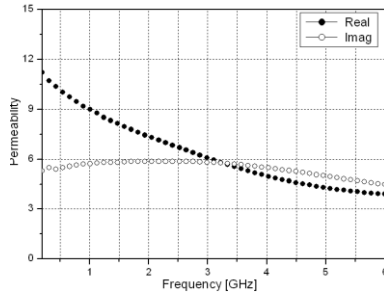


Figure 7: Material property of flake Sendust powder

Table 1: Font Sizes for Papers

Shape	FSSS(mm)	Composition
Sphere	140	Fe-Si-Al
Flake	1	Fe-Si-Al

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