Magnetic Properties of Amorphous FeSiB and Nanocrystalline $Fe_{73}Si_{16}B_7Nb_3Cu_1$ Soft Magnetic Sheets

H.J. Cho, E.K. Cho[1], Y.S. Song*, S.K. Kwon**, K.Y. Sohn[1], and W.W. Park[1]

[1] School of Nano Engineering, Inje University, Gimhae, Gyeongnam, Korea
* AMOSENSE, 189-1 Suchami-Ri, Tongjin-Myun, Kimpo, Gyeongki-Do Korea
**AMOTECH, 189-4 Suchami-Ri, Tongjin-Myun, Kimpo, Gyeongki-Do Korea
karencho@korea.com, cube02@hanmail.net, yssong@amosense.co.kr, skkwon76@amotech.co.kr,
ksohn@inje.ac.kr, wwpark@inje.ac.kr

Abstract

The magnetic inductance of nanocrystalline $Fe_{73}Si_{16}B_7Nb_3Cu_1$ and an amorphous FeSiB powder sheet has been investigated to identify RFID performance. The powder was mixed with binder and solvent and tape-casted to form films. Results show annealing significantly influenced on the inductance of the material. The surface oxidation of the particles was the main reason for the reduced inductance. The maximum inductance of $Fe_{73}Si_{16}B_7Nb_3Cu_1$ alloy was about 88μH at 17.4 MHz, about 65% greater compared to the FeSiB alloy. The higher inductance in the nanocrystalline alloy indicates it may be used as a potential replacement of current RFID materials.

Keywords: nanocrystalline, amorphous, inductance, soft magnetic powder, radiofrequency identification

1. Introduction

During recent years, RFID (radio frequency identification) with the radio frequency of 13.56MHz is normally used for telecommunication devices. The passive electronic identification transponders consist of an electric resonance circuit acting as a receiving/transmitting antenna, and also connected to an electronic microchip. When such a transponder is placed in an electromagnetic field of sufficient field strength, the induced voltage in the resonance circuit powers the microchip to turn on and to start sending back its stored identification number via the resonance circuit. The reader generating the electromagnetic field receives the transmitted code [1].

To respond easily when they are exposed to applied electromagnetic field, the excellent permeability is required and can be obtained from the nanostructured alloy or the FeSiB amorphous alloy [2]. Both the nanocrysalline FeSiBNbCu and the amorphous Fe-Si-B alloys have also high magnetic saturation. Therefore, they can easily respond when they are exposed to applied field.

The RFID sheet was easily fabricated using the Fe-based powders combined with a polymer. The aim of this study is to investigate the RFID characteristics of the nanocrystalline FeSiBNbCu and an amorphous FeSiB powders sheets.

2. Experimental and Results

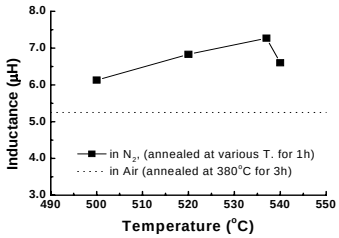
Amorphous ribbons of $Fe_{73}Si_{16}B_7Nb_3Cu_1$ and FeSiB alloy were pulverized and classified into several classes of particle size. For this study, powders with particle sizes of -150 ~ +200 and –270 mesh, ratio of 8 to 2 respectively, were mixed with a polyurethane binder and a solven to tape-cast into a film and dried in an oven. The dried sheet was warm-rolled to reduce the thickness.

The radio frequency identification (RFID) characteristic of the sheet was estimated by measuring the inductance.

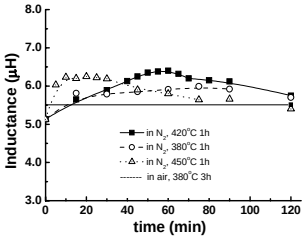
The RFID performance of soft-magnetic material is significantly influenced by the magnetic properties of the powder and the morphology, volume fraction, and distribution of each particle. The variation of inductance on the crystallization annealing temperature of $Fe_{73}Si_{16}B_7Nb_3Cu_1$ particle was shown in Fig. 1(a), which represents the maximum inductance was observed at 535℃. The crystallization of Finemet-type amorphous alloys usually starts at around 500℃. The permeability of the material, depending on the crystallization temperatures, was observed to be maximum in the ribbon annealed at 540~550℃ for 1 hour. However, the maximum permeability of either pulverized powder or compacted inductor core is often observed at somewhat lower temperatures, because of the stored energy in the particles during the fragmentation process.

The annealing atmosphere significantly influenced on the inductance of the material. The maximum inductance of $Fe_{73}Si_{16}B_7Nb_3Cu_1$ powder annealed at 380℃ for 3 hours in open air was only about 5.25 μH. However, the maximum inductance of the same specimen annealed under nitrogen atmosphere increased by 35% or higher compared to the one annealed in air. The main reason in lower inductance of the specimen annealed in air is oxidation. The surface

oxidation of the particles significantly reduced the magnetic permeability and hence the inductance of the material. Therefore, the annealing atmosphere significantly influenced on the inductance of the material. The inductance of the FeSiB amorphous powder also significantly varied with the annealing conditions as shown in Fig 1(b), where the maximum inductance was achieved in the specimen annealed at 420℃ for 1 hour under nitrogen atmosphere. The annealing in air remarkably lowered the inductance of this material as well.



(a)



(b)

Fig. 1. Variations of the inductance of (a) $Fe_{73}Si_{16}B_7Nb_3Cu_1$ nanocrystalline powder and (b) FeSiB amorphous powder.

Fig. 2 shows the inductance of the FeSiB amorphous powder sheets with 0.1 and 0.2mm thickness and the inductance of 0.2mm amorphous sheet was somewhat higher compared to 0.1mm sheet, because of increased volume. Fig. 3 represents the relative variations of inductance in the FeSiB amorphous and $Fe_{73}Si_{16}B_7Nb_3Cu_1$ nanocrystalline powder sheets. The maximum inductance of $Fe_{73}Si_{16}B_7Nb_3Cu_1$ alloy was about 88 at 17.4 MHz, which was about 65% greater compared to the amorphous alloy. The higher inductance in the nanocrystalline alloy indicates that it may enhance the RFID performance.

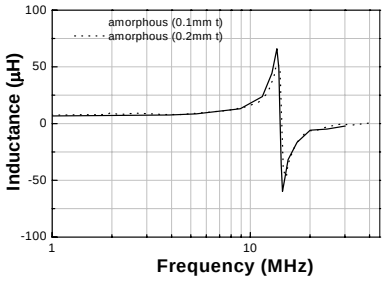


Fig. 2. The inductance of FeSiB amorphous powder sheet with 0.1 mm and 0.2mm thickness.

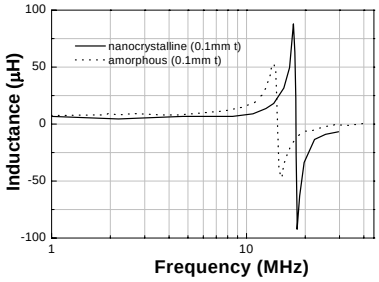


Fig. 3. Comparison of the inductance of amorphous to nanocrystalline powder sheets with 0.1 mm thickness.

3. Summary

The atmosphere for annealing significantly influenced on the inductance of the material. The maximum inductance of $Fe_{73}Si_{16}B_7Nb_3Cu_1$ powder annealed in open air was only about 5.25 μH, while that annealed under nitrogen atmosphere increased by 35%. The surface oxidation of the particles was the main reason for the reduced inductance.

The maximum inductance of $Fe_{73}Si_{16}B_7Nb_3Cu_1$ alloy was greater than that of the amorphous alloy. The higher inductance in the nanocrystalline alloy indicates that it may enhance the RFID performance.

4. References

[1] Mans B, Jansen, Wim Eradus, Computers and Electronics in Agriculture 24 p.109-117 (1999)

[2] Y. Yoshizawa, K. Yamauchi and S. Oguma. J. Appl. Phys. **64** (1988), p. 6044.