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Optical and magneto-optical studies of Fe-Cu-Nb-Si-B amorphous thin films deposited by pulsed laser ablation

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Soft magnetic Fe-Cu-Nb-Si-B amorphous thin films with thickness ranging between 100-200 nm have been prepared onto glass and silicon substrates by means of pulsed laser ablation of amorphous $Fe_{73.5}Cu_1Nb_3Si_{15.5}B_7$ ribbons. The values of the refraction and extinction indices at 632.8 nm were found to be 2 and 2.3, respectively. The surface coercivity increases with the increase of the film thickness. For the same thickness, the coercivity of the films deposited onto silicon substrates is about 35% smaller.

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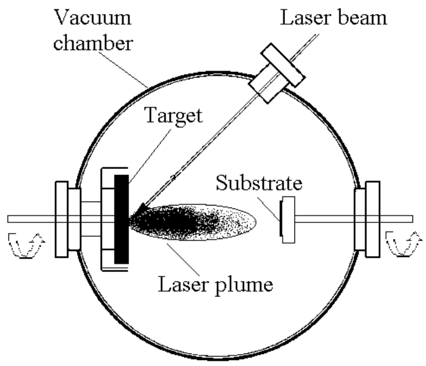
1. Introduction

The magnetic thin films and multilayers are suitable for miniaturized magnetic sensors due to their integrability with microelectronic components [1,2]. The technology for the preparation of amorphous magnetic thin films has evolved considerably over the recent years [2-10]. Production of soft magnetic amorphous thin films by laser ablation has recently been reported [2, 7-10]. The stoichiometry of the pulsed laser deposited films is very close to that of the used target. During pulsed laser deposition, many parameters can be changed to achieve the desired properties in the deposited films. These parameters are the laser characteristics (beam energy density, wavelength, pulse duration and repetition rate) and the preparation conditions (target-substrate distance, revolution speed of the target, background gas and pressure, etc) [7-10].

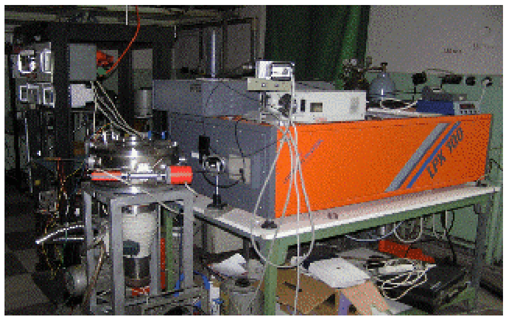
The aim of this paper is to investigate the structural, topological, optical and magneto-optical properties of as-deposited Fe-Cu-Nb-Si-B thin films prepared by pulsed laser ablation, using $Fe_{73.5}Cu_1Nb_3Si_{15.5}B_7$ amorphous magnetic ribbons as target material.

2. Experimental details

The deposition process was performed by means of a XeCl excimer laser (Lambda Physik LPX 100) operating at 308 nm wavelength, with 30 ns pulse duration, 9 Hz repetition rate and 150 mJ maximum pulse energy. The laser beam was focused on a rotating target, made of $Fe_{73.5}Cu_1Nb_3Si_{15.5}B_7$ amorphous magnetic ribbons, using 18 cm focal length lens, resulting in 1 mm^2 spot size. The depositions were performed in a vacuum chamber (10^{-5} Torr). Fig. 1(a) and (b) presents the geometry and the general view of the deposition set-up, respectively.



a



b

Fig. 1. The geometry (a) and the general view (b) of the pulsed laser ablation set-up.

In order to ensure homogeneity in composition and thickness and minimize the demagnetising effect, the films were deposited using a circular shape mask of 10 mm in diameter placed on the substrate. The samples were deposited at room temperature, onto glass and silicon substrates, positioned at 2 - 5 cm target-substrate distance, using 2-6 J/cm^2 laser pulse fluence, for 30-45 minutes deposition time.

The structure of the deposited thin films was analysed by X-ray diffraction, using CoK_α radiation. The surface topography was investigated by means of atomic force microscopy (AFM), using a Quesant Q350 scanning probe microscope. The samples thickness was determined by interferometric measurements.

A reflection ellipsometer (EL X-01R working at 632.8 nm laser wavelength) was used to determine the optical constants (the refraction, n, and extinction, k, indices) of the samples, calculated from the complex amplitude reflection ratio [11]:

$$\tan\psi\, e^{i\Delta} = \frac{\tilde{r}_p}{\tilde{r}_s} \qquad (1)$$

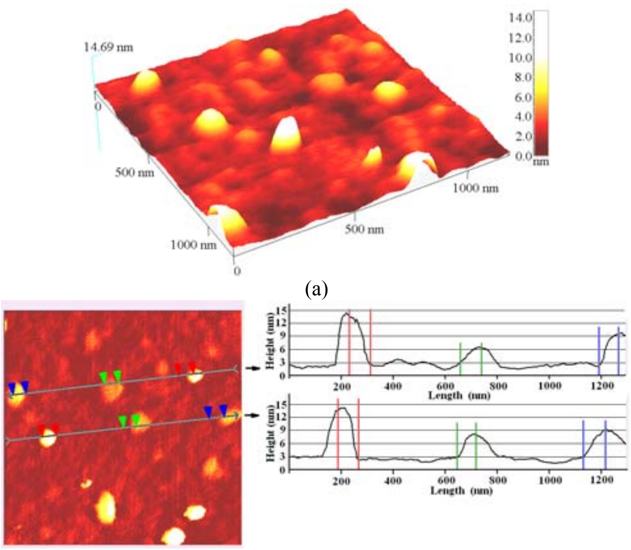
where: $\tilde{r}_p$ and $\tilde{r}_s$ are the complex Fresnel coefficients of the sample for p (in plane of incidence) and s (perpendicular to the incidence plane) polarized light; $\tan\Psi$ is the relative attenuation of the p and s polarized components; Δ is the relative phase shift.

The surface magnetic behavior of the thin films was investigated by means of magneto-optical Kerr effect (MOKE), using an EL X-01R ellipsometer equipped with a pair of Helmholtz coils for the magnetic field generation [4, 6, 8, 10]. The experimental set-up was provided with an additional polarization device, which ensures p or s polarized light.

3. Results and discussion

The X-ray diffraction spectra show that for 2.5 - 3.5 cm target-substrate distance, 3-4 J/cm^2 laser pulse fluence and 30-45 minutes deposition time, amorphous samples are obtained. The thickness of the deposited samples was in the range 100- 200 nm.

Fig. 2 (a) and (b) presents an AFM topographic image and its cross-section topographic profile, respectively. The atomic force microscopy shows that the surface is almost a mirror. The root mean square roughness of the surface is 1.48 nm.



(a)

(b)

Fig. 2. (a) AFM micrograph (1.3 × 1.3 μm²); (b) Cross-section topographic profile of the obtained AFM images.

The hysteresis loops of the deposited films were obtained by plotting the Kerr rotation as function of the applied magnetic field. Fig. 3 shows the obtained results in the longitudinal Kerr geometry for sample (130 nm thickness) deposited onto glass substrate. The coercivity depends on the samples thickness and also on the substrate nature. The value of the coercivity increases with the film thickness increase and in the range of the studied samples thickness, the coercivity was find between 390 and 520 A/m. For samples having the same thickness but different substrates, the coercivity is smaller (with up to 35%) in the case of silicon substrate. The increase in the film surface coercivity with the film thickness and its dependence on the substrate nature can be due to the induced anisotropies during the deposition process determined by the increasing internal stresses with the film thickness and due to the substrate characteristics such as roughness and other inhomogeneities, respectively. The magnetic measurements made on the different sample areas demonstrate the existence of a very weak in plane magnetic anisotropy.

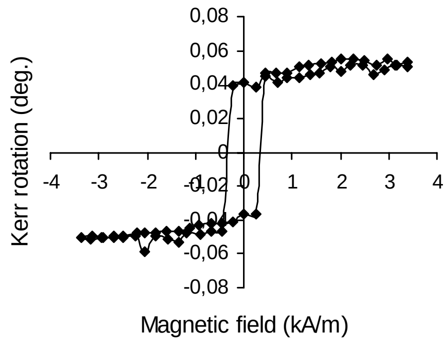


Fig. 3. Hysteresis loop measured in longitudinal Kerr configuration for the sample (130 nm thickness) deposited onto glass substrate.

Fig. 4 presents the dependence of the ellipsometric angles Ψ and Δ on the incidence angle. The measurements were made in the absence, as well as in the presence of an external magnetic field (with the value equal to the surface coercive force),the results being almost identical.

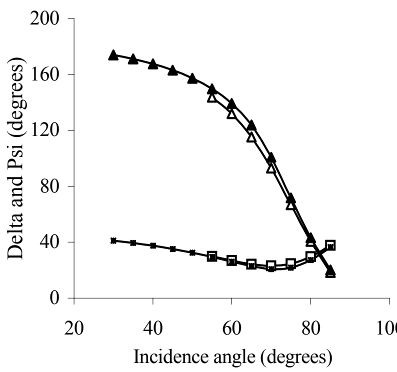


Fig. 4. The dependence of the ellipsometric angles Ψ and Δ on the incidence angle: Δ (in the absence ▲ and in the presence Δ of external magnetic field) and Ψ (in the absence ■ and in the presence □ of external magnetic field).

The refractive index and extinction coefficient were calculated from the measured Ψ and Δ values, using the following equation [11]:

$$(n+ik)^2 = \sin^2\theta_P\left\{1+\tan^2\left[\frac{1-\tan\psi\exp(i\Delta)}{1+\tan\psi\exp(i\Delta}\right]^2\right\} \quad (2)$$

For the used wavelength, the values of n and k indices were find to be 2 and 2.3, respectively.

4. Conclusions

The structure, topography, optical characteristics (refractive index and extinction coefficient) and surface magnetic properties of the Fe-Cu-Nb-Si-B thin films with thickness in the range 100-200nm were investigated. For 2.5 – 3.5 cm target-substrate distance and 3-4 J/cm^2 laser pulse fluence the obtained samples are completely amorphous. The surface coercivity increases with the increase of the films thickness and it depends on the substrate nature. The surface magnetic measurements show a very weak in plane magnetic anisotropy.

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