Journal of Korean Magnetics Society, Volume 5, Number 5, October 1995

THE MAGNETIC PROPERTIES OF ULTRATHIN $Fe_{84}B_9Nb_7$ NANOCRYSTALLINE ALLOY

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Abstract-The magnetic properties of ultrathin $Fe_{84}B_9Nb_7$ nanocrystalline ribbon alloy with the thickness of 7-14 ㎛ were investigated. It was found that the effective permeability at the frequency over 100 kHz increased with decreasing ribbon thickness. Moreover the core loss decreased considerably with reduction of the ribbon thickness. The effective permeability at 1 MHz and the core loss at 1 MHz and 0.1 T for $Fe_{84}B_9Nb_7$ alloy with the thickness of 7 ㎛ were 3,700 and 2.7 W/cc, respectively. The reduction of thickness to less than 10 ㎛ was found to be very effective in obtaining high permeability and low core loss in the MHz frequency range. It was considered that the improvement of magnetic properties in the high frequency range was due to the reduction of the eddy current.

I. INTRODUCTION

The soft magnetic materials are now strongly required to have good high frequency characteristics because of miniaturization and weight reduction of electronic devices. In order to meet these demands, high permeability and low core loss in high frequency range are needed. It is well known that thickness reduction is an effective means to decrease the core loss in high frequency range. Therefore, ultrathin amorphous Co and Fe-based ribbon alloys with 5-10 ㎛ in thickness were produced recently and reported to have good high frequency magnetic properties[1,2]. On the other hand, Fe-based nanocrystalline alloys attract a great attraction becuse they have excellent soft magnetic properties and high saturation magnetization as compared to amorphous alloys[3-5]. Recently, we have studied ultrathin Fe-based nanocrystalline alloys to develop a magnetic core material with low core loss and high permeability at high frequency and reported ultrathin FeBNbCu nanocrystalline alloy to have rather good core properties in MHz range[6]. In this study, high frequency magnetic properties of ultrathin Cu-free FeBNb nanocrystalline alloy were investigated.

II. EXPERIMENTAL

Ultrathin $Fe_{84}B_9Nb_7$ amorphous alloy ribbons were fabricated by single-roll method in a vacuum of $10^{-3}\sim10^{-5}$ Torr. The conditions for producing ultrathin ribbons are as follows ; roll speed 40~60 m/s, ejection pressure 0.005~0.02 kg/cm^2 and rectangular slit dimension 0.15×4 ㎜. The ribbons obtained were 7~14 ㎛ in thickness and 2~4 ㎜ in width. The ribbon alloys were wound into torodial core with 21 ㎜ inner diameter and subsequently annealed at 620℃ for 1 h. The effective permeability and core loss were measured by impedance analyzer and ac B-H analyzer, respectively. The dc hysterisis curve were obtained by B-H recording fluxmeter.

III. RESULTS AND DISCUSSION

The effective permeability as a funtion of ribbon thickness for $Fe_{84}B_9Nb_7$ alloy annealed at 620℃ for 1 h is shown in Fig. 1. The effective permeability decreases with decreasing the ribbon thickness. This result agrees well with those for thin amorphous Co-based and Fe-based alloys[1,6]. It has been reported that the decreased effective permeability for ultrathin Co-based ribbon in the

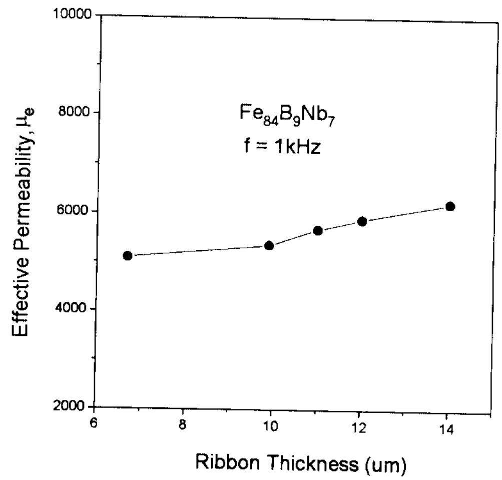

Fig. 1 Effective permeability as a function of ribbon thickness for $Fe_{84}B_9Nb_7$ alloy

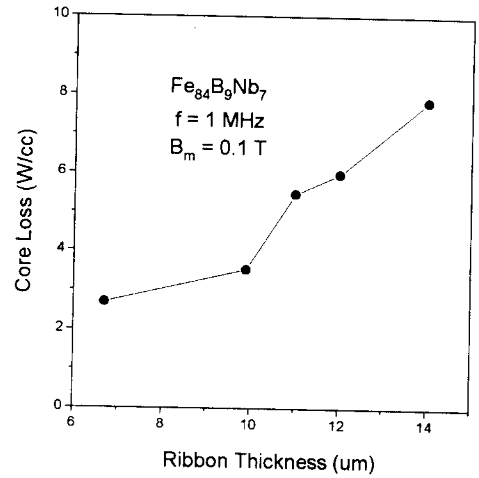

Fig. 3 Core loss at 1 MHz as a function of ribbon thickness for $Fe_{84}B_9Nb_7$ alloy

low frequency is due to the decrease of the number of domain walls and the increase of surface effect[1,6].

Fig. 2 shows the frequency dependence of effective permeability for the $Fe_{84}B_9Nb_7$ alloys with 7 and 14 μm thickness. It is seen that frequency dependence of permeability is improved by thickness reduction in the frequency higher than 100 kHz. Moreover the difference between the two values becomes larger as the frequency increase. In case of the alloy with 7 μm thickness, the effective permeability of 3,700 was obtained at 1 MHz. This value is higher than that of Cu-added FeBNbCu quarternary nanocrystalline alloy[6], which posseses 3000 at 1MHz. This result means that revealing better high-frequency characteristics can be obtained for this alloy than Cu-added FeBNbCu alloys in high fequency range. Furthermore, the core loss measured at 1 MHz and B_m = 0.1 T (B_m : maximum induction) decreased significantly with decreasing thickness as shown in Fig. 3. The core loss of 2.7 W/cc is obtained for ultrathin ribbon

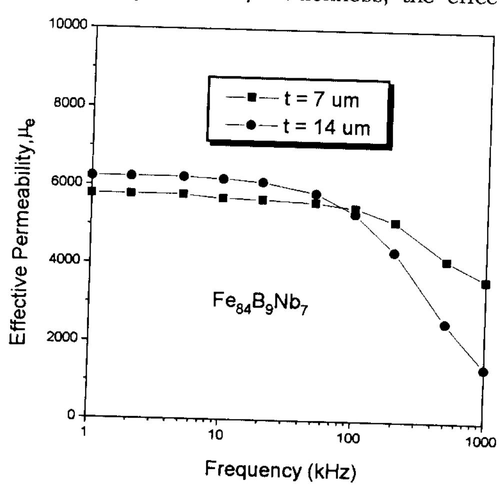

Fig. 2 Effective permeability as a function of frequency for $Fe_{84}B_9Nb_7$ alloy

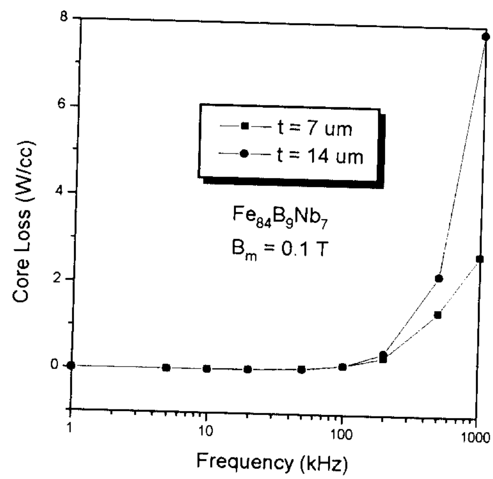

Fig. 4 Core loss as a function of frequency for $Fe_{84}B_9Nb_7$ alloy

with 7 ㎛ thickness. From these results, it was found that reduction of ribbon thickness was very effective in improving the permeability and the core loss in the high frequency range.

In Fig. 4 are shown the changes in the core loss as a function of frequency for $Fe_{84}B_9Nb_7$ nanocrystalline alloys with 7 ㎛ and 14 ㎛ thickness. The core loss is largely improved by reduction in thickness in high frequency range. According to the Maxwell's equation[7], eddy current loss is inversely proportional to the thickness of magnetic materials. Therefore, it is considered that reduction in core loss with decreasing ribbon thickness in Fig. 4 is due to the decrease of the eddy current loss. This result is proved by Fig. 5 which shows the frequency dependence of eddy current loss with ribbon thickness.

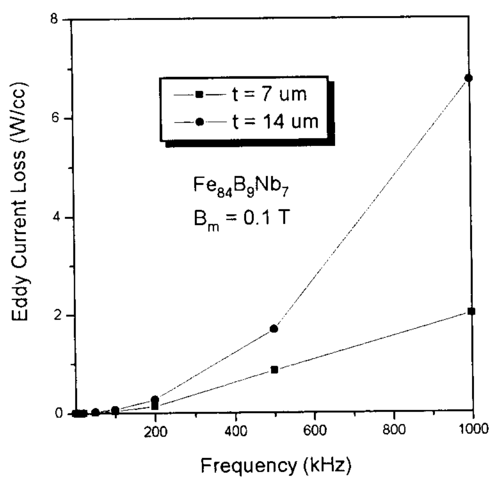

Fig. 5 Eddy current loss as a function of frequency for $Fe_{84}B_9Nb_7$ alloy

Fig. 6 shows variation of the hysteresis and eddy current loss measured at 1 MHz and B_m = 0.1 T with ribbon thickness. Little change in the hysteresis loss with ribbon thickness is observed, while the eddy current losses largely changed with ribbon thickness as shown in Fig. 6. The eddy current loss increase rapidly with increasing ribbon thickness.

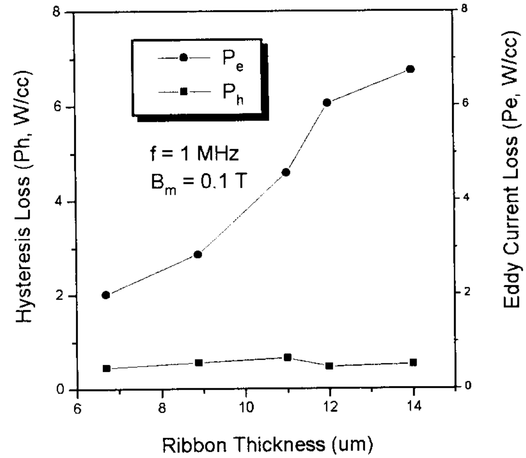

Fig. 6 Variations of hysteresis and eddy current loss as a function of ribbon thickness for $Fe_{84}B_9Nb_7$ alloy

From these results, it was considered that excellent magnetic properties in the thinner ribbon as compared to the thicker one was principally due to the decrease in eddy current loss.

Ⅳ. CONCLUSION

The change in magnetic properties with ribbon thickness for $Fe_{84}B_9Nb_7$ nanocrystalline alloy were investigated. The effective permeability of thinner ribbon increased comparing to the thicker one in high frequency range over 100 kHz. The effective permeability of 3,700 was obtained at 1 MHz for the alloy with 7 ㎛ thickness. Furthermore, core loss decreased significantly with reduction of ribbon thickness. Particulary, the improvement of the magnetic properties becomes prominent at the frequencies near 1 MHz as the thickness decreases, because eddy current loss becomes dominant in this frequency range. It was found that low core loss in the thinner ribbon was chiefly due to the reduction of the eddy current loss.

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