Kerr Rotation and XPS Spectra of Co/Pd Multilayers

Zdeněk Šimša, Josef Zemek and Jarmila Šimšová

Institute of Physics, Academy of Science, Cukrovarnická 10, Praha 6, Czech Republic

Poul de Haan and Cock Lodder

MESA Research Institute, University of Twente, P.O.Box 217, 7500 AE Enschede, The Netherlands

Abstract—The influence of the surface conditions of a series of the polycrystalline Co/Pd multilayers on the spectral dependence of the polar Kerr rotation, θ_k , was studied. Starting from low θ_k values, $|\theta_k|$ was found to increase towards short wavelengths, reaching 0.2 degree at the blue region. Using angular resolved photoelectron spectroscopy the oxidation states and the binding conditions of Co and Pd nearest surface layers were examined.

I. INTRODUCTION

Magnetic Co/Pd and Co/Pt multilayers (MLs) range among promising magneto-optical recording materials in the short wavelength optical region [1]. The favourable magneto-optical (Kerr rotation) and magnetic properties (perpendicular anisotropy, magnetization) are mostly due to the surface/interface effects. In the early paper of Carcia [2] the sharper interfaces in Co/Pd MLs were found in comparison with Co/Pt MLs. In the later paper of He et al. [3] the influence of the sputtering conditions on the surface and the interface microstructure and on the magnetic coercivity of Co/Pt MLs was studied. They supposed, in accordance with Miedema model [4], that sufficient kinetic mobility of Co and Pt atoms is responsible for the formation of the Co-Pt alloy at the interfaces between Co and Pt layers. Also Sato et al. [5] could explain the magneto-optical spectra of Co/Pt MLs by formation of rather thick alloy layer at the interfaces. For cobalt and palladium atoms, contrary to cobalt and platinum, much lower heat of mixing was estimated [4] preventing the easy formation of the alloy layers.

In the present paper the influence of the surface conditions, as determined by the angular resolved X-ray photoelectron spectroscopy (XPS), on the polar Kerr rotation of five Co/Pd MLs with different thicknesses of the ferromagnetic Co layer ($t_{Co} = 0.23 \div 1.27$ nm) is investigated. The effects of the ion etching and the

time stability for two samples with $t_{Co} \approx 0.4$ nm are also reported. A comparison of the results of XPS and polar Kerr rotation (PKR) measurements can give valuable information on the interface states due to the different information probe depths of both methods.

II. EXPERIMENTAL

A. Samples

Polycrystalline Co/Pd MLs were prepared by rf sputtering onto Si(100) substrates in the Leybold Z-400 system as described in more detail elsewhere [6]. The main characteristics of the five studied samples are gathered in table 1. Here t_{Co} , T , M_s , H_c and K_{eff} are the thickness of the cobalt layer and the multilayered film, the saturated magnetization of Co layers, the coercive force and the effective anisotropy constant of MLs, respectively. Magnetic properties of the MLs were described in detail earlier [6].

TABLE 1
THE MAIN PARAMETERS OF Co/Pd
MULTILAYERED FILMS

Sample No.	t_{Co} (nm)	T (nm)	M_s (kA/m)	K_{eff} (kJ/m ³)	XPS
1 910816-1	1.27	67.0	1759	-306	a
2 910814-1	0.85	56.3	1850	42	
3 910807-1	0.45	46.5	2026	1006	a
					d
4 910111-2	0.43	46.5	1581	1548	a
					b
					c
5 910808-1	0.23	41.0	2445	1615	a

Conditions of XPS measurements:

- a - as prepared
- b - after ion etching resulting in Pd on the surface
- c - after ion etching resulting in Co on the surface
- d - after eight months interval

B. Polar Kerr Rotation

Spectral dependence of the polar Kerr rotation, Θ_k , was measured at wavelengths between 400 and 2000 nm by conventional polarisation modulation method at magnetic field intensities of 320 kA/m as described in [7].

C. XPS Measurements

Photoelectron spectra (XPS) were measured at room temperature using Mg K_α or Al K_α radiation. The energy analyzer was operated in the constant energy mode at 50 or 100 eV pass energy. Angular resolved spectra were recorded in regions of Co2p, Pd3d, O1s and C1s lines at fixed position of the sample by moving the electron analyzer around the sample at photoelectron take-off angles in the range of 0 to 65 degrees relative to the sample normal.

Ion beam sputter-etching (IBSE) was accomplished by means of Xe ion beam characterized by the energy and the current of 3000 eV and 2×10^{-5} A, respectively. The beam was inclined by 70 degrees relative to the surface normal and etched 1 cm diameter spot at the target.

III. RESULTS AND DISCUSSION

Polar Kerr rotation spectra of the as prepared MLs are represented in Fig. 1. It is seen that with the increasing photon energy of light, $|\Theta_k|$ also increases attaining at 3.1 eV values $\Theta_k \approx -0.2$ degree in agreement with other papers, see e.g. [8] - [12]. As some of the authors claim that the Kerr rotation spectra of Co/Pt and Co/Pd MLs are identical with the spectra of respective alloys, we attempted to remove alternating individual layers of

Fig. 1 Spectral dependences of the polar Kerr rotation of the as prepared samples # 1 (■), 2 (●), 3 (▽) and 5 (□).

Co and Pd by Xe ion beam bombardment.

The XPS investigation of outer surfaces of the as prepared samples revealed large contribution of oxidic binding states of Co (CoO and/or Co(OH)_2) as it is demonstrated in Fig. 2 by the presence of the broad peaks in the 780 to 790 eV region. The Co-Co binding state of cobalt at 778 eV is obscured by the oxidic states and can be clearly distinguished only with a more penetrating Al K_α radiation (curve a_1). Removing of the oxidized Co surface states by IBSE recovers 2p_{3/2} peak at 778 eV (and 2p_{5/2} at 793 eV) characteristic for pure cobalt. It is clearly detected with outer Co layer (curve c) and also with outer Pd layer (curve b) but with a much smaller intensity.

Figure 3 demonstrates that IBSE of the MLs surfaces decreases also the magnitude of the Kerr rotation at shorter wavelengths and, moreover, Θ_k values of freshly cleaned surfaces seem to be independent of whether the outer layer is Pd or Co. A similarity of curves b (Pd outer layer) and c (Co outer layer) in Fig. 3 might suggest that Θ_k is indeed due to Co-Pd alloy. On the

Fig. 2 Cobalt 2p XPS spectra of the as prepared (a) and ion-etched surfaces of # 4 resulting in Pd (b) or Co (c) outer layer. As prepared curves were measured with Al K_α (a_1), Mg K_α at $\vartheta=0^\circ$ (a_2) and Mg K_α at $\vartheta=50^\circ$ (a_3).

Fig. 3 Spectral dependences of the polar Kerr rotation of the as prepared a(○) and ion-etched b(□) and c(▽) sample # 4 - for parameters and sample surface conditions see table 1. Solid line represents Θ_k for 28 at% Co - 72 at% Pd alloy after [8].

other hand, XPS investigation using MgK_{α} radiation at high angles with interaction depth less than 1 nm shows that the individual layers are composed predominantly of one kind of atom, i.e. Pd or Co. This fact is also supported by the finding that the time needed for obtaining the Co spectrum via Pd layer takes about three times the usual pick-up time measured with the outer Co layer. As the interaction depth of the infrared and visible light at perpendicular incidence (more than 10 nm) is larger than the period of MLs we cannot argue that the similarity of spectra b and c of Fig. 3 is in favour of the presence of the Co-Pd alloy (solid line). Moreover, the identical results of XPS and PKR measu-

rements on sample # 3 in 8 months interval with nearly the same t_{Co} as sample No 4 indicate negligible influence of the aging of MLs at ambient atmosphere.

An interesting fact is also the dependence of Θ_k on the Co layer thickness for various wavelengths λ as shown in Fig. 4. The monotonous decrease of Θ_k at larger wavelengths is replaced by the occurrence of maximum of $|\Theta_k|$ at 460 nm. This fact might support the finding of Weber et al. [13] who suggest a significant spin-splitting of the Co/Pd interface states when Co thickness is about one atomic layer. These spin-split states are supposed to be the origin of the observed enhanced polar Kerr rotation at short wavelengths [13].

REFERENCES

- [1] F.J.A. den Broeder, H.W. van Kesteren, W. Hoving, and W.B. Zeper, "Co/Ni multilayers with perpendicular magnetic anisotropy: Kerr effect and thermomagnetic writing," *Appl. Phys. Lett.*, vol. 61, pp. 1468-1470, September 1992.
- [2] P.F. Carcia, "Perpendicular magnetic anisotropy in Pd/Co and Pt/Co thin film layered structures," *J. Appl. Phys.*, vol. 63, pp. 5066-5073, May 1988.
- [3] Ping He, et al., "Sputtering pressure effect on microstructure of surface and interface, and on coercivity of Co/Pt multilayers," *J. Appl. Phys.*, vol. 70, pp. 6044-6046, November 1991.
- [4] A.R. Miedema, "The heat of formation of alloys," *Philips Techn. Rev.*, vol. 36, pp. 217-231, 1976.
- [5] K. Sato, et al., "Magneto-optical spectra in Pt/Co and Pt/Fe multilayers," *Jpn. J. Appl. Phys.*, vol. 31, pp. 3603-3607, November 1992.
- [6] P. de Haan, Q. Meng, T. Katayama, and J.C. Lodder, "Magnetic and magneto-optical properties of sputtered Co/Pd multilayers," *J. Mag. Mag. Mater.*, vol. 113, pp. 29-35, 1992.
- [7] Z. Šimša, H. LeGall, and P. Šíroký, "Polar Kerr effect of magnetite in the visible and near infrared spectral regions," *phys. stat. sol.*, vol. (b)100, pp. 665-669, 1980.
- [8] K. Nakamura, S. Tsunashima, S. Iwata and S. Uchiyama, "Magneto-optical properties of PdCo based multilayered films," *IEEE Trans. Mag.*, vol. 25, pp. 3758-3760, 1989.
- [9] S. Hashimoto and Y. Ochiai, "Co/Pt and Co/Pd multilayers as magneto-optical recording materials," *J. Mag. Mag. Mater.*, vol. 88, pp. 211-226, 1990.
- [10] S. Hashimoto, Y. Ochiai and K. Aso, "Light wavelength dependence of Magneto-optical properties in ultrathin Co/Pt and Co/Pd multilayered films," *Jap. J. Appl. Phys.*, vol. 28, pp. L1824-L1826, October 1989.
- [11] E.R. Moog, J. Zak and S.D. Bader, "Analysis of Kerr rotation from Cu/Co, Pd/Co and Pt/Co superlattices," *J. Appl. Phys.*, vol. 69, pp. 4559-4561.
- [12] K. Nakamura, S. Tsunashima, S. Iwata and S. Uchiyama, "Magnetic and magneto-optical properties of Pd/Co multilayered films," *IEEE Transl. J. Mag. Jap.*, vol. 5, pp. 522-528, 1990.
- [13] W. Weber, D. Hartmann, D.A. Wesner and G. Güntherodt, "Spin-split electronic states at interfaces: Pd/Fe, Pt/Co and Pd/Co," *J. Mag. Mag. Mater.*, vol. 104-107, pp. 1791-1792, 1992.

Fig. 4 Dependence of the polar Kerr rotation, Θ_k , on the Co layer thickness, t_{Co} , for wavelengths $\lambda = 460$ (○), 620 (□), 800 (▽) and 1000 nm (●).