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Preparation And Characterization Of Fe-Si-B Thin Films

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Abstract. Thickness dependence of structural and magnetic properties of Fe₇₉Si₈B₁₃ films has been studied using magnetic measurements, X-ray diffraction (XRD) and scanning electron microscopy (SEM). Prepared films exhibit the presence of nanocrystalline α -Fe phase embedded in amorphous matrix. Magnetic measurements show their homogeneous nature (within film plane). Direction perpendicular to film plane is the hard direction of magnetization. A cross-sectional SEM measurement provides film thickness. SEM also reveals the granular structure of the films.

Keywords: Hysteresis measurements, SEM, XRD.

PACS: 61.05.cn, 68.37.Hk, 75.30.Gw, 75.70.Rf

INTRODUCTION AND EXPERIMENTS

In order to utilize the soft magnetic properties of amorphous and nanocrystalline films at their best, an understanding of their structural and magnetic properties is required. The film thickness strongly influences some important physical and chemical properties, such as composition, atomic order, stresses, magnetic anisotropy, etc. [1]. As a function of thickness, significant variations are observed in the coercive field [2]. Hence, in the present work we report the thickness dependence of magnetic and structural properties of Fe₇₉Si₈B₁₃ films.

Amorphous ribbons of nominal composition Fe₇₉Si₈B₁₃ were used to deposit thin films on Si substrate using thermal evaporation method. Film of thicknesses: 110 nm, 160 nm and 170 nm were prepared. Hysteresis loops of the deposited thin films having different thicknesses were measured using LakeShore Model 7410 vibrating sample magnetometer (VSM) with a maximum applied field of ± 1000 Oe. Magneto-optical Kerr effect (MOKE) hysteresis loops of the samples with different thickness were done in using He-Ne laser of wavelength 632.8 nm [3]. In film-plane magnetic field of ± 200 Oe was applied using a pair of Helmholtz coils. X-ray diffraction measurements were done using a Siemens D5000 diffractometer, with Cu-K α radiation ($\lambda = 0.154$ nm). Low-vacuum scanning electron microscopy

(SEM) imaging of the surfaces was performed with an FEI Quanta 400FEG.

RESULTS AND DISCUSSIONS

Table 1 summarizes the coercivity values (H_c) of the studied thin films, obtained using VSM and MOKE measurements. Perusal of table 1 shows thickness dependence of in-plane H_c values along two orthogonal directions. H_c values obtained from the measurement with the field applied perpendicular to film plane shows much higher values, suggesting that this direction is the hard direction of magnetization. As a function of thickness, significant variation in coercivity is seen (Table 1). It is worth noting that combining MOKE and VSM data, provides information on magnetic properties as a function of thickness. MOKE would provide magnetic signal from the layer (~ 30 nm) up to which the laser penetrates within the

TABLE 1. Coercivity obtained from MOKE and VSM data, where t – Sample thickness, H_c – Coercivity

t (nm)	H_c (Oe) obtained from	
	MOKE Data	VSM Data
110	81.86*, 83.38*	86.5*, 82.01*, 490.03+
160	8.09*, 13.39*	6.17*, 12.30*, 156.04+
170	12.49*, 10.44*	11.04*, 10.77*, 314.81+

*Two orthogonal measurements in film plane,

+Measurement done perpendicular to film plane

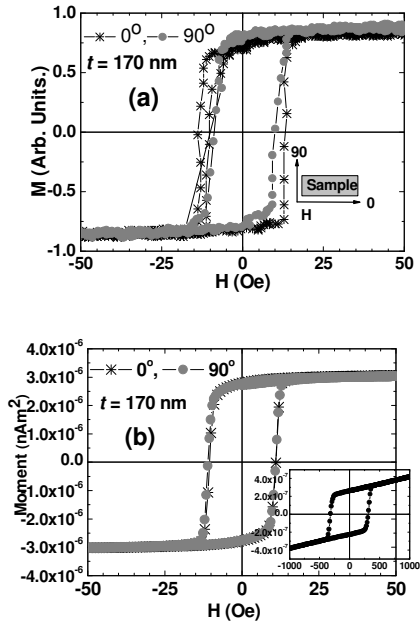


FIGURE 1. (a) and (b) respectively depicts the representative MOKE and VSM loops. Inset: Loop measured perpendicular to the film plane.

film, whereas the VSM provides signal from the whole sample. Thus, variation of magnetic properties as a function of thickness is reflected in the H_c , obtained from MOKE and VSM data. Table 1 also shows that within the film plane values of H_c obtained from both the measurements are quite comparable, and the observed difference can be ascribed to the variation in the surface roughness, as can be seen in SEM images (Fig. 2) and the variation in the grain size (Table 2).

Figures 1a and 1b respectively depict the representative MOKE and VSM loops of the film of thickness 170 nm. The VSM loop measured perpendicular to the film plane is shown as inset, and the observed behavior is ascribable to randomly oriented exchange coupled particles. The out-of-plane hardness is attributed to the shape anisotropy. Perusal of figure 1 shows that the obtained H_c is rather similar, revealing homogeneous magnetic properties within the film plane.

Table 2 depicts the parameters of XRD analysis. It also reveals that films consist of amorphous and nanocrystalline α -Fe phase. D and V_x of the crystalline phase range respectively between 30 – 34 nm and 35 –

TABLE 2. XRD analysis parameters; t – sample thickness, a – Lattice parameter, D – Average grain diameter, V_x - Volume fraction of the nanograins

t (nm)	a (nm)	D (nm)	V_x (%)
110	0.2876 ± 0.0002	30 ± 3	37 ± 4
160	0.2856	34	41
170	0.2855	32	35

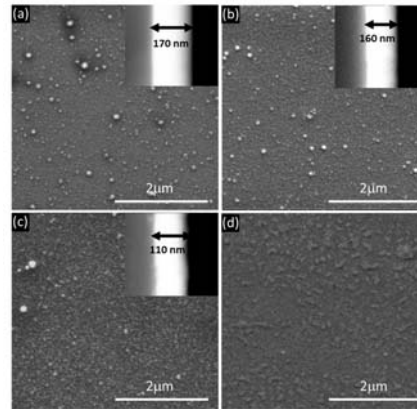


FIGURE 2. Topographic images of the thin films surface and cross section views (insets). The secondary SEM images show the surface views of the samples with several thicknesses (a) 170 nm (b) 160 nm and (c) 110 nm; (d) shows a representative backscattered SEM image of a surface view.

41 %. Variation in film thickness affects D and V_x . The first near-neighbour distance in amorphous phase: 0.248 ± 0.001 nm remains unchanged, revealing similar mass density in the prepared specimens.

Figure 2 shows that the studied samples have granular structure, which changes with the film thickness. Insets give information on film thickness. The crystalline phase appears also to be more uniformly distributed within the amorphous matrix.

To summarize, thickness dependent magnetic and structural studies of $\text{Fe}_{79}\text{Si}_8\text{B}_{13}$ thin films are reported. Prepared films display a co-existence of amorphous and nanocrystalline α -Fe phase, whose volume fraction varies with film thickness. Both MOKE and VSM study reveal that the prepared films are fairly isotropic within film plane. The direction perpendicular to film plane is the hard direction of magnetization.

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