19Aa I-2

FABRICATION OF FERRITE/PERMALLOY LAMINATED CORE BY SPARK PLASMA SINTERING

S. Yamamoto*, S. Horie*, N. Tanamachi*, H. Kurisu*, M. Matsuura* and K. Isida**
* Faculty of Engineering, Yamaguchi University
2-16-1 Tokiwadai, Ube, Yamaguchi 755-8611, Japan
** Yamaguchi Prefectural Industrial Tech. Institute
4-1-1 Asutopia, Ube, Yamaguchi 755-0151, Japan

1. Introduction

Recently, magnetic devices such as inductor and transformer used in many kinds of portable electronic sets become smaller and higher frequency operation. Development of a new core material with high saturation magnetic flux density and high permeability at high frequencies is needed. In this study, to meet this demand, the fabrication of ferrite/permalloy laminated core was tried using Spark Plasma Sintering (SPS) method.

2. Structure and Fabrication Method of Ferrite/Permalloy Laminated Core

In metallic magnetic material, while saturation magnetic flux density (Bs) is high, permeability decreases at high frequencies because of Eddy current loss. On the other hand, in ferrite magnetic material, Eddy current is small, however, Bs is essentially small. It is difficult to satisfy the requirements of high Bs and high permeability at high frequencies using one kind of magnetic material.

The magnetic core in which high Bs metallic ribbons and electrically highly resistive ferrite layer are laminated may be one of the candidates satisfying high Bs and superior soft magnetic properties at high frequencies suppressing Eddy current loss. In this study SPS method was introduced to fabricate ferrite/permalloy laminated core. The SPS is a new method to sinter the powder starting materials under the uni-axial pressing with the aid of high energy of spark plasma generated between the powders . Using SPS method, sintering of ferrite and connection of ferrite layer and permalloy layer at lower temperature is possible compared with conventional sintering method.

3. Experimental

SPS apparatus (IZUMI TECH. CO., LTD. SPS-511S) was used in fabrication of ferrite/permalloy laminated core. 45 permalloy ribbons whose Bs was 13.4kG, and coercivity was 8.25 Oe were used as permalloy layers. As ferrite layers, Mn-Zn ferrite powder was prepared. At first, permally ribbon was put in a graphite die with an inner diameter of 15mm. Mn-Zn ferrite powder was spread on it. After this procedure was repeated in several times, finally, permalloy ribbon was put on the top. This laminated materials was pressed by graphite punches from top and bottom sides. This sample holder composed of die and punches was set in a vacuum chamber. With pressing sample at a pressure of 0.3 to 0.9tf/cm^2, Off and on DC voltage was supplied through graphite punches to heat up the sample and generate spark plasma. Sintering was performed at 1000°C for 2 to 10 minutes. After sintering, pressure was released and sample holder cooled down to room temperature.

Magnetic properties of ferrite/permalloy laminated core was measured with a vibrating sample magnetometer (VSM) and Hc meter. Measurement of adhesive force between ferrite layer and permalloy layer was done by Sebastian method. In observation of cross section of laminated core, SEM was used. EPMA was used to analyze the element. Peameability of laminated core was calculated from inductance measured with LCZ meter

4. Results and Discussion

By SPS method, ferrite/permalloy laminated plate cores were prepared. The size of the core is 15mm in diameter and 1mm in thickness. Cross sectional SEM image of the laminated core using 0.1mm thick six permalloy ribbons is shown in figure 1. It was proved by the measurement of adhesive force, that the ferrite layer and permalloy layer was so strongly connected as to prevent from peering off against the peering force of 102 kgf/cm^2.

By EPMA, it was found that Ni element was diffused into ferrite layer from permalloy ribbon. Strong adhesion was supposed to be achieved by the diffusion of element at the interface between ferrite layer and permalloy layer.

In figure 2, magnetic properties of laminated core were plotted against the total thickness of permalloy layer. For all of the samples, the thickness of laminated core was set to 1mm. It was found that lower coercivity and higher Bs was obtained with increasing the occupancy of permalloy.

Frequency dependence of permeability was shown in figure 3. For non-laminated core which is composed only permalloy, permeability was drastically decreased at high frequencies because of Eddy current loss. However, for ferrite/permalloy laminated core, drop of permeability at high frequency was suppressed by using thinner permalloy ribbons.

5. Summary

Soft magnetic core in which permalloy ribbon and Mn-Zn ferrite layer were laminated was fabricated by SPS method. The fabricated core showed strong adhesive force, higher Bs than ferrite, and high permeability at high frequencies. This new magnetic core is a promising candidate applicable to high frequency magnetic devices.

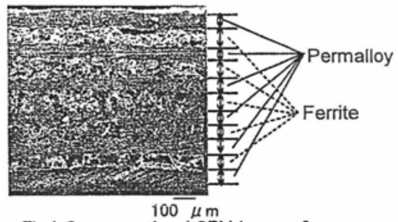

Fig.1 Cross sectional SEM image of sintered sample
(Permalloy layer: 0.1mm^t × 6 layers)

References

1) M. Tokita, *J. Soc. Powder Tech. Jpn.*, 30, 790-804 (1993).

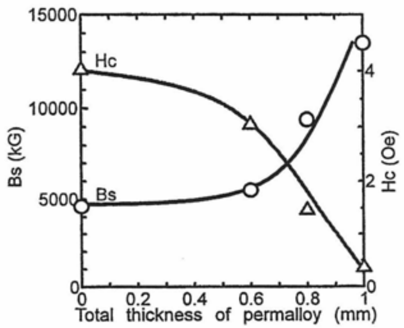

Fig.2 Dependence of Hc and Bs on total thickness of Permalloy in 1mm^t laminated samples
(Total thickness of 0mm corresponds to only Mn-Zn ferrite, and total thickness of 1mm corresponds to only Permalloy)

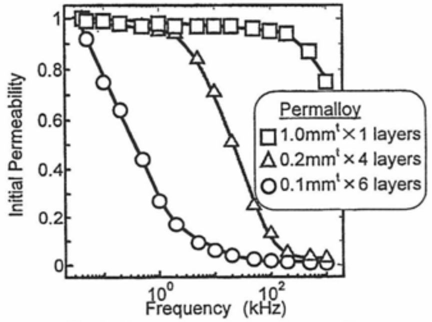

Fig.3 Frequency dependence of Initialpermeability of laminated samples
(Permeability is normalized at 50 Hz)