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Effect of Thickness on Magnetic Properties of $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ Thin Film Prepared by Thermionic Vacuum Arc

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$Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ amorphous thin films have been produced by thermionic vacuum arc with thickness varying from 200 nm to 260 nm. X-ray diffraction has been employed to reveal a predominant amorphous phase in the as-prepared samples, although a small crystalline fraction cannot be excluded. The bulk magnetic properties of thin films were examined at room temperature using an ADE Magnetics EV9 vibrating sample magnetometer with maximum magnetic field strength of 1750 kA/m, real-time field control and dynamic gauss range capable of reaching a resolution of 0.08 A/m at low fields. The minimum value of the coercivity for the as-prepared samples was about 7 kA/m.

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1. Introduction

Amorphous magnetic alloys have been the subject of large interest because of their excellent magnetic properties [1–4]. Magnetic ribbons and wires are used in many areas. However magnetic amorphous thin films are preferred especially in microelectronics and sensor applications [1]. The knowledge and the control of the bulk magnetic properties of magnetic amorphous thin films are important in order to obtain miniaturized magnetic devices with improved performances [1, 2].

There are different methods to prepare amorphous thin films, such as pulsed laser, RF sputtering, etc. [5]. Another method to produce thin films is thermionic vacuum arc (TVA). Thin films prepared by TVA method are compact and nanostructured, having also high quality, high purity, and low roughness [6].

In this study we investigate the bulk magnetic behavior of the $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ amorphous thin films produced from the $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ alloy by TVA. The effect of thickness on the coercive field was also analyzed.

2. Experimental

The Fe–Co-based ingots with nominal compositions were first homogenized by arc-melting the pure elements in Zr-gettered argon atmosphere for at least four times. The ingots were then cast from boron nitrate-coated alumina crucibles into pre-cooled rectangular copper moulds with cavity dimensions of t mm × 16 mm × 70 mm, where t varies in the range 1–3 mm, in argon atmosphere via a Manfredi Multihertz Neutromag Digital centrifugal casting device. The amorphous thin films on glass substrates were prepared by TVA from as-cast alloy of nominal composition $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$. The thickness of the thin films was measured electromechanically by a Dektak 6M profilometer. The amorphous state of the obtained films was examined by X-ray diffraction (XRD). The surface morphology of the samples was studied by atomic force microscopy (AFM). The bulk magnetic properties of thin films were examined at room temperature using an ADE Magnetics EV9 vibrating sample magnetometer (VSM) with maximum magnetic field strength of 1750 kA/m, real-time field control, and dynamic gauss range capable of reaching a resolution of 0.08 A/m at low fields.

3. Results and discussion

The thickness of the samples was measured in the range of 200–260 nm, depending on the deposition time. The XRD patterns of $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ thin films alloys are shown (Fig. 1a–c). It can be depicted from XRD patterns of thin films that the $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ alloys are fully amorphous, as evidenced by the absence of diffraction peaks.

Figure 2a–c shows the AFM micrographs of samples deposited on glass substrates by TVA. The surface average roughness of samples in thin films thickness of 200, 240 and 260 nm are found to be 6.013 nm, 3.629 nm and 4.910 nm, respectively.

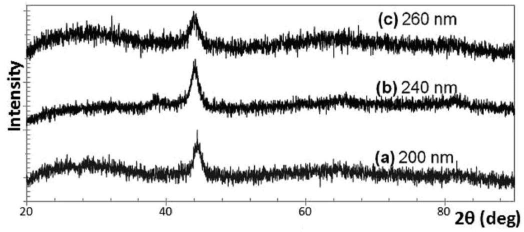

Fig. 1. Characteristic XRD patterns of the deposited $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ thin films prepared by TVA for different thicknesses: (a) 200 nm, (b) 240 nm, (c) 260 nm.

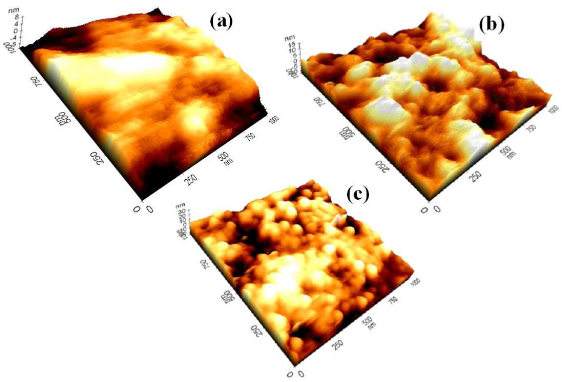

Fig. 2. AFM micrographs of the deposited $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ thin films prepared by TVA for different thicknesses: (a) 200 nm, (b) 240 nm, (c) 260 nm.

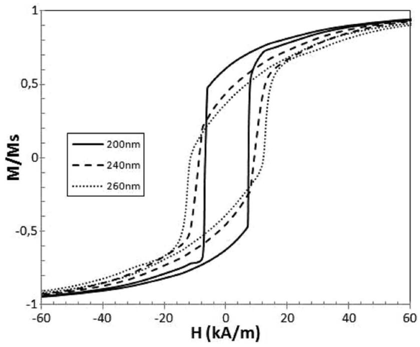

Fig. 3. The bulk hysteresis loop of $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ amorphous films prepared by TVA for different thicknesses.

The hysteresis loops for the as-deposited $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ alloy with different thin film thickness are shown in Fig. 3. The coercivity values of $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ amorphous films prepared by TVA for different thicknesses are listed in Table.

When the film thickness increases from 200 nm to 260 nm, an increase up to about 70% in bulk coercivity value has been observed. The increase in the coercivity with the film thickness can be explained to the induced anisotropies during the deposition process determined by the higher values of internal stresses as the film thickness increases [2].

TABLE

The coercivity values of $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ amorphous films prepared by thermionic vacuum arc for different thicknesses.

Film thickness [nm]	Coercivity [kA/m]
200	7
240	9
260	12

The results show that $Fe_{36}Co_{36}B_{19.2}Si_{4.8}Mo_2W_2$ amorphous magnetic thin films can be produced from as-cast alloy in the shape of wedge by TVA.

4. Conclusion

Amorphous magnetic thin films have been successfully deposited onto glass substrates via TVA. The surface morphology and bulk magnetization for the prepared samples are investigated. The roughness in the surface of the films is low. The bulk coercivity presents an increase when the thin film thickness increases.

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References

[1] M. Neagu, M. Dobromir, G. Popa, H. Chiriac, G. Singurel, C. Hison, *Sens. Actuators A* **129**, 172 (2006).

[2] M. Dobromir, M. Neagu, V. Pohoata, F. Borza, T. Meydan, T.A. Ovari, G. Popa, H. Chiriac, *J. Optoelectron. Adv. Mater.* **10**, 410 (2008).

[3] I. Kucuk, M. Aykol, O. Uzun, M. Yildirim, M. Kabaer, N. Duman, F. Yilmaz, K. Erturk, M.V. Akdeniz, A.O. Mekhrabov, *J. Alloy Comp.* **509**, 2334 (2011).

[4] F. Celegato, M. Coisson, E. Olivetti, P. Tiberto, F. Vinai, *Phys. Status Solidi A* **205**, 1745 (2008).

[5] R.R. Gareev, S.S. Alimpiev, Y.V. Bugoslavskii, S.M. Nikiforov, A.I. Maslov, G.Y. Shubnii, A.N. Zherichin, *Acta Phys. Pol. A* **91**, 321 (1997).

[6] M.Z. Balbag, S. Pat, M. Ozkan, N. Eken, G. Musa, *Physica B* **405**, 3276 (2010).