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Soft Magnetic Properties of Fe-ferrite Based Aerosol Deposition Film

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Soft magnetic properties of Fe-ferrite based composite film prepared by Aerosol Deposition (AD) method were investigated. The difference of deposition rates and magnetic properties (saturation magnetization and coercive force) depending on substrates, such as glass, ABS resin are discussed. The deposition rates of Fe-ferrite composite AD films are more than ten times than that of ferrite based AD film for both substrates. Magnetic properties of as-deposited films showed higher values without heat treatment after deposition. The magnetic wave absorbing properties of the composite films evaluated by transmission loss measurements with Micro Strip Line method in GHz ranges up to 20GHz showed remarkable potential ability for practical use as materials for electrical magnetic compatibility (EMC) measures, which is becoming essential for electrical products for further and rapid communication, such as mobile phones, satellite phones and so on in higher Ghz ranges.

Key words: Aerosol Deposition method, thin film, Fe-ferrite, magnetic property, transmission attenuation, EMC

1. INTRODUCTION

Recently the importance of the countermeasures in Electromagnetic Compatibility (EMC) related issues are significantly increasing according to the advance in the electronics industry, such as consumer electronics, wireless communications and so on. Besides certain conventional EMC countermeasures using circuit simulation, EMC countermeasure parts and electronic shielding, some researchers report the attempt of application of magnetic materials to reduce the electromagnetic interferences in high frequency range [1]. For example, Yoshida showed the effectiveness of the flexible magnetic sheet and explained the relationship between the magnetic properties and transmission attenuation [2].

Even though these flexible sheets have certain characteristics and exhibit noise reduction, there are still certain points that are expected to be improved from the practical point of view, thickness, for instance. As the volume of the electronics gadget decreases day by day, the space to be filled with those sheets is decreasing accordingly. In terms of solving this problem, thin magnetic materials with high permeability in high frequency range are expected to develop.

In order to compatible less thickness and high performance, nano-granular magnetic thin film is extensively studied by Ohnuma et al. [3]. The imaginary part of permeability (μ") over 1000 and thickness of 1μm was obtained, although this nano-granular thin film is still in a feasibility stage. Magnetic film that has the thickness of between 1μm and 50μm was studied by Abe et al. [4] and μ" of around 100 was reported. However, this film was deposited through galvanization method and also in a feasibility phase.

Authors started to study Aerosol Deposition method [5], which has practical advantages, for instance, high deposition rate, inexpensive equipments, and potential to accomplish the nano-structured composite. We reported the soft magnetic properties of iron based aerosol deposition (AD) film previously [6]

. To develop high performance magnetic materials to reduce electromagnetic interference in the GHz range, we investigated the soft magnetic properties of ferrite based AD film, especially on plastic substrate, in foreseeing the application of AD film inside the body of mobile appliances[7].

S. Sugimoto reported soft magnetic properties of Fe-ferrite composite particles based aerosol deposited film of high permeability and magnetic loss without annealing after deposition [8].

In this study, we investigated soft magnetic properties and magnetic wave absorbing properties of Fe-ferrite composite AD film deposited on glass substrates and ABS resin substrates without applying adhesive layer between substrates and AD films.

2. EXPERIMENTAL PROCEDURE

Ni-Zn-Cu ferrite powder was prepared by high temperature furnacing process. The particle size was arranged between 200 and 400nm. Iron powder was prepared by deoxidization process. The particle size was arranged between 400 and 600nm. The ferrite powder and iron powder were mixed by 20% and 80%, respectively in an aerosol chamber and shook vertically by 250Hz. Helium was used as carrier gas to mix with the powder to be formed into aerosol. The aerosol was transferred to deposition chamber, evacuated to 20 Pa in advance, and finally injected into the chamber through the nozzle to form AD film on the glass substrates or ABS substrates at ambient temperature. Deposition pressure changed from 700pa to 1300Pa depending on the flow rate of helium.

The flow rate of aerosol was controlled between 3 litters/min and 7 litters/min. The distance between substrate and nozzle was kept constant at 20 mm. Ferrite aerosol was deposited in a rectangular shape, or 25× 10mm. Deposition time was set at 10 min The process diagram is shown in Fig. 1.

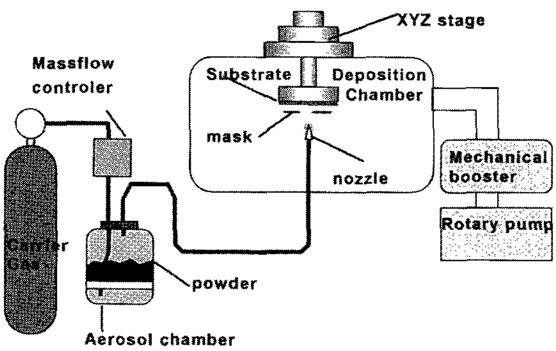

Fig.1 Process diagram of AD method

The magnetic properties of the deposited films were measured with VSM (Vibrating Sample Magnetometor). Maximum applied magnetic field was set at 5000 Oe. X ray diffraction method was used to determine characteristics of AD film. To evaluate the noise loss effectiveness of the film, authors measured transmission loss of a microstrip line. The testing circuit boards made of glass-epoxy resin (FR-4) were prepared and connected to the two ports network analyzer via SMA connectors. Frequency was swept from 50MHz to 10GHz. An overview of experimental apparatus is shown in Fig. 2.

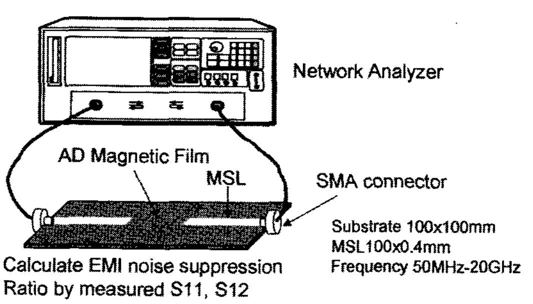

Fig. 2 Overview of experimental apparatus

S11parameter and S21 parameter were used to estimate the transmission loss of the microstrip line.

3. Results and discussion

3.1 Characteristics of the starting powder

Firstly the magnetic properties of starting powders were measured. Saturation magnetization for ferrite powder was 71.5 emu/g and coercive force was 95 Oe and for iron powder, 203 emu/g and 136 Oe, respectively.

3.2 Deposition on glass substrate

Fig.3 shows the dependence of film thickness of Fe-ferrite composite AD film on the flow rate of helium deposited for 10 minutes. The deposition rate increased with the flow rate of helium and the resulted film thickness increased as well.

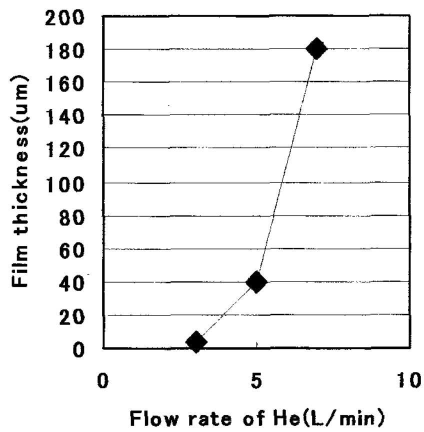

Fig.3 Dependence of film thickness on He flow rate

Fig.4 shows the XRD spectra for above samples. Intrinsic peaks for iron was stronger than those for ferrite and the peaks growing with the flow rate of helium.

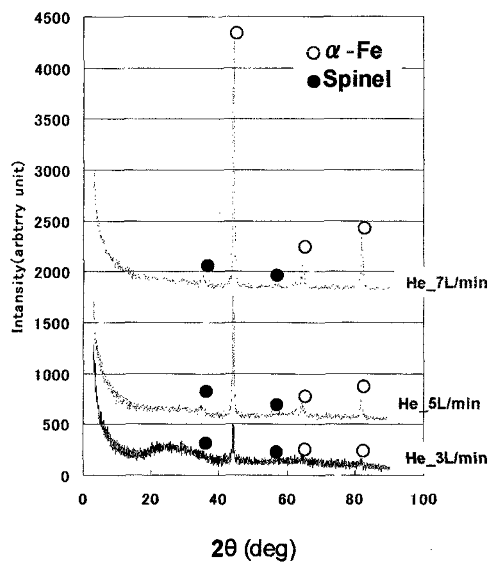

Fig.4 XRD spectra for Fe-ferrite composite film

Fig. 5 shows the dependence of saturation magnetization on film thickness with different flow rate of helium. For the AD film of 3L/min of helium flow rate, saturation magnetization was lower than the others and similar value for ferrite powder. For the AD film of 5 and 7 L/min of helium flow rate, saturation magnetization was higher and similar value to iron powder. This indicates the difference of the composition of substance in AD film.

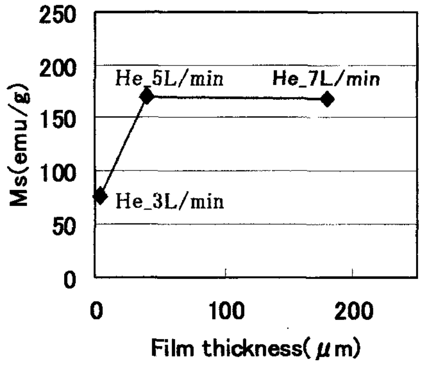

Fig. 5 Dependence of saturation magnetization on helium flow rate.

Fig. 6 shows the atomic fraction of the AD film obtained by SEM-EDX. The atomic fraction of ferrite deceased with helium flow rate. This change of atomic fraction influenced the difference of saturation magnetization.

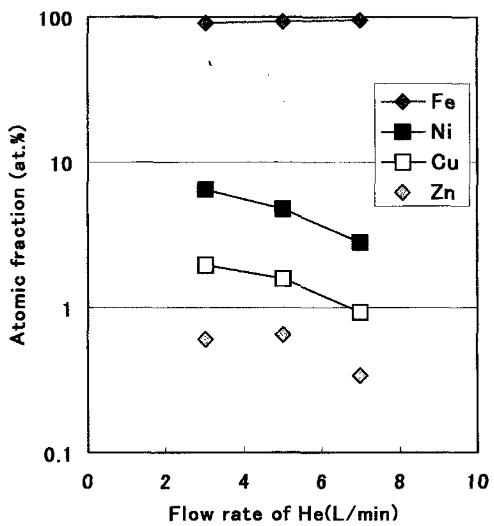

Fig. 6 Dependence of atomic fraction of AD film on the flow rate of helium

Fig.7 shows the results of transmission loss caused by the AD film placed on the micro strip line. Below 3GHz, transmission loss for the AD film of the helium flow rate of 5 and 7L/min was higher than that for 3L/min. Above 3GHz, the transmission loss for the latter sample, or the flow rate of 3L/min became higher than the former two samples. This is because by the higher surface roughness for the samples of 5 and 7L/min as shown in Fig.8. In the higher frequencies, the thinner AD film of 4um with small surface roughness was more effective in transmission loss than the thicker ones with large surface roughness.

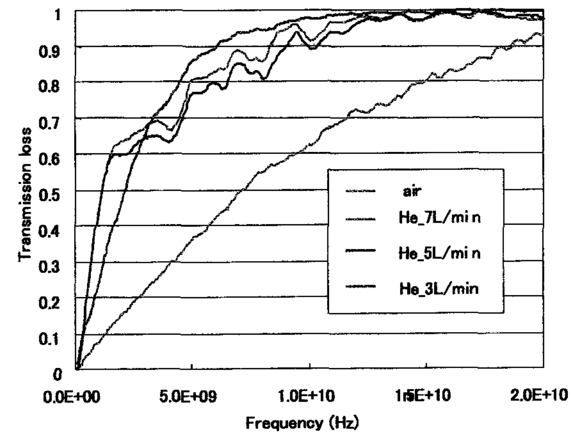

Fig.7 Frequency dependence of transmission loss caused by placed AD films on MSL.

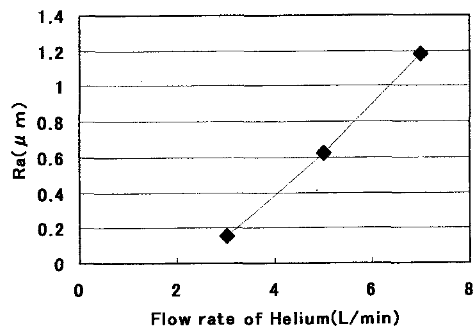

Fig. 8 Dependence of surface roughness of the flow rate of helium

3.3 Deposition on ABS substrate

In the previous paper [7], we reported the difficulty of deposition of ferrite on plastic substrates and improving of deposition with adhesive layer. As shown in Fig. 9, for Fe-ferrite composite particles,

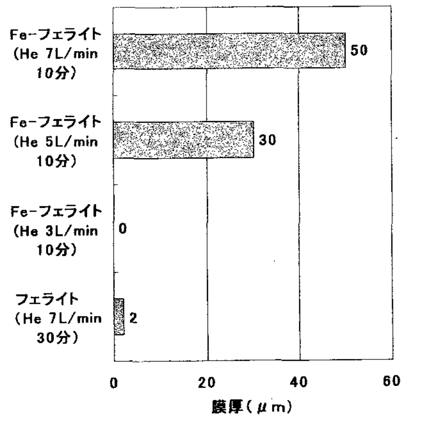

Fig.9 Thickness of AD film on ABS substrate

deposition took place on ABS substrate without adhesive layer the flow rate of helium above 5L/min. At 3L/min, no deposition occurred. In comparison, less deposition of ferrite occurred on ABS substrate than glass sbstrate.

Fig. 10 shows XRD spectara for the flow rate of 5 and 7 l/min. The intrinsic peaks were similar to the glass substrate samples, or iron peaks were stronger than ferrite peaks.

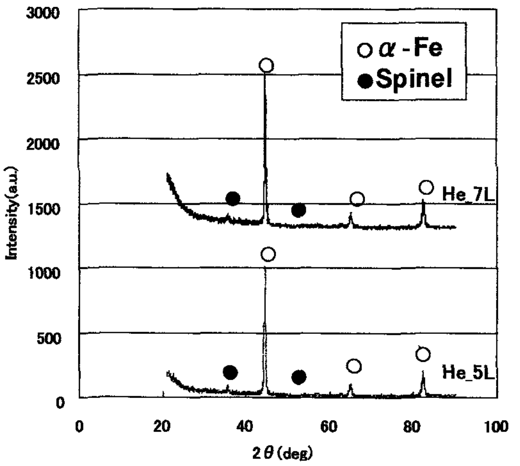

Fig. 10 XRD spectra for the AD film on ABS substrate

Table 1 shows saturation magnetization of AD film on ABS substrates. The values were about 10% lower than the value of iron, but higher than the value of AD film on glass substarte.

Table 1 Saturation magnetization of AD film on ABS substrates

Flow rate of He (l/min)	Saturation magnetization (emu/g)
3	no deposition
5	185.3
7	183.5

Fig. 11 shows the dependence of S21 from the MSL measurement. The AD film shows high ability of absorption of electromagnetic wave.

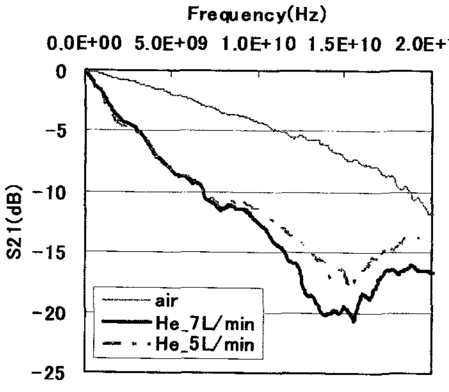

Fig. 11 S21 of AD film on ABS

Fig. 12 shows the dependence of transmission loss of AD film from the MSL measurement.

Both show that the AD films of Fe-ferrite on ABS substrates exhibit high ability of electromagnetic absorption.

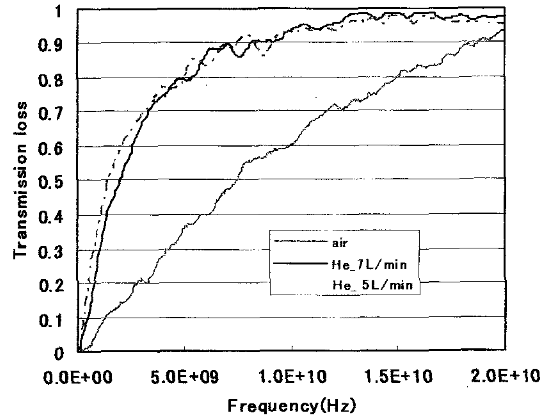

Fig.12 Dependence of transmission loss on frequency

4. SUMMARY

Fe-ferrite films were prepared by using AD method. Magnetic properties and transmission loss properties of the films were investigated. The AD film on glass substrates and ABS substrates both showed high ability of electromagnetic absorption without annealing after deposition.

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