

Magnetic properties of Fe-based amorphous thin films

M. DOBROMIR^{*}, M. NEAGU, V. POHOATA, F. BORZA^a, T. MEYDAN^a, T. A. OVARI^a, Gh. POPA, H. CHIRIAC^b

Faculty of Physics, Al. I. Cuza University, 11 Carol I Blvd., Iasi, 700506, Romania

^aWolfson Centre for Magnetism, Cardiff School of Engineering, Cardiff University, Newport Road, Cardiff, CF24 3AA, UK

^bNational Institute of R&D for Technical Physics, 47 Mangeron Blvd., Iasi, 700050, Romania

Results on the bulk and surface magnetic behavior of Fe-Si-B-C amorphous thin films, with thickness in the range of 80 – 250 nm, deposited onto glass substrates using RF sputtering and pulsed laser deposition techniques are presented. In the as-deposited state the coercivity of the samples prepared by pulsed laser deposition is higher than of the RF sputtered samples. The obtained results show a small difference between bulk and surface magnetic behaviour. The thermal treatments reduce both surface and bulk coercivity values.

(Received January 30, 2008; accepted after revision February 15, 2008)

Keywords: Amorphous thin films, Magnetic properties, Magneto-optical Kerr effect

1. Introduction

The large numbers of studies on amorphous magnetic thin films have revealed a rich, interesting set of magnetic and magnetoelastic properties, with a remarkable applicative potential in a wide-range of innovative, miniaturized, integrated magnetic devices [1-10]. The thorough knowledge and control of the surface magnetic properties of these materials are very important for basic research as well as for developing a new generation of magnetic devices with improved performances [1-6]. One of the most frequently used techniques for the surface magnetic characterization is based on the magneto-optical Kerr effect (MOKE) [1, 2, 4, 6].

The aim of this paper is to investigate the bulk and surface magnetic properties of as-deposited and thermally treated Fe-Si-B-C amorphous thin films prepared from amorphous ribbons by RF sputtering and pulsed laser deposition.

2. Experimental

The Fe-Si-B-C amorphous thin films were deposited on glass substrate by RF sputtering and pulsed laser deposition using as target a stack of several layers of Fe₈₁Si_{3.5}B_{13.5}C₂ amorphous ribbons.

The RF sputtering was performed in a Kurt J. Lesker vacuum system under 10⁻⁴ Torr argon pressure, after reaching a base vacuum of 10⁻⁸ mbars using a magnetron sputtering source.

The pulsed laser deposition was performed in vacuum (10⁻⁶ Torr), by means of a XeCl excimer laser operating at 308 nm wavelength, with the pulse duration, repetition rate and pulse energy of 30 ns, 25 Hz and 55 mJ, respectively.

The films microstructure was investigated by X-ray diffractometry (XRD).

The film thickness was measured using an interferometric method and also by scanning electron microscopy (SEM).

The surface morphology of the samples was studied by atomic force microscopy (AFM) and by scanning electron microscopy (SEM).

Axial hysteresis loops of the samples have been obtained by a differential inductive method at 50 Hz, using an integrating fluxmeter.

The surface magnetic behavior of the films was investigated by magneto-optical Kerr effect. The hysteresis loops were obtained by measuring the change in the light intensity reflected by the film surface.

The samples were investigated in as-deposited state and after thermal treatments at temperatures between 350°C-370 °C, for 30 minutes.

3. Results and discussions

The thickness of the studied samples was found to be in the range of 80-250 nm, depending on the deposition time.

Fig. 1 presents a representative XRD pattern of the as-deposited thin films obtained by pulsed laser deposition. There is no evidence of crystalline peaks, the diffraction spectra indicating that all deposited films are amorphous. Similar XRD pattern was obtained for the films prepared by RF sputtering.

The SEM image of the cross sectional area and of the surface morphology of a pulsed laser deposited sample is presented in Fig. 2.

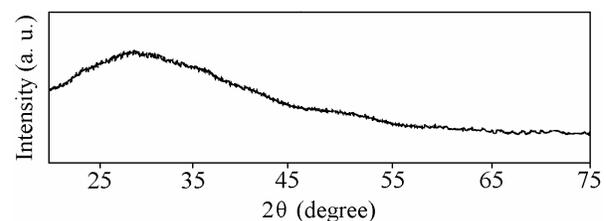


Fig.1. Characteristic XRD pattern of the as-deposited Fe-Si-B-C thin films obtained by pulsed laser deposition.

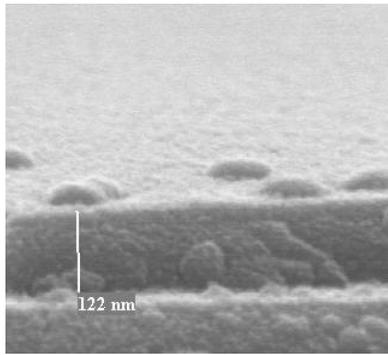


Fig. 2. The SEM image of the surface and cross section of an as-deposited Fe-Si-B-C thin film (122 nm in thickness) obtained by pulsed laser deposition.

Fig. 3 (a and b) shows the AFM micrographs of samples deposited by RF sputtering (a) and by pulsed laser deposition (b). For all studied samples the surface roughness of the films is low (smaller than 35 nm). The AFM micrographs presented in figure 3b reveals the formation of droplets on the surface of the films, which is typical for the pulsed laser deposition procedure.

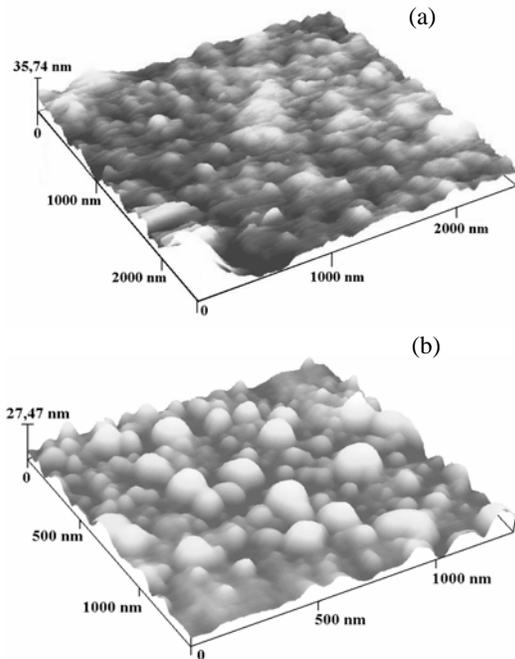


Fig. 3. The AFM micrographs of as-deposited amorphous Fe-Si-B-C thin film obtained by: (a) RF sputtering; (b) pulsed laser deposition.

Figs. 4 and 5 show the surface hysteresis loops in the longitudinal configuration for as-deposited samples with 122 nm thickness obtained by RF sputtering and pulsed laser deposition, respectively. The bulk hysteresis loops for the same samples prepared by RF sputtering and

pulsed laser deposition are presented in Figs. 6 and 7, respectively.

The obtained results show that the bulk and surface coercivity is higher for samples obtained by pulsed laser deposition. For all studied samples the surface coercivity is higher with respect to the bulk one. The surface coercivity is about 1800 A/m and about 1650 A/m, for samples obtained by pulsed laser deposition and by RF sputtering, respectively. The bulk coercivity is about 1730 A/m for pulsed laser deposited samples and about 1580 A/m for RF sputtered samples. This behaviour can be explained by the difference in the magnitude of internal stresses induced through different deposition mechanisms.

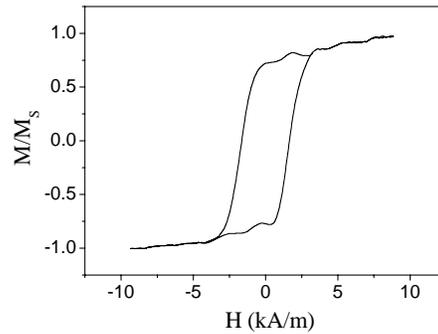


Fig. 4. The surface hysteresis loop of a Fe-Si-B-C amorphous film (122 nm in thickness) obtained by RF sputtering.

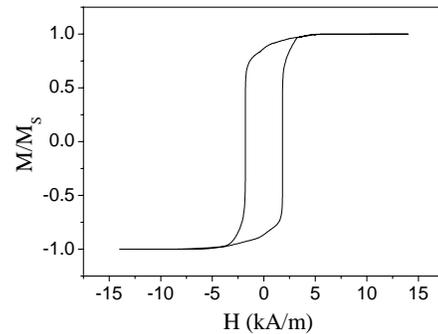


Fig. 5. The surface hysteresis loop of a Fe-Si-B-C amorphous film (122 nm in thickness) obtained by pulsed laser deposition.

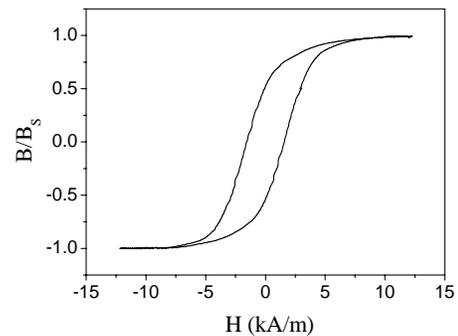


Fig. 6. The bulk hysteresis loop of a Fe-Si-B-C amorphous film (122 nm in thickness) obtained by RF sputtering.

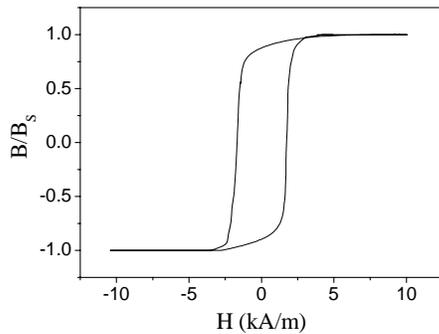


Fig. 7. The bulk hysteresis loop of a Fe-Si-B-C amorphous film (122 nm in thickness) obtained by pulsed laser deposition.

The obtained results show that for the whole range of investigated thickness, for the samples in as deposited state, there is a small difference in the coercivity values. When the sample thickness increases from 80 nm to 250 nm an increase up to about 2.5% and 2% in the surface and bulk coercivity values, respectively, has been observed.

The increase in the film coercivity with the film thickness can be ascribed to the induced anisotropies during the deposition process determined by the higher values of internal stresses as the film thickness increases.

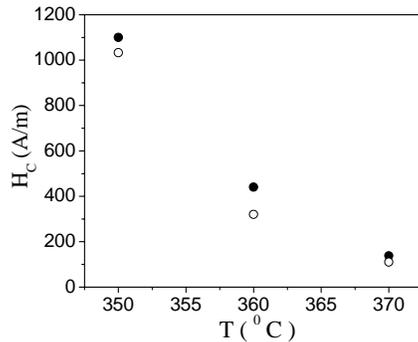


Fig. 8. The surface coercivity dependence on the annealing temperature, for Fe-Si-B-C samples obtained by: ● pulsed laser deposition; ○ RF sputtering.

The thermal treatment samples performed at temperatures between 350 °C – 370 °C relieves the internal stresses induced during the deposition process and, as a consequence, the surface and bulk coercivity value strongly decrease. Fig. 8 presents the surface and bulk coercivity dependence on the annealing temperature, T, after 30 minutes annealing, for samples having 122 nm thickness, obtained by pulsed laser deposition and RF sputtering. As can be seen in Fig. 8 for samples annealed at 370 °C the coercivity value for pulsed laser deposition or RF sputtered samples is about the same (about 120 A/m).

4. Conclusion

Fe-Si-B-C amorphous thin films deposited onto glass substrates using RF sputtering and pulsed laser deposition techniques from $\text{Fe}_{81}\text{Si}_{13.5}\text{B}_{13.5}\text{C}_2$ amorphous ribbon targets are prepared. The surface and bulk magnetization for the obtained samples are investigated. The surface coercivity is higher with respect to the bulk one with about 4 % for all studied samples. The surface and bulk magnetic studies show that the coercivity values are lower for the films obtained by RF sputtering. For the whole range of thicknesses of as-deposited samples, the surface as well as the bulk coercivity presents a small increase when the thickness increases. After the thermal treatments both surface and bulk coercivity values were reduced.

Acknowledgements

Part of the work has been supported by Romanian Ministry of Education and Research, under Project CEx05-D11-41/2005.

References

- [1] M. Ali, R. Watts, W. J. Karl, M. R. J. Gibbs, *J. Magn. Magn. Mater.*, **199**, 190 (1998).
- [2] G. V. Kurllyandskaya, J. M. Barandiaran, P. Minguez, I. Elbaile, *Nanotechnology* **14**, 1246 (2003).
- [3] H. S. Shin, J. W. Hong, T. Jang, Y. P. Yoon, I. Kim, G. Y. Yeum, J. W. Park, *Vacuum* **67**, 185 (2002).
- [4] P. I. Nikitin, A. A. Beloglazov, A. Yu. Toporov, M. V. Valeiko, V. I. Konov, *J. Appl. Phys.* **82**, 1408 (1997).
- [5] R. Krishnan, M. Tessier, M. C. Contreras, I. Iglesias, *IEEE Trans. Magn.* **28**, 2427 (1992).
- [6] S. Acquaviva, A. P. Caricato, E. D'Anna, M. Fernandez, A. Luches, Z. Frait, E. Majkova, M. Osvold, S. Luby, P. Mengucci, *Thin Solid Films* **433**, 252 (2003).
- [7] Z. G. Sun, H. Kuramochi, M. Mizuguchi, F. Takano, Y. Semba, H. Akinaga, *J. Magn. Magn. Mater.* **271-276**, 1160 (2004).
- [8] Z. G. Sun, H. Kuramochi, M. Mizuguchi, F. Takano, Y. Semba, H. Akinaga, *Surface Science* **556**, 33 (2004).
- [9] B. Kundys, Yu. Bukhantsev, H. Szymczak, M. R. J. Gibbs, R. Zuberek, *J. Magn. Magn. Mater.*, **258-259**, 551 (2003).
- [10] B. Peng, W. L. Zhang, W. X. Zhang, H. C. Jiang, S. Q. Yang, *J. Magn. Magn. Mater.*, **288**, 326 (2005).

*Corresponding author: mdobromir@plasma.uaic.ro