JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 8, No. 5, October 2006, p. 1752 - 1754

# Surface magnetic characterization of Fe-rich amorphous ribbons

M. DOBROMIR, M. NEAGU[*], H. CHIRIAC[a]
*"Al. I. Cuza" University, Faculty of Physics, 11 Carol I Blvd., Iasi 700506, Romania*
[a]*National Institute of R&D for Technical Physics, 47 Mangeron Blvd., Iasi 700050, Romania*

Surface magnetic behavior of the as-cast $Fe_{77.5}Si_{7.5}B_{15}$ amorphous ribbons was investigated using the longitudinal magneto-optical Kerr effect. The magnetic hysteresis loops were performed for the both ribbon surfaces, in contact with the quenching wheel and the other one (free side), with the external magnetic field parallel and perpendicular to the ribbons length. In the case of magnetic field parallel to the sample longitudinal axis, the coercive field for the ribbon side in contact with the quenching wheel (about 500 A/m) is higher than for the free side (about 250 A/m). The coercive field value (175 A/m) obtained by standard magnetic measurements shows that the surface magnetic behavior is different from the bulk one.

(Received September 5, 2006; accepted September 13, 2006)

*Keywords:* Amorphous magnetic materials, Coercive force, Magnetic measurements, Magneto-optical Kerr effect

## 1. Introduction

There is an increasing interest for the investigation of the surface magnetic properties of the amorphous materials in view of both fundamental research and applications [1, 2]. One of the frequently used nondestructive technique for the surface magnetic characterization is the magneto-optical Kerr effect (MOKE) [3-10]. This effect consists in the change of polarization of the incident polarized light when reflected by the surface of a magnetized medium. The Kerr rotation/ellipticity of the light polarisation is proportional to the investigated sample magnetization.

The aim of this paper is to investigate the surface magnetic properties of the as-cast $Fe_{77.5}Si_{7.5}B_{15}$ amorphous ribbons using the longitudinal magneto-optical Kerr effect. The bulk magnetic behavior of the samples is also investigated.

## 2. Experimental details

The $Fe_{77.5}Si_{7.5}B_{15}$ amorphous ribbons (30 μm thickness and 2-6 mm width) were prepared by the melt-spinning technique. The amorphous state of the samples was checked and confirmed by X-ray diffractometry using Cu $K_\alpha$ radiation, while the surface topography was investigated by atomic force microscopy.

The longitudinal magneto-optical Kerr measurements were taken with an EL X-01R ellipsometer at 632.8 nm laser wavelength, equipped with a pair of Helmholtz coils and an additional polarization device which ensures that the electric field vector in the incident radiation is parallel or perpendicular to the incidence plane. The magnetic hysteresis loops were obtained by plotting the Kerr rotation/ellipticity as function of the applied magnetic field. The measurements were performed for two orthogonal directions, parallel and perpendicular to the ribbon longitudinal axis, for both sample sides: in contact with the quenching wheel (wheel side) and the opposite one (free side). The investigations were conducted on different aria from the samples surface in order to check its magnetic uniformity.

Standard magnetic measurements were developed for all studied samples in order to investigate also the bulk magnetic behavior. The axial hysteresis loops were performed by a differential inductive method at 50 Hz, using an integrating fluxmeter. All measurements were performed at room temperature.

## 3. Results and discussion

Fig. 1 (a and b) shows the longitudinal Kerr hysteresis loops of the $Fe_{77.5}Si_{7.5}B_{15}$ amorphous ribbons, for the central regions of the free and wheel side, respectively, when the external magnetic field is parallel to the ribbon longitudinal axis. The measurements performed in the central region of the surface, show that for all studied samples the coercive field value, $H_c$, is higher for the wheel side, (about 500 A/m), than for the free side, (about 300 A/m). The measurements conducted on different areas along the ribbon length show variations in the coercive field values which do not exceed $\pm$35 A/m with respect to the values obtained for the central region of the samples.

The longitudinal magneto-optical Kerr measurements performed on the central region of the samples, for the magnetic field perpendicular to the ribbon longitudinal axis, confirm the existence of an easy magnetization axis along the ribbon length. In this case, the measurements performed on different areas along the transversal axis of both ribbon sides show variations in the coercive field values up to maximum $\pm$30 A/m with respect to the central regions.

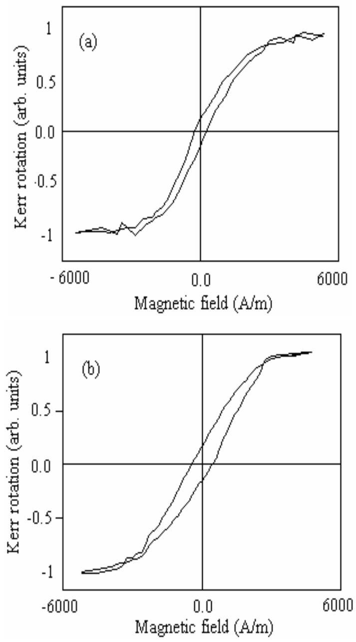


*Fig. 1. Longitudinal Kerr hysteresis loops for the as-cast $Fe_{77.5}Si_{7.5}B_{15}$ amorphous ribbons with the external field parallel to the ribbon longitudinal axis: (a) free side; (b) wheel side.*

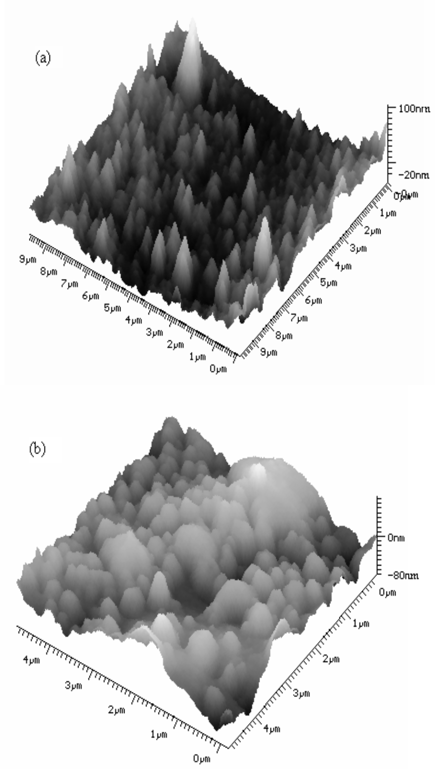


*Fig. 2 (a and b). Presents the typical atomic force images for the free and wheel side, respectively. It is well known that the magneto-optical response of a material is strongly dependent on its microstructure and morphology. The surface topography images presented in Fig. 2 show two different kind of topographies for the free and wheel side.*

*Fig. 2. Atomic force images for the as-cast $Fe_{77.5}Si_{7.5}B_{15}$ amorphous ribbons: (a) free side; (b) wheel side.*

The technique used to prepare the amorphous ribbons determines different quenching rates along the material thickness and different topographies for the two surfaces. The free side exhibits characteristic conical shape roughness with almost equal heights and random distribution, while for the wheel side the roughness tends to organize on certain directions, probably determined by the wheel surface characteristics and also by the dynamic of the melt puddle. Therefore the different magnetic behaviour observed for the free and wheel side are determined by the different surface anisotropies induced by the internal stresses derived during the production process as consequence of the wheel roughness and defects as well as by the free side smoothness.

It is well known that the penetration depth of the light is directly proportional to the radiation wavelength and inversely proportional to the absorption coefficient of the medium. After determining the refraction and absorption indices (by ellipsometry) of the $Fe_{77.5}Si_{7.5}B_{15}$ ribbons, we established that in the given experimental conditions the penetration depth of the light in the studied samples is smaller than 12 nm. In order to understand if the bulk magnetic behavior can be described by the surface one, we developed standard magnetic measurements. The axial hysteresis loop for the analyzed $Fe_{77.5}Si_{7.5}B_{15}$ amorphous ribbons is shown in Fig. 3. The coercive field value was about 175 A/m. The surface magnetic behavior of the Fe-Si-B amorphous ribbons obtained by the melt-spinning technique is different from the bulk magnetic behavior.

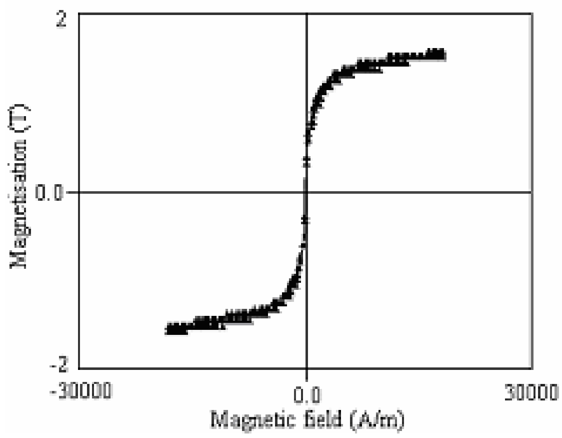


*Fig. 3. Axial hysteresis loop for the as-cast $Fe_{77.5}Si_{7.5}B_{15}$ amorphous ribbons.*

## 4. Conclusions

The obtained results show different coercive force values for the two ribbons sides as well as for the sample orientation (mutually perpendicular directions) in the external magnetic field. The bulk magnetic measurements on the studied amorphous ribbons show a much softer bulk behavior than the surface magnetic one.

**Acknowledgement**

This work has been supported by Romanian Ministry of Education and Research, under Project CERES, 4-256/2004.

## References

[1] J. M. Barandiaran, J. Gutirre, C. Gomez-Polo, Sensors and Actuators A **81**, 154 (2000).
[2] E. Hristoforou, Review Article, Meas. Sci. & Technol. **14**, R15 (2003).
[3] P. Vavassori, L. Callegaro, E. Puppin, F. Malizia, F. Ronconi, J. Magn. Magn. Mater. **157/158**, 171 (1996).
[4] C. G. Kim, Y. W. Rheem, C. O. Kim, E. E. Shalyguina, E. A. Ganshina, J. Magn. Magn. Mater. **262**, 412 (2003).
[5] E. A. Ganshina, N. S. Perov, M. Yu. Kochneva, P. M. Sheverdyaeva, C. G. Kim, C. O. Kim, J. Magn. Magn. Mater. **239**, 484 (2002).
[6] J. Gonzalez, A. Chizhik, A. Zhukov, J. M. Blanco, J. Magn. Magn. Mater. **258-259**, 177 (2003).
[7] M. Ali, R. Watts, W. J. Karl, M. R. J. Gibbs, J. Magn. Magn. Mater. **190**, 199 (1998).
[8] E. E. Shalyguiana, L. M. Becoeva, N. I. Tsidaeva, Sensors and Actuators A **81**, 216 (2000).
[9] J. M. Gonzalez, J. L. Vicent, J. Appl. Phys. **57**, 5401 (1985).
[10] Chun-Yeol You, Sung-Chui Shin, J. Appl. Phys. **84,** 541 (1998).

*Corresponding author: mneagu@uaic.ro.