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Tb/Fe multilayered films studied by conversion electron Mössbauer spectrometry and Kerr effect

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ABSTRACT : Fe/Tb multilayers of fixed Tb thickness (1.9 nm) and various Fe thicknesses (in the range 0.2-3.3 nm) have been prepared by rf-pulverization on Si(111) substrates. Conversion Electron Mössbauer Spectrometry was used to get information on the structure and the spin texture of the multilayers. Polar Kerr hysteresis loops have been used to obtain the global magnetic properties. The iron layers are amorphous up to 2.1 nm and the magnetic anisotropy lies in the plane of the layers above $e_{Tb}/e_{Fe}=0.9$.

I. INTRODUCTION :

Rare earth-transition metal (RE/TM) nanometer scale multilayers include both interface and quasi-two-dimensional magnetism. So, they are extensively studied for their promising applications as magnetic information storage media in perpendicular magneto-optical recording field. Recent studies have evidenced that Tb/Fe multilayers exhibit a strong perpendicular magnetic anisotropy (PMA), have a compensation temperature close to the ambient temperature and a high coercive field in a given Tb/Fe composition range. In this study, ^{57}Fe conversion electron Mössbauer spectroscopy (CEMS) has been applied to obtain microscopic information on the spin texture of iron atoms and to characterize the crystallographic state of iron layers in relation with their thickness. The global magnetic behaviour has been studied using Polar Kerr Effect.

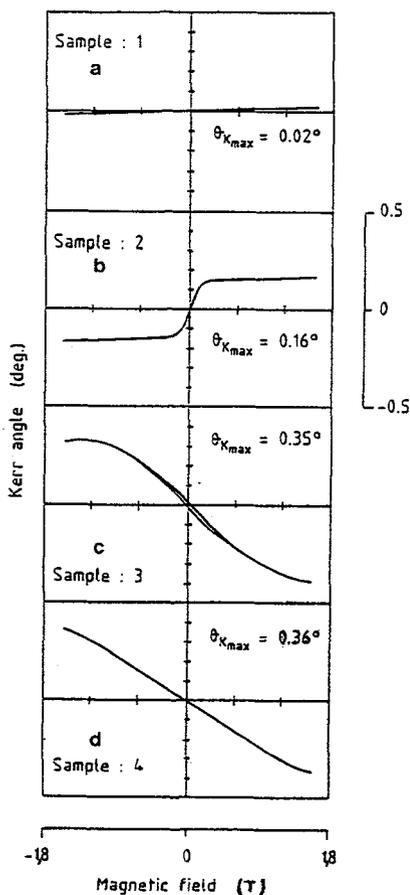
II. EXPERIMENTAL :

The Tb/Fe multilayered films have been deposited at room temperature on commercially available Si(111) substrates using a reactive diode rf-sputtering system. They have been chemically etched before their introduction into the deposition chamber and covered with a 10 nm thick Si_3N_4 buffer layer. The Tb/Fe stacks have been always started with a Fe layer and systematically finished with a 10 nm thick Si_3N_4 top layer to prevent corrosion and oxidation. Layer thickness and global structure of the films were determined by grazing X-ray reflectometry and X-ray diffraction¹. CEMS room temperature measurements were performed using a conventional spectrometer equipped with a helium/methane proportional

counter and a ^{57}Co source in a rhodium matrix. Samples were set perpendicular to incident γ beam. Polar Kerr magneto-optical spectra were realised at room temperature using a piezobirefringent modulator system with a helium-neon light source ($\lambda = 632.8$ nm). The available magnetic field was in the 0-1.6 T range. Its scanning frequency was taken equal to 10 mHz.

III. RESULTS AND DISCUSSION :

The thickness of terbium layers was fixed to 1.9 nm and the iron one chosen in the 0.2-3.3 nm range so that to have $e_{\text{Tb}}/e_{\text{Fe}}$ thickness ratio in the 0.5-9 range. All samples were deposited with 86 periods (table 1).



A. Magneto-optical properties

As previously observed², the magnetic properties of the samples strongly depend on the $e_{\text{Tb}}/e_{\text{Fe}}$ thickness ratio² (see table 1). Indeed, for high values of the ratio ($e_{\text{Tb}}/e_{\text{Fe}} \approx 9$), Kerr cycles (fig 1, sample 1) are almost flat even for the highest values of the magnetic field (1.6 T). This means that, in the sample, the magnetization is strongly anisotropic and that the magnetic moments are confined in the plane of the layers. For $e_{\text{Tb}}/e_{\text{Fe}}$ values around 2, Kerr cycles (fig 1, sample 2) turn loop-shaped with saturated branches : the anisotropy is weaker than in the preceding case since the magnetization can be forced perpendicular to the sample plane. Kerr rotation takes then typical values for such multilayered Tb/Fe materials, i.e 0.15° when saturated. When $e_{\text{Tb}}/e_{\text{Fe}}$ is around 0.6-0.7, Kerr cycles (fig 1, samples 3 and 4) have a reverse shape in comparison with the previous ones and Kerr angles values are as high as 0.4°. The shape reversal means that the considered samples have their compensation temperature below the room temperature, in agreement with previously published results².

Fig 1 : Polar Kerr hysteresis loops of four Tb/Fe rf-sputtering deposited multilayers with $e_{\text{Tb}} = 1.9$ nm and 86 periods :

- a) $e_{\text{Fe}} = 0.22$ nm b) $e_{\text{Fe}} = 0.88$ nm c) $e_{\text{Fe}} = 2.72$ nm d) $e_{\text{Fe}} = 3.30$ nm

Thickness		e_{Tb}/e_{Fe}	Polar Kerr measurements	
e_{Fe} (nm)	e_{Tb} (nm)		Hc(T)	θ_k (deg)
0.22	1.9	8.6	0.000	≈ 0
0.88	1.9	2.2	0.004	0.15
2.72	1.9	0.7	0.015	0.40
3.30	1.9	0.6	0.006	0.40

Table 1 : Structural characteristics and magneto-optical properties of four Tb/Fe rf-sputtering deposited multilayers (the number of periods is equal to 86).

B. Conversion electron Mössbauer study

CEMS room temperature spectra of the same samples are shown in fig 2. Results are summarized in table 2.

e_{Fe} (nm)	e_{Tb}/e_{Fe}	Structure	Magnetism	Mössbauer parameters			Anisotropy
				δ (mm/s)	H (T)	β (deg)	
0.22	8.6		P	-0.12	0.0		
0.88	2.2	A	M	-0.06	14.9	40	intermediate
2.10	0.9	A	m	-0.09	05.0	88	//
2.72	0.7	A + C	M	0.01	27.5	90	//
3.30	0.6	A + C	M	0.00	28.9	90	//

Table 2 : Mössbauer parameters :

δ =isomer shift with respect to bulk α -iron, \bar{H} =average hyperfine field, β =average angle between the hyperfine field and the γ -ray direction perpendicular to the film plane

(P=paramagnetic, M=magnetic, m=weakly magnetic, A=amorphous, C=crystal).

According to previous results³, it is assumed that the Tb layers are amorphous for the thickness e_{Tb} equal to 1.9 nm.

For $e_{Fe} < 0.5$ nm, the Mössbauer spectrum is a paramagnetic doublet with slightly broadened lines (linewidth $\Gamma = 0.4$ mm/s, quadrupolar splitting QS = 0.46 mm/s). This result is in agreement with flat Kerr cycles exhibiting no coercivity. The isomer shift is close to the value observed in amorphous iron phases in these compounds (table 2). Increasing e_{Fe} in the 0.5-1.5 nm range leads to spectra which are typical of amorphous iron magnetic structure as already observed^{4,5}. The fitted mean texture angle β is close to 40°. This means that the anisotropy is intermediate between the perpendicular and the in-plane configuration and that each contribution is of the same order. Two interpretations can be given : either all the spins are oriented along the same direction (40°) or they are distributed in a cone with the axis normal to the plane. The mean value of the hyperfine field distribution is about 15 Tesla. For $1.8 < e_{Fe} < 2.2$ nm, both the shape and the fitted parameters of the spectra (fig 2a) give evidence for weakly magnetic amorphous layers with a planar magnetic

anisotropy. When $e_{Fe} > 2.3$ nm, the spectra (fig 2b) are typical of both a crystalline iron component ($\approx 60\%$) with planar anisotropy and an amorphous iron component ($\approx 40\%$) in agreement with previous results^{4,5}. As seen on P(H) curves, the hyperfine field of amorphous part spreads over a large range ($\approx 0-30$ T). The mean value of the hyperfine field is around 28 T. This high value, due to the crystalline component, could explain the high Kerr angle values (0.4° instead of $0.15-0.2^\circ$).

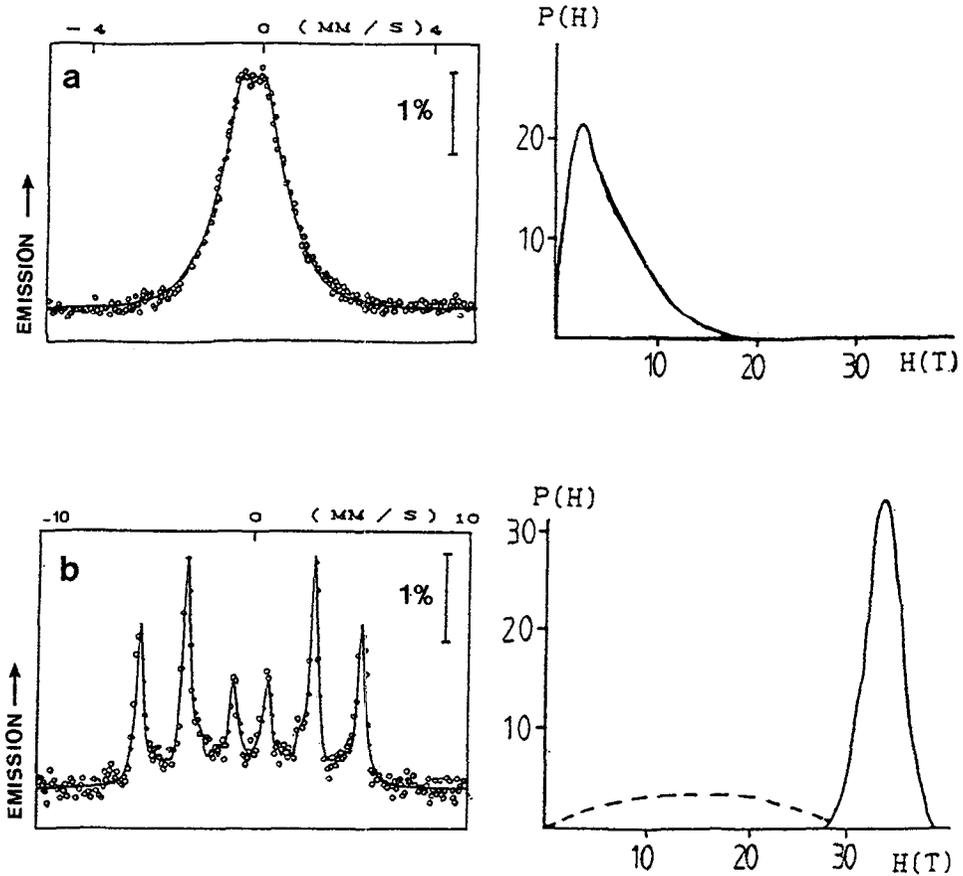


Fig 2 : CEMS spectra and hyperfine field distributions :

a) $e_{Fe} = 2.10$ nm b) $e_{Fe} = 2.72$ nm

solid line : crystallized phase

dashed line : amorphous phase.

All these results can be consistently interpreted. When the iron layer is thin, both the interface and the amorphous structure of terbium impose an amorphous structure for iron. Here, it seems that crystallisation of the central part of iron layer is not observed before 2.0 nm (8 iron monolayers). Increasing the thickness of the iron layer, the magnetic anisotropy, first perpendicular because of the interface anisotropy, rotates towards the plane of the layer due to the increasing effect of basal bulk anisotropy. The falling of the hyperfine field for $e_{Fe} > 1.5$ nm is not yet entirely understood and is under study.

References:

- [1] PIERRE.F, BOHER.P, KERGOAT.R, HOUDY.Ph, FERRE.J and PENISSARD.G, *J.Appl.Phys.* 69 (1991) 4565.
- [2] PIERRE.F, BOHER.P, HOUDY.Ph, FERRE.J, PENISSARD.G, GROLIER.V, TEILLET.J and FNIDIKI.A, to be published in *J.Magn.Magn.Mater.*
- [3] YAMAUCHI.K, HABU.K and SATO.N, *J.Appl.Phys.* 64 (1988) 5748.
- [4] SCHOLZ.B, BRAND.R.A, KEUNE.W, KIRSCHBAUM.U, WASSTERMANN.E.F, MIBU.K and SHINJO.T, *J.Magn.Magn.Mater.* 93 (1991) 499.
- [5] CHERIFI.K, DUFOUR.C, PIECUCH.M, BRUSON.A, BAUER.Ph, MARCHAL.C and MANGIN.Ph, *J.Magn.Magn.Mater.* 93 (1991) 609.