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Effect of Au thickness on magnetoresistance and Kerr spectra in Co/Au multilayers

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Abstract

Magnetotransport and magneto-optical (MO) results on sputtered Co/Au multilayers at 300 K are reported. The thickness of Co layer was fixed at $t_{Co} = 1$ nm while that of Au, t_{Au}, varied between 2.2 and 4 nm. Two giant-magnetoresistance (GMR) maxima were observed for $t_{Au} \approx 2.4$ and 3.9 nm. For $t_{Au} \approx 2.4$ nm the coercive field and switching fields are 7 and ± 30 Oe, respectively. MO Kerr hysteresis loops and spectra were measured in polar and longitudinal configurations. The loops provide evidence for the exchange coupling at the first GMR maximum and interface magnetic anisotropy for $t_{Au} < 3$ nm. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Giantmagnetoresistance; Magneto-optics; Exchange coupling

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The only system of sputtered TM/Au multilayers (TM = magnetic material) that exhibits oscillatory magnetoresistance (GMR) with a period of Au layer thickness $t_{Au} \approx 1.2$ nm, was reported in untextured $Ni_{81}Fe_{19}$/Au films [1] while the most recent results for Co/Au sputtered MLs [2] are related with interesting magneto-optical (MO) properties. In the present study, Co/Au MLs grown by magnetron sputtering, were found to show a GMR oscillation with t_{Au}, and a sensible change in GMR ratio per unit field for the $[Co(1\ nm)/Au(2.4\ nm)]_{30}$ composition. A series of magnetron sputtered $[Co(1\ nm)/Au(t_{Au})]_{30}$ MLs, nominal $t_{Au} = 2.2, 2.4, 2.5, 3, 3.6, 3.9$ and 4 nm, has been deposited on Si(1 0 0) covered with 100 nm thick SiN_x buffer. The samples were characterized by X-ray diffraction and cross-section TEM. Sharp interfaces and an (1 1 1) preferred orientation are evident along the growth direction [3]. All the samples were studied by polar and longitudinal Kerr spectroscopy. The present paper reports on magnetotransport (MR) and selected magneto-optical (MO) investigations.

The GMR measurements were performed at 300 K with the four-point-probe method, using a DC current of 1 mA for two directions of the applied field H: first with H lying in the film plane parallel to current ($H \| I$) and then with H applied perpendicular to film ($H \perp I$). All MR measurements were performed by first applying the maximum positive field H of 4 kOe and then completing the loop.

In Fig. 1 are shown the GMR curves for the $[Co(1\ nm)/Au(2.4\ nm)]_{30}$ sample. In the ($H \| I$) configuration the coercive field H_c, that is the field where the GMR maximum is observed, and the switching field H_s, that is the field where the GMR ratio approaches its lower value from both sides around H_c are 7 and ± 30 Oe, respectively. For comparison the observed values in the trilayers [4,5] are $H_c \approx 500$ Oe and $H_s \approx \pm 50$ Oe. This order of magnitude improvement of H_c brings the Co/Au MLs in the area of applications for GMR sensors.

In Fig. 2 are shown the MR ratio, $[R_{max} - R(H_s)]/R(H_s)$, H_s and H_c as a function of t_{Au}, with $H \| I$. For $t_{Au} > 2$ nm, two MR maxima were observed for $t_{Au} \approx 2.4$ and 3.9 nm (~ 10 and 16 Au atomic planes),

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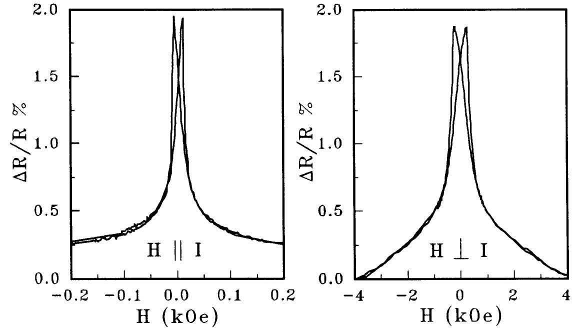

Fig. 1. GMR measurements in $[Co(1\,nm)/Au(2.4\,nm)]_{30}$ MLs. On the left is plotted the GMR loop with H lying in the film plane parallel to current flow ($H \| I$). On the right is plotted the transverse field ($H \perp I$) GMR loop with H perpendicular to film.

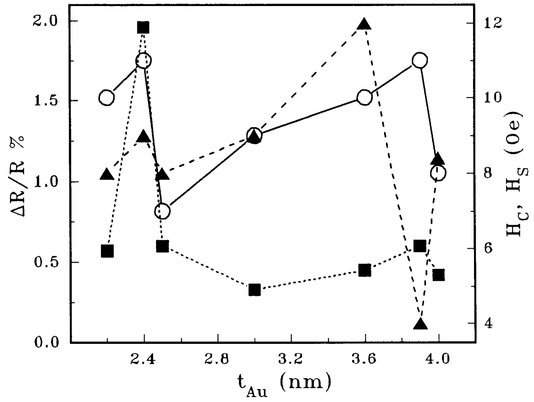

Fig. 2. Variation of the GMR ratio (squares), H_c (triangles) and H_s (circles) with t_{Au}, for H applied parallel to current flow direction.

respectively, attributed to the GMR effect. The existence of a residual GMR ratio about 0.4% in t_{Au} regions where the interlayer coupling is expected to be ferromagnetic is attributed to intralayer ('bulk') spin-dependent scattering [6]. These oscillations differ from those observed in epitaxial Co/Au(1 1 1)/Co trilayers [4] where GMR maxima occur for $t_{Au} \approx 5, 9$ and 14 atomic planes (1.2, 2.1 and 3.3 nm). In the epitaxial trilayers the mean oscillation period is 4.5 atomic planes in agreement with the theoretical prediction [6]. A comparison t_{Au} values at the GMR maxima indicate that our first GMR peak, at ~ 10 atomic planes of Au, is near the second GMR maximum of the trilayer in Ref. [4]. For $t_{Au} \approx 2.4$ nm the GMR effect is mainly due to interfacial spin-dependent scattering while for thicker Au layers the increase of magnetic decoupling between adjacent Co layers enhances the contribution of intralayer spin-dependent scattering. The variation of H_c and H_s fields with t_{Au} (Fig. 2), obtained from the GMR curves with $H \| I$, are in agreement with the last argument.

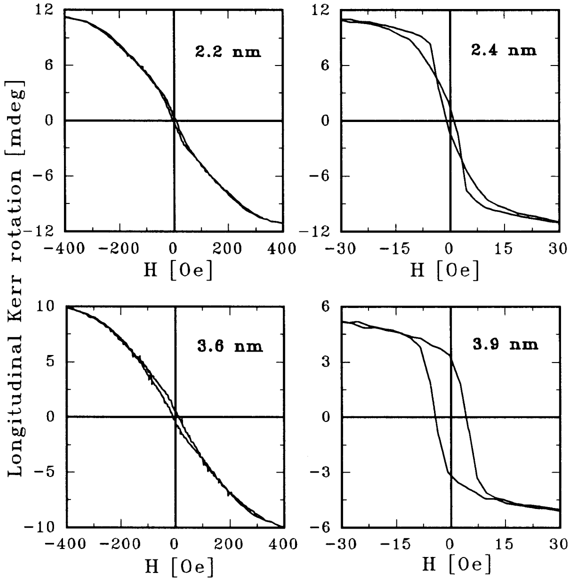

Fig. 3. Longitudinal Kerr-effect hysteresis loops for selected thicknesses t_{Au} at the photon energy of $E = 2.76$ eV for a s polarized wave incident at 45°.

In Figs. 3 and 4 are shown the longitudinal Kerr-effect hysteresis loops. At the GMR minima ($t_{Au} = 2.2$ and 3.6 nm) they reveal a significant magnetic anisotropy, that may be induced in the Co layers from a high concentration of step edges [7] located at the Co/Au interfaces due to surface reconstruction of the Au (1 1 1) planes. For $t_{Au} = 2.4$ nm there is a manifold loop with insignificant residual magnetization, inferring coexistence of the so-called [8,6] 'bilinear' and 'biquadratic' interlayer coupling terms at the first GMR maximum. However, at the second GMR maximum there is a ferromagnetic loop, characteristic for a random distribution of Co magnetic moments (uncoupled layers) that contributes into 'bulk-like' spin scattering [6,7].

The polar loops confirmed the presence of the interface-induced anisotropy which reduces the saturation field below 3 kOe, while the coercive field varies between 10 and 65 Oe. The Kerr spectra show a distinct Au plasma edge peak centered near 2.5 eV. A narrowing and reduction in the amplitude of the peak is observed by increasing t_{Au}. These trends were reproduced by computer simulations [9] with the experimental amplitudes about 50% smaller. This difference can be attributed to extended intralayer and/or interface disorder, located mainly at the ferromagnetic Co layers, and to changes in Au electronic states induced by adjacent Co layers.

In summary, it is shown that magnetron sputtered Co/Au MLs with (1 1 1) texturing display GMR effects, for $t_{Au} > 2$ nm, with small saturation and switching

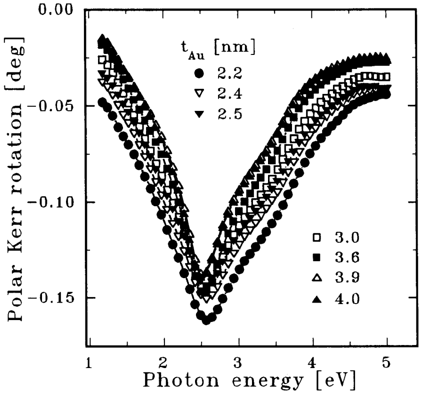

Fig. 4. Saturated polar Kerr rotation spectra of [Co(1 nm)/ Au(t_{Au} nm)]$_{30}$ multilayers with a fixed Co thickness, $t_{Co} = 1$ nm and t_{Au} between 2.2 and 4.0 nm.

fields. Static deposition of the constituents with low rates, on SiN_x buffer layer, seems to enable the development of a considerable fraction of faults in the atomic packing of Co layers along the growth direction. Thus, the observed differences in magnetotransport properties, between the examined here Co/Au MLs and those reported by now, can be attributed to the development of a specific microstructure in the magnetic layers. The practical advantage of the prepared Co/Au MLs is the achievement of a low H_c, obtained under deposition conditions requiring less demand on the growth process, that makes possible their use in GMR sensors.

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