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Giant magnetoimpedance effect in nanocrystalline $Fe_{73.5-x}Mn_xSi_{13.5}B_9Nb_3Cu_1$ (x= 1, 3, 5) alloys

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Abstract

The giant magnetoimpedance (GMI) of $Fe_{73.5-x}Mn_xSi_{13.5}B_9Nb_3Cu_1$ (x= 1, 3, 5) alloys prepared by a rapid quenching technique has been measured to investigate the influence of the structural changes in the crystallization process as well as the changes of the soft magnetic properties such as permeability, coercivity, magnetic anisotropy, etc. after thermal treatment. Magnetoimpedance ratio (MIR) and incremental permeability ratio (PR) measurements were investigated in the frequency range of 1-10 MHz and at a fixed current of 10 mA. Ultrasoft magnetic behavior has been observed in the samples annealed at 560°C. The PR curves become narrower and sharper after heat treatment due to the decrease of anisotropy. The MIR and PR coincided with the softness of the magnetic properties of the thermally treated samples.

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I. INTRODUCTION

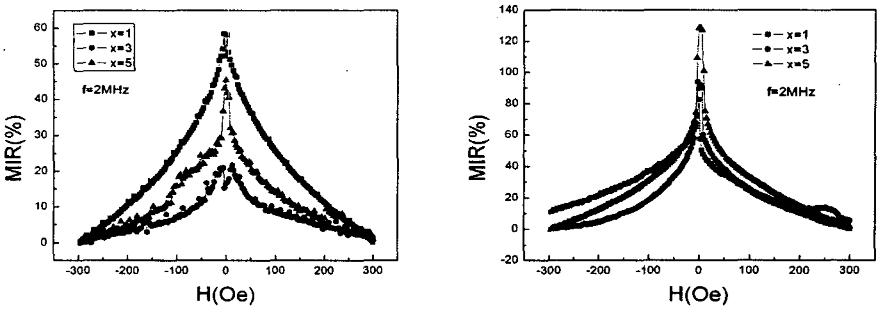
The magnetoimpedance (MI) effect consists of a large variation in the impedance (both real and imaginary components) of a soft magnetic sample when submitted to static magnetic filed. This effect is of great interest due to its possibilities for use in technological applications, such as magnetic field sensors, stress sensors, and many others [1, 2]. This effect has been observed in different types of the samples: amorphous wires and microwires, ribbons, thin films and also in nanocrystalline wires and ribbons. The electromagnetic origin of the MI effect has been surmised to the combination of a skin effect and field dependence of the circumferential magnetic permeability associated with circular motion of magnetic moments. Since the MI effect can be obtained only in ultrasoft magnetic materials, we have investigated the annealing effect on the structural changes in the nanocrystalline $Fe_{73.5-x}Mn_xSi_{13.5}B_9Nb_3Cu_1$ (x= 1, 3, 5) alloys via the MI effect.

II. EXPERIMENT

The nanocrystalline $Fe_{73.5-x}Mn_xSi_{13.5}B_9Nb_3Cu_1$ (x= 1, 3, 5) alloys were prepared by a rapid quenching technique. The samples were of 8mm in width and 20 μm in thickness. In order to obtain the nanocrystalline phase, the amorphous alloys were annealed in vacuum for 1 hour at temperatures 535°C and 560°C. For the MI measurements, the external field applied by a solenoid can be swept through the entire cycle from -300 Oe to 300 Oe. The frequency of the MI measurements was ranging from 100 kHz to 10 MHz, and the ac current was fixed at 10 mA for all measurements. The structure of as-cast and annealed samples was examined by X-ray diffraction (XRD) and transmission electron microscopy (TEM).

III. RESULTS AND DISCUSSIONS

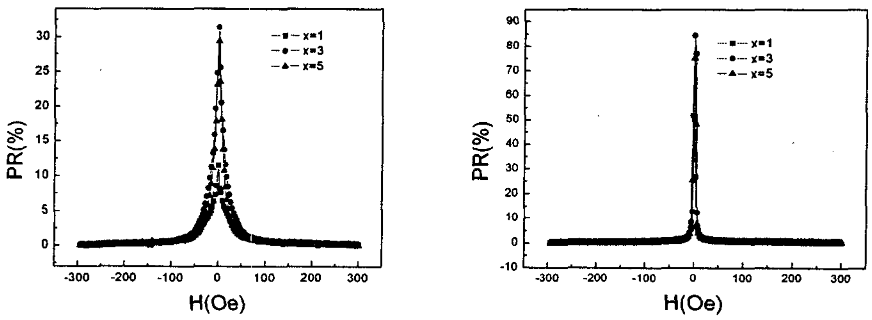
The magnetoimpedance ratio (MIR) can be defined as MIR (H)= $\Delta Z/Z(H_{max})= 1-|Z(H)/Z(H_{max})|$, where H_{max} is an external magnetic field sufficient for saturating the magnetoimpedance. In our experiment H_{max}=300 Oe. The permeability ratio (PR) can be defined as PR (H)=$\Delta\mu/\mu(H_{max})=1-|\mu(H)/\mu(H_{max})$ similar to MIR.



(a) (b)

Fig.1. The MIR vs the external field H measured at 2 MHz in $Fe_{73.5-x}Mn_xSi_{13.5}B_9Nb_3Cu_1$(x=1, 3, 5) alloys annealed at (a) 535°C and (b) 560°C.

Fig.1. show that the maximum MIR values are increased drastically in the samples annealed at 560°C with x=5. The maximum MIR is increased extremely high as much as 128% in the annealed samples at 560°C with x=5 indicating that the samples are ultrasoftened by nanocrystallization.



(a) (b)

Fig.2. The PR curves vs the external field H measured at 1 MHz in (a) as-cast samples and (b) the samples annealed at 560°C in $Fe_{73.5-x}Mn_xSi_{13.5}B_9Nb_3Cu_1$ (x=1,3,5) alloys.

The PR curves vs the external field H measured at 1 MHz in as-cast samples and the samples annealed at 560°C are shown in Fig. 2. The PR curves become narrower and sharper after heat treatment due to the decrease of anisotropy. This indicates that the anisotropy field is small enough for being soft magnetic materials.

IV. CONCLUSION

The giant magnetoimpedance effect in nanocrystalline $Fe_{73.5-x}Mn_xSi_{13.5}B_9Nb_3Cu_1$ (x=1, 3, 5) alloys has been studied. An ultra-magnetic softness in these alloys can be obtained by proper thermal treatment. The nanocrystalline $Fe_{73.5-x}Mn_xSi_{13.5}B_9Nb_3Cu_1$ (x=5) alloys at 560°C for 1h show the softest magnetic properties such as nearly zero coercivity and anisotropy, high permeability ratio (PR), and high MIR values.

References

[1] Heebok Lee, Kyeong Jae Lee, Yong Kook Kim, Taik Kee Kim, Chong Oh Kim, Seong Cho Yu, J. Appl. Phys. 87(9) (2000) 5269

[2] B. Hernando, M. L. Sanchez, V.M. Prida, M. Tejedor, M. Vazquez, J. Appl. Phys. 90(9) (2001) 4783