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Soft Magnetic Properties of Ferrite based Aerosol Deposition film

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Soft magnetic properties of ferrite based film prepared by Aerosol Deposition (AD) method were investigated. On the adhesive tape as a substrate, deposition rate of 0.8μm/min was obtained at the flow rate of helium 7 l/min. Saturation magnetization and coercive force of the film was 54.7 emu/g and 136 Oe, respectively. The EMC effect of AD film was measured by transmission loss of a microstrip line and it showed the loss 5-10% higher than adhesive tape as reference in the 7 to 10 GHz range.

Key words: Aerosol Deposition method, thin film, 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. In this study we also describe the transmission loss properties of microstrip line to evaluate the EMC property of the film.

2. EXPERIMENTAL PROCEDURE

Ni-Zn-Cu ferrite powder was prepared by high temperature furnacing process. The particle size was arranged between 200 and 400nm. Fig. 1 shows the SEM image of this starting material. The the powder of 150g was put in an aerosol chamber and shook vertically by 250Hz. Helium was used as carrier gas, leading to the aerosol chamber and mixing with the powder to be formed into aerosol. The aerosol was transferred to deposition chamber, evacuated to 10-100 Pa in advance, and finally injected into the chamber through the nozzle to form AD film on the substrate at ambient temperature.

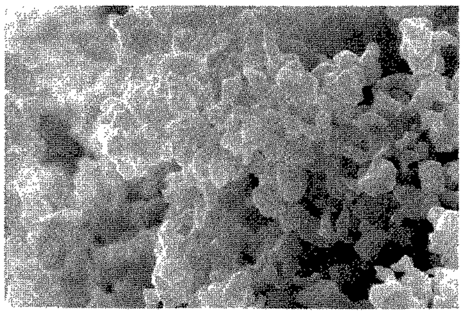

Fig. 1 SEM image of ferrite powder

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 15× 10mm. Deposition time was chosen between 10 min and 60 min, to clarify the relationship between the thickness and the deposition time. The process diagram is shown in Fig. 2.

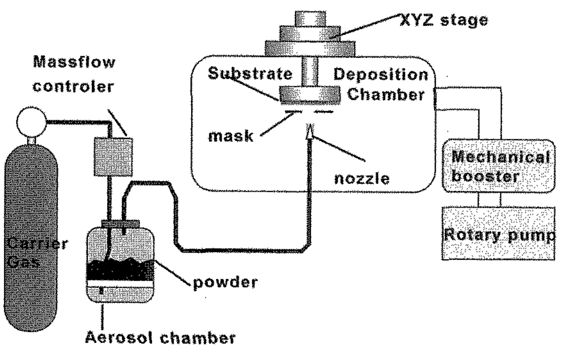

Fig. 2 Process diagram of AD method

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 starting powder. 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. 3.

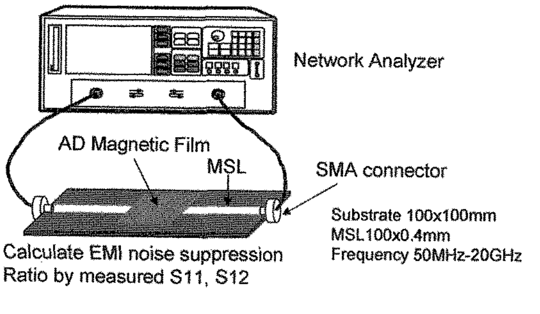

Fig. 3 Overview of experimental apparatus

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 powder were measured. Fig. 4 shows magnetic hysteresis loop of the feriite powder. Saturation magnetization was 71.5 emu/g and coercive force was 95 Oe, respectively. Fig.5 shows the X-ray diffraction pattern of the ferrite powder.

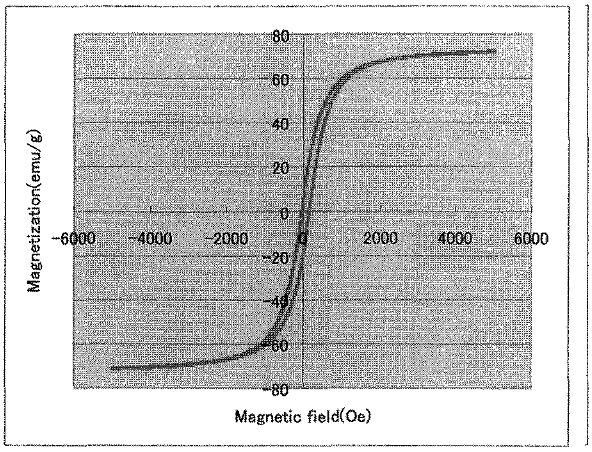

Fig. 4 Magnetic hysteresis loop of ferrite powder

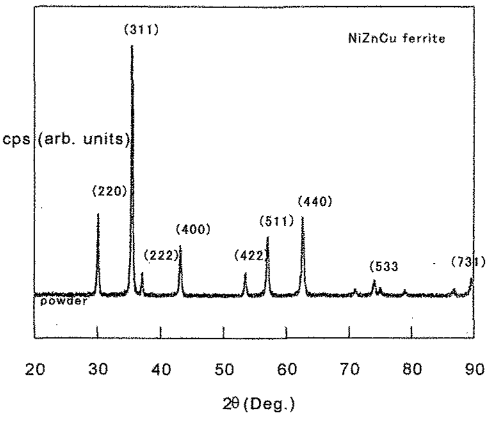

Fig.5 X-ray diffraction pattern of ferrite powder

3.2 Deposition on the plastic substrates

At first hand, we used four kinds of plastic substrates for deposition of ferrite powder, namely, PET, polyimid, FR-4 and ABS. Deposition time was fixed at 30 min and Helium gas flow rate was 7 litters/min. In Fig. 6 the thickness of ferrite AD film is shown. In this experiment, film thickness of the ferrite AD film on PET, polyimid and ABS are 1.0 μ m, 1.5 μ m and 2.0 μ m, respectively. On the other hand, no deposition of ferrite AD film was observed on FR-4 substrate. The difference among them may be ascribed to surface roughness and surface hardness of plastic substrate. Even for ABS 2.0 μ m in film thickness, is investigate the relationship between surface characteristics of plastic substrates and ferrite deposition furthermore.

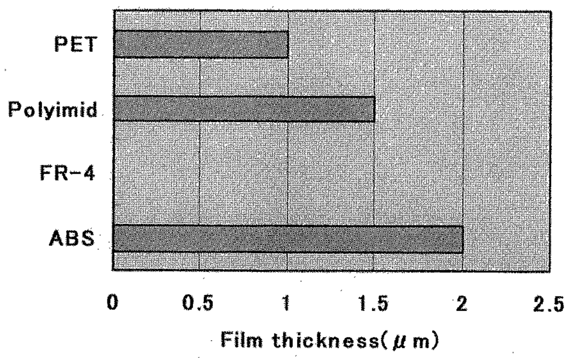

Fig. 6 Thickness of ferrite AD film on different substrates

3.3 Deposition of ferrite AD film on the adhesives

Next we tried to deposit ferrite AD film on adhesives coated on plastic substrates. The deposition of ferrite was conducted on the adhesive face of the tape. The dependence of thickness on the flow rate of helium was measured for the deposition time of 30 minutes. From Fig. 7, which shows the relationship between the deposition time and the thickness, linear relationship was observed. In this deposition experiment, the film thickness 25μm was obtained at the flow rate of helium 7 litters/min. This corresponds to approximately 0.8 μm /min deposition rate. So this AD method proved to be able to exhibit practical deposition rate compared to the other thin film process.

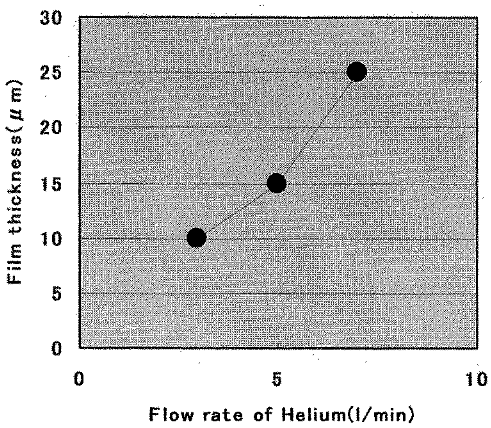

Fig. 7 Dependence of ferrite AD film thicknes on the flow rate of helium

Fig. 8 shows the dependence of film thickness on deposition time at flow rate of helium 7 l/min. In this experiment, we obtained the film as thick as nearly 60 μm. Thus deposition on adhesives is more effective to obtain thicker films than direct deposition on plastic substrates. The adhesive tape can be stick to wherever needed for EMC measures after deposition, so it has process merits in terms of no necessity to direct deposition on electrical appliances which is not in favor of powdery environment, or deposition chamber.

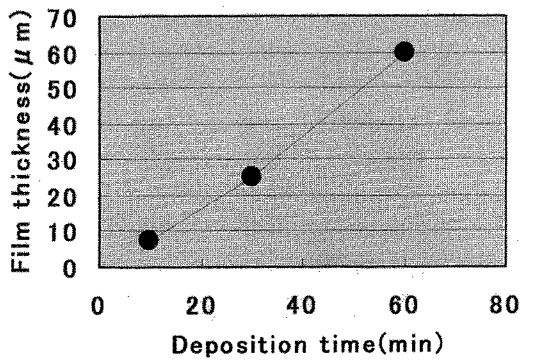

Fig. 8 Dependence of film thickness on Helium flow rate

3.4 Magnetic characteristics of ferrite AD film

The magnetic property of the deposited ferrite AD film was measured by VSM. Fig. 9 shows its magnetic hysteresis loops.

Saturation magnetization decreased from 71.4 emu/g for ferrite powder to 54.7 emu/g for ferrite AD film of 25μm, while the coercive force increased from 95.0 to 136 Oe.

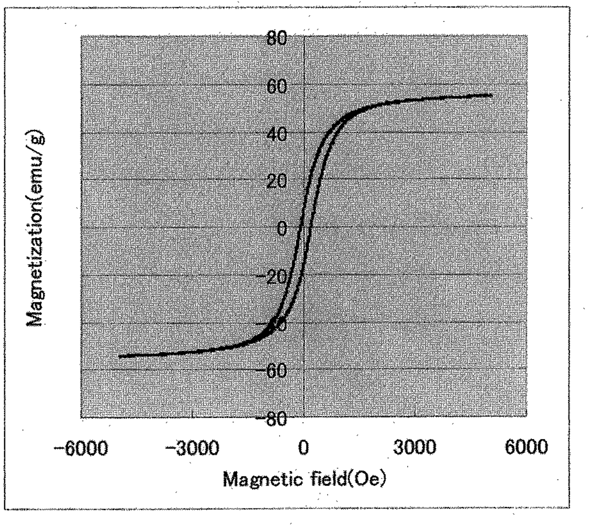

Fig. 9 Magnetic hysteresis loops of the as deposited ferrite AD film

3.7 Evaluation of the EMC properties of the film

To evaluate the EMC effectiveness of the ferrite AD film, 15x10mm ferrite film was deposited on the adhesive tape, and then the tape was sticked to microstrip line by facing the deposited area down. With measured S11 and S22, transmission loss is calculated by subtracting S11 and S21 from insersion signal energy. Fig. 10 shows the dependence on the flow rate of helium on transmission loss. The flow rate of helium 5 l/min and 7 l/min exhibited loss 5-10% higher than 3l/min and adhesive tape as reference only in 7-10 GHz range. This implies that the ferrite film have the potential to reduce noise coupling among the circuits or between the two devices.

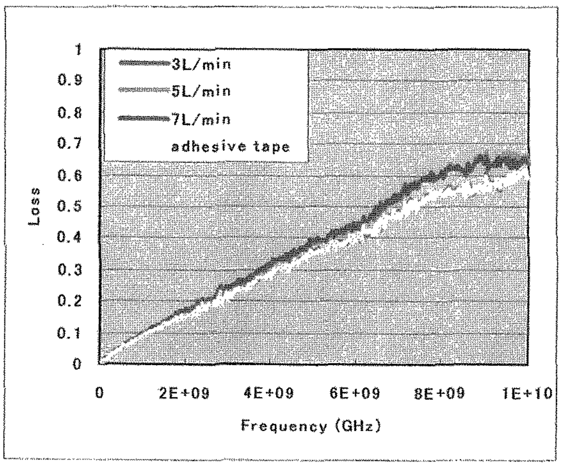

Fig. 10 Transmission loss of the microstrip line

Fig. 11 shows the dependence of deposition time, or film thickness, on transmission loss. There is not much difference among three samples, which indicates that the film of deposition time 10min is enough for EMC measures at the flow rate of helium 7 l/min.

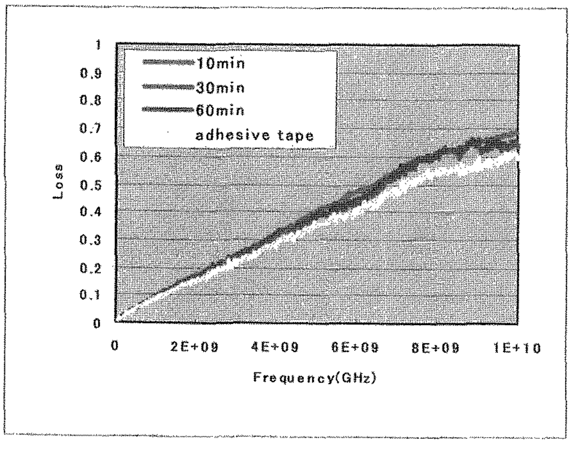

Fig. 11 Transmission attenuation of the micro strip line

4. SUMMARY

Ferrite films were prepared by using AD method. Magnetic properties and transmission loss properties of the films were investigated.

(1) Saturation Magnetization of 54.7 emu/g was obtained. Under the gas flow rate of 7litters/min, the deposition rate of 0.8 to 1.0μm/min was obtained.
(2) Using microstrip line, for the flow rate of helium 7 l/min, transmission loss 5-10% higher than adhesive tape as reference was observed in the 7-10 GHz range.

In the future study, we aim to

(1) Optimize the deposition condition
(2) Apply to the practical circuit boards
(3) Measure high frequency permeability of the film
(4) Optimization of properties adhesives

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