High-Frequency Noise Suppression Using Ferrite-Plated Film

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Abstract

Ferrite-plated film is a flexible magnetic sheet that can be deposited at ordinary temperatures. Its high electrical resistance and high permeability up to the UHF band allows the film with a thickness of only a few microns to effectively suppress high-frequency electromagnetic noise without side effects. It can be formed directly onto electronic components and circuit boards and contains no organic substances such as polymers, so that it can withstand reflow soldering process and may even be used inside IC chips or in the inner layers of multi-layer boards. The active application of this device is currently under way based on the expectation that it will provide a simple solution to problems that are likely to become even more complex in the future, such as prevention of the high-frequency noise of electronic devices and improvements to signal integrity.

Keywords

noise suppression sheet, ferrite-plated film, high-frequency noise, EMI, autotoxemia, signal integrity

1. Introduction

The composite-type noise suppression sheet (BUSTERAID) is used widely to solve the problem of high-frequency noise that has recently become an issue of increasing seriousness[1]. The noise suppression sheet has been adopted rapidly as an "attach and function" quick countermeasure without side effects, such as secondary electromagnetic interference. This is due to its loss characteristics, which feature frequency selectivity and to its high electrical resistance. The mounting evaluation method has come to be standardized by the International Electrotechnical Commission (IEC)[2].

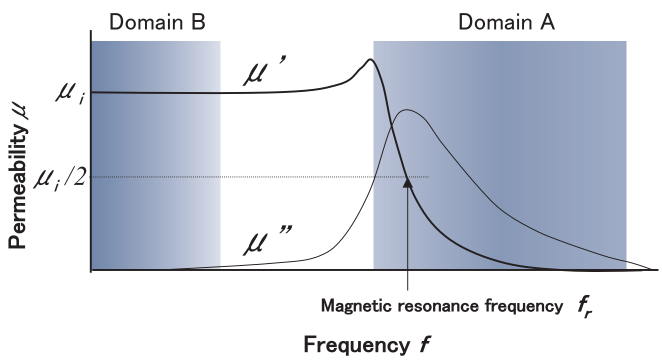
The thickness requirements for noise suppression sheets are now reaching 10μm following the expansion of its application to equipment with little excess space such as cellular phones and DSCs (Digital Still Cameras). It has already become difficult to provide a suppression capability (proportional to the product of sheet thickness and permeability μ) for the composite sheets that are in use as the current mainstream choice. As a result, the ferrite-plated films and the nano-granular thin films are both attracting attention as the next-generation noise suppression sheets because of their excellent high-frequency permeability.

The ferrite-plated film (BUSTERFERRIX) that we introduce in this paper, is a newly developed thin-film magnetic material. Its deposition process was developed by Professor Abe of Tokyo Institute of technology[3] and NEC TOKIN is currently working with the aim of practical implementation. BUSTERFERRIX is attracting attention as a new noise solution for suppressing the electromagnetic interference that may occur in very small areas of printed circuit boards with high-density mounting or largely integrated electronic devices such as SiPs (System in Packages). As a thin film of only a few microns thickness, it can provide an excellent noise suppression effect and can be plated on a wide range of materials. In addition, the thinness, excellent high-frequency permeability and steep magnetic resonance characteristics of the ferrite-plated film is also effective for improving the transmission/reception performance of the rapidly spreading RFID systems. Therefore, the film is also expected to become a signal integrity solution for the UHF-band RFID systems that has been difficult to implement using composite magnetic sheets.

In this paper, we discuss the features of the ferrite-plated film, its conducted noise suppression effects and the result of our investigations into variations in radiation noise by direct plating of the ferrite film onto the surface of a printed circuit board on which a microcomputer is mounted.

2. Magnetic Properties Required for High-Frequency Noise Suppression

Fig. 1 shows a scheme diagram of the frequency spectra of the permeability μ (complex permeability μ = μ' – jμ") of the magnetic material (hereinafter referred to as the permeability profile). In the following, we will describe the permeability of magnetic materials required for the suppression of



Domain A: Domain suitable for noise suppression because of big loss due to magnetic resonance.
Domain B: Domain suitable for signal integrity improvement of the RFID signal transmission/reception properties, etc., because of the low magnetic loss.

Fig. 1 Frequency distribution of magnetic permeability and domains for different applications.

high-frequency noise and the improvement of signal integrity based on Fig. 1.

The noise suppression sheet and ferrite-plated film suppress high-frequency noise by means of frequency domain separation making use of the magnetic resonance that is controllable according to the composition and shape of the magnetic material. Consequently, since the magnetic materials should not have a magnetic loss in the signal frequency domain and should be accompanied with a significant loss in the noise domain in order to attenuate only the noise component, domain A in Fig. 1 is used for the noise suppression.

On the other hand, in the application to the magnetic circuitry of RFID, the magnetic shielding effect is obtained before the start of the frequency dispersion of permeability due to magnetic resonance, as in domain B of Fig. 1, so the resonance frequency f_r should be much higher than the signal frequency. Therefore, to obtain a high noise suppression effect and magnetic shielding performance, it is required that; 1) the product $\mu_i \bullet f_r$ of the initial permeability (μ_i) and resonance frequency (f_r) is large; 2) the resonance frequency f_r should be controllable over a wide frequency range, and; 3) the resonance loss rises steeply.

Fig. 2 shows the permeability profile of ferrite-plated film. As the resonance frequency f_r is from five times to more than ten times higher than the bulk, the $\mu_i \bullet f_r$ product becomes significantly larger.

Fig. 3 shows diagrams of the cross-sectional structures of the ferrite-plated film and composite noise suppression sheet, and

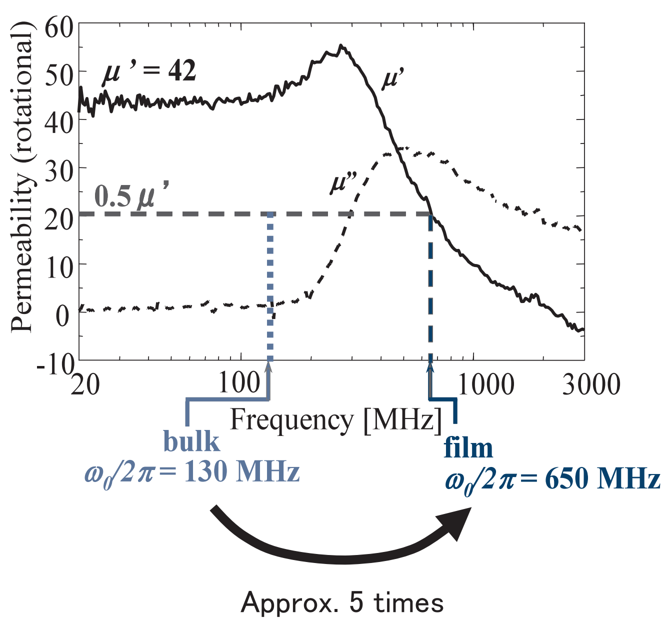


Fig. 2 Examples of the permeability properties of ferrite-plated film.

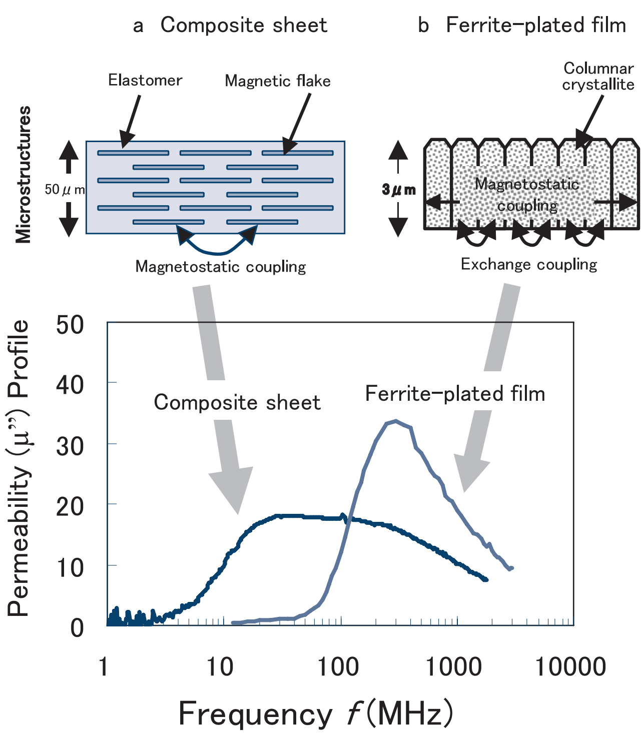


Fig. 3 Microstructures of composite-type noise suppression sheet and plated ferrite film, difference in their permeability (μ") profiles.

the corresponding permeability (μ") profiles. Their comparison shows that the rise with the ferrite-plated film is very steep, suggesting that it is very convenient for signal integrity improvement for RFID systems as well as for high-frequency noise suppression.

3. Conducted Noise Suppression Effect of Ferrite-Plated Film

The ferrite-plated film can be formed on a wide range of substances including polymer film such as PET film, FPC board composed of polyimide, glass epoxy wiring board on which electronic components are mounted, and major electronic component surface materials such as semiconductor sealants. In this section, we will describe one of the simplified evaluation methods of noise suppression effect when magnetic sheets or films are placed onto a micro-strip line.

The conducted noise suppression effect of the noise suppression sheet and ferrite-plated film when it is placed on a transmission line can be expressed as the power loss per unit line length, P_{loss}, using the following formula.

$P_{loss} \propto M \cdot \mu" \cdot f \cdot \delta$ ------------------------ (1)

Here, M is the coupling coefficient between the high-frequency flux produced by the current flowing through the transmission line and the noise suppression sheet, and δ is the depth of magnetization caused by the high-frequency current. The coupling coefficient *M* in formula (1) contains the effect of the gaps due to the adhesive tape or similar material between the transmission line and the noise suppression sheet. As a result, if the noise current flowing through the transmission line is weak, both *M* and δ become small and the noise suppression effect drops.

Therefore, to obtain a high suppression effect with the composite-type noise suppression sheet, it is necessary to eliminate the gaps that degrade the coupling coefficient. A composite sheet with a self-tacking property has been developed for this purpose, but the use of adhesive tape is usually necessary to ensure the attaching strength. On the other hand, the ferrite-plated film is formed directly onto the target components/circuits so that it can render the coupling coefficient *M* larger than the composite sheet and is therefore very advantageous for actual use in mounting. **Fig. 4** shows the comparison of the conducted noise suppression effect P_{loss} between the case in which a composite noise suppression sheet with 50μm thickness (μ_i = 50) is placed in close contact on a micro-strip line without using an adhesive sheet and the case in which a ferrite-plated film of 3μm thickness (μ_i = 45) is formed directly on it.

Fig. 5 shows images of the mounting of each magnetic film onto an actual circuit. Fig. 5(a) is the image of the composite noise suppression sheet and Fig. 5(b) is the image of the ferrite-plated film.

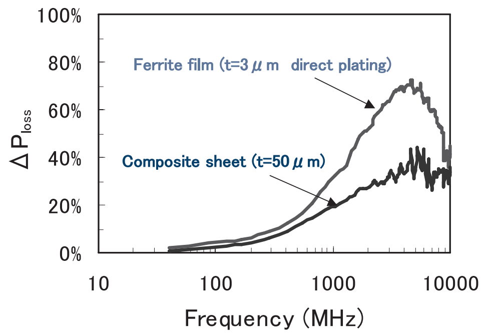


Fig. 4 Conducted noise suppression effects P_{loss} of ferrite-plated film and composite noise suppression sheet.

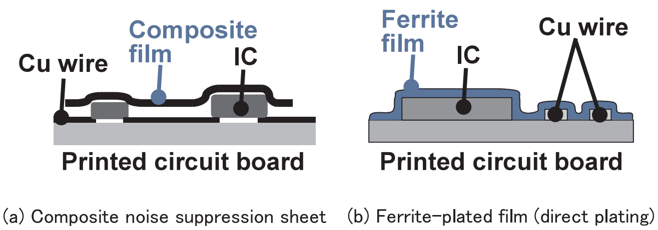


Fig. 5 Model mounting diagrams of ferrite-plated film and composite noise suppression sheet.

As seen above, the ferrite-plated film can be formed directly onto electronic components and circuits and can exhibit an adequate noise suppression effect with a thickness of only 3μm. It is therefore capable of suppressing the high-frequency conducting noise of complicated structures with which the noise suppression sheet cannot be easily applied, for example an electronic circuit board with high-density mounting, very small electronic components or an internal layer of a multilayer circuit board.

4. Radiated Noise Suppression Effect of Direct Plating onto a Printed Circuit Board

We formed a Ni-Zn ferrite-plated film of 3μm thickness directly onto a printed circuit board carrying a microcomputer chip with 20MHz clock operation using the spin spray process. **Fig. 6** shows the permeability profile of the ferrite-plated film. Ni and Zn composition control was utilized to achieve a permeability profile with which the magnetic loss becomes dominant at above 100MHz, which corresponds to 5 times the microcomputer's clock frequency. We then placed the printed

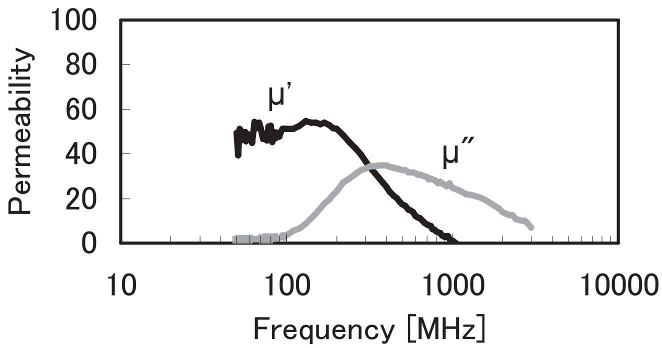


Fig. 6 Relative permeability of ferrite-plated film plated directly onto a microcomputer circuit board.

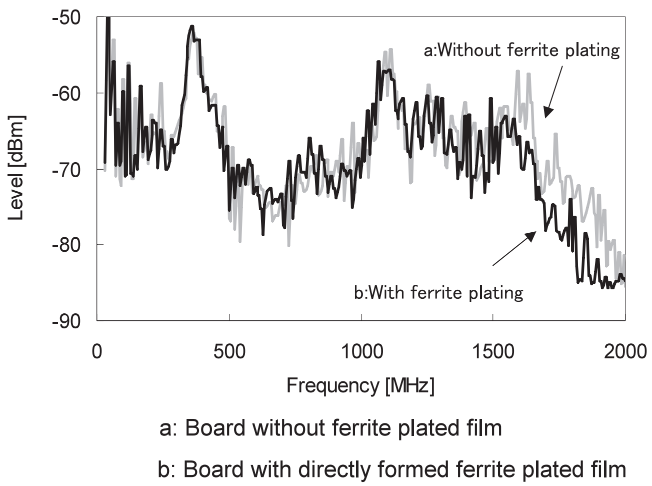


Fig. 7 Radiation noise spectrum of a microcomputer circuit board.

circuit board with the ferrite-plated film in a TEM cell, connected it to a spectrum analyzer via an placed, and measured and evaluated the radiated noise during operation of the microcomputer.

Fig. 7 shows the spectra of the radiated noise. The radiation level dropped for the printed circuit board with the directly plated ferrite film plating compared to the printed circuit board without the ferrite-plated film. This effect became more noticeable as the frequency increased, and was eventually recognizable as a clear difference at 1.5GHz or more.

This result very much resembles the frequency dependency of the conducting noise suppression effect obtained by forming the ferrite-plated film on a transmission line in the previous section. Namely, it can be judged as the result that the formation of ferrite-plated film almost all over the printed circuit board surface made it possible to absorb the high harmonic current propagated from the microcomputer chip to the board surface by means of the magnetic loss of the ferrite-plated film.

The printed circuit board used in the test carried multiple electronic components including capacitors in addition to microcomputer chips but we did not recognize any problem that would affect their performance including operation malfunction due to the direct plating of the ferrite-plated film. This was because the ferrite-plated film can be formed at the relatively low temperature of about 80°C and presents high electrical resistance and is also thermally stable.

5. Conclusion

Nowadays, it is hardly possible to achieve design performance criteria of IT equipment that is under rapid progress with such developments as the cellular phone without solving the problem of high-frequency electromagnetic interference. Noise suppression sheets are required to provide a high-frequency magnetic shielding function for improving signal integrity by manipulating the flow of the flux induced by high-frequency current as well as featuring a significant magnetic loss function for suppressing high-frequency noise (EMI or “autotoxemia”).

Under these circumstances, the new applications of ferrite-plated film that features high electrical resistance and excellent permeability are being increasingly adopted. These include direct forming onto printed circuit boards as well as improvements in the transmission/reception characteristics of UHF-band RFID systems. Expectations for ferrite-plated film as an effective solution to the problem of high-frequency electromagnetic interference have thus increased to a very high level.

In closing this paper, we would like to express our deep gratitude to Professor Masanori Abe of Tokyo Institute of Technology and Professor Emeritus Yutaka Shimada of Tohoku University for their guidance and assistance in the present developments.

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