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Journal of Magnetism and Magnetic Materials 272–276 (2004) e873–e874
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Structural, morphological and magnetic study of CoPt/Cr/MgO films by energy dispersive X-ray diffractometry and reflectometry measurements

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Abstract

We report the results of joint energy dispersive X-ray diffraction and reflectometry studies of the structural and morphological characteristics of double layer CoPt/Cr thin films, deposited by pulsed laser deposition at various temperatures ($T_{dep} = 25-500°C$) on (1 0 0) MgO substrates. The observed characteristics were correlated to the magnetic properties investigated by SQUID measurements.

PACS: 79.20.D; 75.50.S; 61.10.E; 60.10.K

Keywords: CoPt/Cr thin film; Structural and magnetic propertie; Energy dispersive X-ray technique; Laser ablation

We present the investigation of the structural, morphological and magnetic properties of double layer CoPt/Cr thin films deposited by pulsed laser deposition (PLD) on MgO (1 0 0). The main advantage of using PLD over other deposition techniques is the capability of film growth from a high energy plasma, which can produce a highly crystalline film with smooth surface. Cr film acts as a structural template inducing the epitaxial growth of the magnetic CoPt film, which is to be used as multilayered magnetic media for high-density magnetorecording [1,2]. A fundamental step to optimize the structural and magnetic properties is the understanding of the interrelationship between the deposition process and the resulting crystalline texture. The combined use of the energy dispersive X-ray diffraction (EDXD) and energy dispersive X-ray reflectometry (EDXR) techniques allowed us to correlate the structural properties of the samples to their morphological characteristics [3]. The main advantages of the energy dispersive (ED) technique, with respect to the usual angular dispersive one, fully discussed in Ref. [4], are connected to the fixed geometry of the experimental apparatus during the measurement.

The films were deposited in a HV vacuum chamber by PLD using a Lambda Physik excimer laser ArF ($\lambda = 193$ nm), at an energy Fluence of 5 J/cm^2 and a pulse repetition rate of 10 Hz. Samples were deposited at temperature ranging from 25 to 500°C and at a growth pressure of 2×10^{-7} mbar. A carousel with a metallic Cr target and a composite target with nominal atomic composition $Co_{0.5}Pt_{0.5}$ were sequentially used to deposit the two layers. The films grew with a very ordered crystalline structure and a high degree of epitaxy, in the whole range of deposition temperature. Processing the X-ray diffraction spectra, the Cr underlayer grown along the (1 1 0) direction and the cubic CoPt phase grown with (1 1 1) orientation were identified. The rocking curves (RC) are shown in Fig. 1. On the x-axis, the asymmetry parameter $\alpha = (\vartheta_i - \vartheta_r)/2$, where ϑ_i = incidence angle, ϑ_r = reflection angle and $\vartheta_i + \vartheta_r = 2\vartheta$ is the diffraction angle, is reported. The RC maxima for the Cr and the CoPt peaks do not coincide with the maximum of the RC for the substrate peak. The displacement $\Delta\alpha$ ranges between 0.026° and 0.057° for the Cr film and between 0.026° and 0.155° for the CoPt film. Besides the effect on the film orientation of a

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doi:10.1016/j.jmmm.2003.12.1366

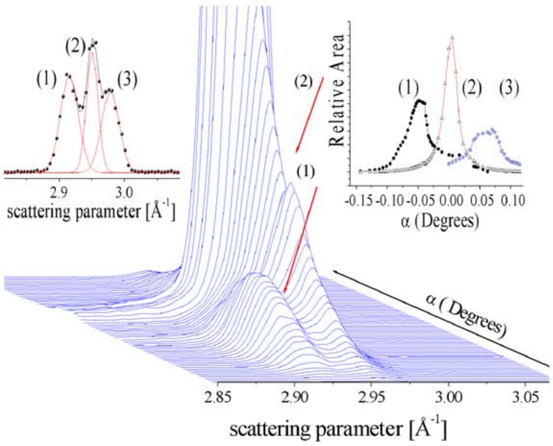

Fig. 1. Sequence of the EDXD patterns for the sample deposited at 100°C, acquired during the α scan. In the inset on the right, the diffraction pattern acquired at $\alpha = 0.0669°$ is reported: the observable reflections are (1) the [1 1 1] of CoPt cubic phase [6] at $q = 2.943$ Å^{-1}, (2) the [2 0 0] of MgO at $q = 2.981$ Å^{-1} and (3) the [1 1 0] of Cr at $q = 3.082$ Å^{-1}. The inset on the left reports the result of the RC analysis for the above reflections.

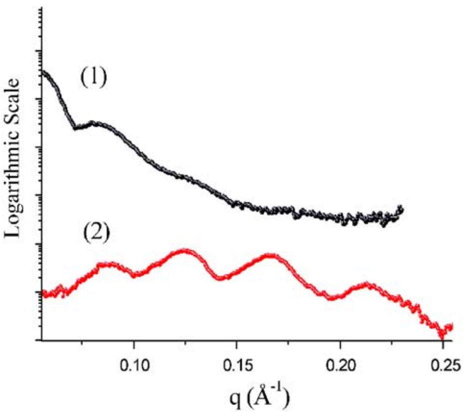

Fig. 2. EDXR experimental data for films deposited at 500°C (1) and 100°C (2): the roughness of the CoPt layer increases with increasing deposition temperature as shown by the faster dumping of the oscillations.

possible substrate miscut, this is to be attributed to the way the film crystalline lattice matches the substrate lattice [3].

The FWHM of the RC gives an estimation of the epitaxy index and, for both the Cr and CoPt films, it was estimated below 0.040°.

A fit of the EDXR experimental data (Fig. 2) was performed using the Parrat's model [5] in order to evaluate the film thickness and the surface roughness.

The CoPt film thickness ranges between 43 and 145 Å. The EDXR study showed, for the CoPt layer, a very low

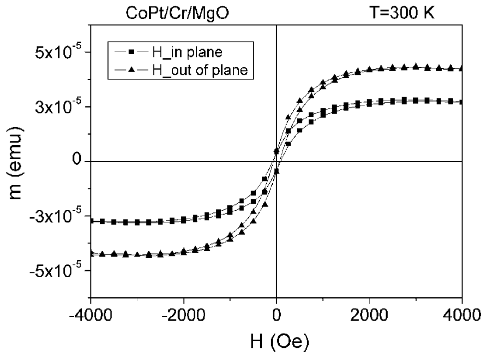

Fig. 3. Hysteresis cycles at room temperature for H parallel and perpendicular to the film plane.

roughness value (atomically flat for $T_{dep} = 25-100°C$) that increases up to an almost constant value (22±4 Å) when the deposition temperature exceeds 200°C. This information is of an extreme importance for magnetorecording applications, requiring media having a roughness controlled in the range 15–50 Å.

Magnetic measurements have been carried out at different temperature with H applied parallel and perpendicular to the film plane using a SQUID magnetometer. The room temperature hysteresis cycles, corrected for the substrate contribution, are reported in Fig. 3 for a film deposited at 400°C. For $H_{\|}$ the coercive field varies from 220 Oe at 50 K to 100 Oe at room temperature.

We can conclude that, when the PLD deposition is performed under controlled working conditions, the CoPt/Cr layer shows a high crystalline quality independent of the deposition temperature. Epitaxial films with strong texture were obtained, with very smooth surfaces as shown by the very low roughness values, particularly when the deposition is carried out at low temperature. The low values of the measured coercive field are consistent with the low magnetic anisotropy of the FCC CoPt phase.

Work supported by UE Growth program, Project HIDEMAR, Contract No. G5RD-2002-00731.

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