

Development of an Electromagnetic Wave Shielding Textile by Electroless Ni-Based Alloy Plating

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A polyester nonwoven textile with Ni-based alloy coating was fabricated, and the effect of electromagnetic wave shielding was evaluated. The Ni-based was coated by electroless plating on the textile. The electromagnetic wave shielding effect of the textile with Ni-B coating was about 99.98% over the induction range of 6–13 GHz. Because the textile has thin, light, flexible, and breathable characteristics, it will be versatile for the various electromagnetic wave shielding applications.

Index Terms—Electroless plating, electromagnetic wave shielding, metallic magnetic material, Ni-based alloy, polyester nonwoven textile.

I. INTRODUCTION

ELECTROMAGNETIC interference (EMI) has become extremely serious in various electronic equipment such as personal computers (a few gigahertz), cellular phones (0.8–2 GHz), and others. Not only the noise of the fundamental frequency but also the noises of the harmonic high frequency in the equipment or the system must be removed. Therefore, it is necessary to develop a wideband noise suppressor sheet for the EMI measures [1].

The authors developed a textile with the metallic magnetic material which was Ni-Fe coating by sputtering unit. The textile was lighter than the noise suppressor sheet, and it was flexible and breathable. And the electromagnetic wave shielding effect of the textile was about 90% from 1 to 13 GHz [2]. However, the Ni-Fe was hard to be coated to the inside of the textile, so then it was difficult to obtain a higher electromagnetic wave shielding effect. Therefore, an electroless plating was used to coat the metallic magnetic material inside the textile. This paper describes the development of an electromagnetic wave shielding textile by electroless Ni-based alloy plating.

II. FABRICATION

The textile used here was the polyester nonwoven textile (Kurabo Industries) with a weight of 60 g/m², a thickness of 210 μm, and a mean fiber diameter of 40 μm.

First, the textile was given the pretreatment for the electroless plating as described in Table I. Then, the metallic magnetic material, Ni-based alloy, was coated on the textile with the electroless plating as shown Fig. 1. The electroless plating conditions are shown in Table II.

III. MEASUREMENT

The imaginary part of permeability was measured using a thin-film permeameter (Ryowa Denshi; PMM-9G1) [3].

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TABLE I
PRETREATMENT CONDITIONS FOR ELECTROLESS Ni-BASED ALLOY PLATING

Process	Temperature [°C]	Time [min]
1. Alkaline degreasing	50	5
2. Alkaline washing	50	5
3. Acid neutralization	40	4
4. Etching	25	5
5. Conditioning	25	5
6. Pd catalyzing	25	5

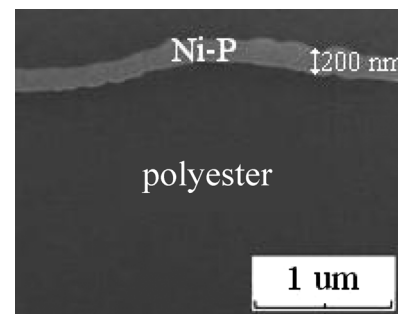


Fig. 1. Typical SEM image of the shielding textile sample Ni-P_M.

TABLE II
ELECTROLESS PLATING CONDITIONS OF Ni-BASED ALLOY

Sample name	Ni-P _M	Ni-P _L	Ni-B
Additive	P	P	B
Average composition of electroless plating film [wt.%]	Ni _{92.5} P _{7.5}	Ni ₉₈ P ₂	Ni _{99.8} B _{0.2}
Bath temperature [°C]	80	90	65
pH	4.6	6.5	6.7
Ni density [g/L]	5.0	5.5	6.7
Coating ratio [nm/s]	2.8	5.6	1.4
Reductant	Hypophosphorus acid	Hypophosphorus acid	Dimetil-aminobenzaldehydo

The electromagnetic wave shielding effect defined as SE in the nanofiber shielding textile was measured using a vector network analyzer, an S-parameter test set, and the waveguide components in Fig. 2. The nanofiber shielding nonwoven textile

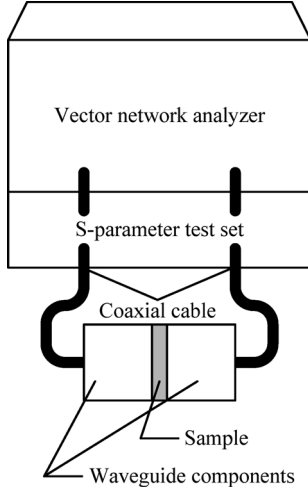


Fig. 2. Schematic of the measurement system for the electromagnetic wave shielding effect.

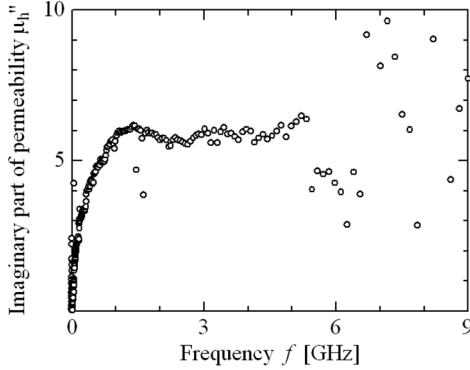


Fig. 3. Frequency dependence of the imaginary part of permeability measured for the sample Ni-B.

sandwiched between the waveguide components was connected to the S-parameter test set.

$SE (= 1 - P_{\text{thru}}/P_{\text{in}})$ was calculated with the following equation [4]:

$$\begin{aligned} SE &= (P_{\text{ref}} + P_{\text{loss}})/P_{\text{in}} = 1 - P_{\text{thru}}/P_{\text{in}} \\ &= 1 - 10^{(S_{21}[\text{dB}]/10)} \end{aligned} \quad (1)$$

where P_{ref} is the reflective power, P_{loss} is the loss power, P_{in} is the input power, P_{thru} is the through power, and S_{21} is the forward transmission coefficient. S_{21} for the nanofiber shielding textile was obtained by the vector network analyzer and the S-parameter test set, and $P_{\text{ref}}/P_{\text{in}}$ and $P_{\text{loss}}/P_{\text{in}}$ were calculated with the following equations:

$$P_{\text{ref}}/P_{\text{in}} = 10^{(S_{11}[\text{dB}]/10)} \quad (2)$$

$$P_{\text{loss}}/P_{\text{in}} = 1 - \left(10^{(S_{11}[\text{dB}]/10)} + 10^{(S_{21}[\text{dB}]/10)} \right) \quad (3)$$

where S_{11} is the input reflection coefficient, which was obtained by the vector network analyzer and the S-parameter test set.

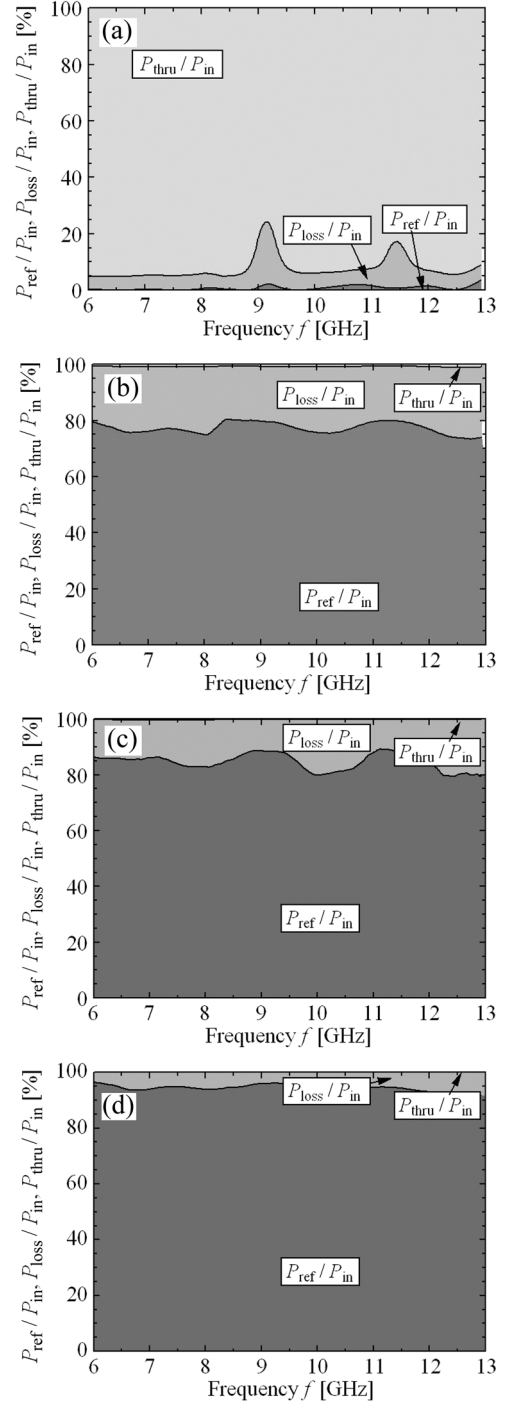


Fig. 4. Frequency dependences of $P_{\text{ref}}/P_{\text{in}}$, $P_{\text{loss}}/P_{\text{in}}$, $P_{\text{thru}}/P_{\text{in}}$ in (a) the polyester nonwoven textile, (b) the sample Ni- P_M , (c) the sample Ni- P_L , and (d) the sample Ni-B.

IV. RESULTS AND DISCUSSION

A. Imaginary Part of Permeability in Shielding Textile

Fig. 3 shows a frequency dependence of the imaginary part of permeability μ''_h measured for the sample Ni-B. In Fig. 3, the imaginary part of permeability μ''_h in the sample Ni-B was about 6 over 1 GHz because of the resonance loss in the Ni-B. The imaginary part of permeability μ''_h in the sample Ni- P_M

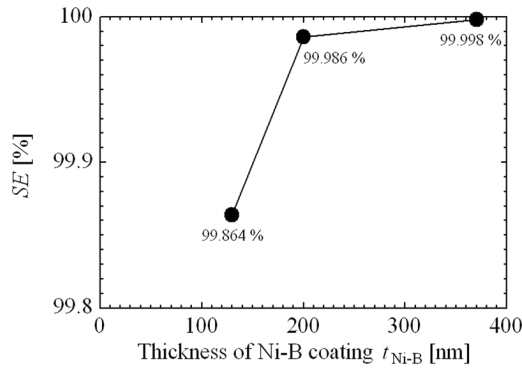


Fig. 5. Relation between the electromagnetic wave shielding effect and the thickness of Ni-B coating on the textile.

and the sample Ni- P_L disappeared because of the nonmagnetic material.

B. Electromagnetic Wave Shielding Effect

1) *Electromagnetic Wave Shielding Effect of Each Shielding Textile by Electroless Ni-Based Alloy Plating:* Fig. 4 shows the frequency dependences of P_{ref}/P_{in} , P_{loss}/P_{in} , P_{thru}/P_{in} , where P_{thru}/P_{in} means $1 - (P_{ref} + P_{loss})/P_{in}$ in the polyester nonwoven textile (a), the sample Ni- P_M (b), the sample Ni- P_L (c), and the sample Ni-B (d). The thickness of Ni-based alloy coating in all samples was 200 nm.

In Fig. 4(a), SE of the polyester nonwoven textile was about 5% in the measured frequency band. On the other hand, in Fig. 4(b), SE of the sample Ni- P_M was about 99% in the measured frequency band, which is higher than SE of the textile with the Ni-Fe coating by sputtering. Because the Ni-P was coated inside the textile, it has a higher EMI shielding effect. In Fig. 4(c), SE of the sample Ni- P_L was about 99.7% in the measured frequency band, which is higher than that of the sample Ni- P_M . Because the conductivity of the sample Ni- P_L was higher than that of the sample Ni- P_M , the sample Ni- P_L obtained higher P_{ref}/P_{in} . In Fig. 4(d), SE of the sample Ni-B exhibited about 99.98% in the measured frequency band, and it was the highest in other samples. Because the conductivity of the sample Ni- P_L was the highest in other samples, it had the imaginary part of permeability μ''_h as described above, so then the sample Ni- P_L obtained higher SE.

2) *Relation Between Electromagnetic Wave Shielding Effect and Thickness of Ni-B Coating on Textile:* Fig. 5 shows the relation between SE and the thickness of the Ni-B coating t_{Ni-B} on the textile at 10 GHz.

In Fig. 5, when increasing the thickness of Ni-B coating t_{Ni-B} , the SE increased. The electromagnetic wave shielding

textile with Ni-B coating showed sufficient reflection and absorbance of the electromagnetic wave.

V. CONCLUSION

The electromagnetic wave shielding textile with Ni-based alloy coating was investigated. The results obtained are as follows.

- 1) The imaginary part of permeability μ''_h in the electromagnetic wave shielding textile with Ni-B coating was about 6 over 1 GHz.
- 2) The SE of the electromagnetic wave shielding textile with Ni-based alloy coating by the electroless plating was over 99% in the measured frequency band, which is higher than the SE of the textile with the Ni-Fe coating by sputtering.
- 3) The SE of the electromagnetic wave shielding textile with Ni-B coating exhibited about 99.98% in the measured frequency band, and it was the highest in other samples.
- 4) When increasing the thickness of Ni-B coating t_{Ni-B} , the SE increased in the electromagnetic wave shielding textile with Ni-B coating.

The textile has an electromagnetic wave shielding ability light, flexible, and breathable properties. The materials for various electromagnetic wave shielding applications are expected with this electromagnetic wave shielding nonwoven textile.

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