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Influence of Co on the Magnetic and Magneto-Optical Properties of Co-Ni/Pt and Co-Ni/Au Multilayers

R. Krishnan, M. Seddat, M. Porte, M. Tessier, S. Visnovsky* and M. Nyvlt*

Laboratoire de Magnétisme et d'Optique, Bâtiment Fermat, 45 avenue des États-Unis, 78035 Versailles cedex, France

** Institute of Physics, Charles University, Ke Karlovu 5, 12 116 Prague 2, Czech Republic*

Résumé : Nous décrivons nos études magnétiques et magnéto-optiques sur des multicouches Co-Ni/M ($M = \text{Pt, Au}$) préparées par évaporation sous ultra vide. L'anisotropie de surface K_s augmente linéairement avec la teneur en Co ce qui vérifie le modèle à un ion. La teneur relative de Ni permet d'ajuster la température de Curie afin de pouvoir utiliser ces matériaux pour l'enregistrement thermomagnétique. La rotation Kerr présente un pic vers 4 eV pour les multicouches à base de Pt, qui se situe vers 2,5 eV pour celles d'or. On discute des résultats.

1. INTRODUCTION

Magnetic multilayers are a new class of materials with novel properties. One of the most promising applications of magnetic multilayers (ML) is for magneto-optic (MO) storage media. The typical examples such as Co/Pt and Co/Pd, by virtue of their strong uniaxial anisotropy and good magneto-optical effects, are potential candidates for MO storage applications in the blue light wavelength and hence have attracted much attention from several research groups [1, 2, 3]. New class of materials based on Co-Ni/Pt instead of pure Co/Pt have also been suggested recently by some authors and by us as well [4, 5, 6] which show similar properties as Co/Pt but with a relatively lower Curie temperature of the order of 250°C. Writing at such temperatures is far more safer and will not cause any interfacial diffusion which is of great importance for application. We found that the surface anisotropy (K_s) in this system varied linearly with the Co concentration which is of fundamental importance [5]. We therefore wanted to study in detail this aspect and extended our study to Co-Ni/Au. We chose the system based on Au for the following reasons. Co/Au has been intensely studied in the past [7, 8] and it shows perpendicular anisotropy for thin Co layers. We had shown that in Ni/Au multilayers K_s is negative [9] and it is therefore interesting to see if the addition of Co would make K_s positive. We describe in this work the magnetic and the magneto-optical properties of $(\text{Co}_x\text{Ni}_{1-x})/\text{M}$, ($M=\text{Pt, Au}$) multilayers prepared by evaporation.

2. EXPERIMENTAL DETAILS

The multilayers were prepared by sequential evaporation using a dual e-beam under ultra high vacuum conditions. The details of the deposition can be found in ref. 2. For depositing the $\text{Co}_x\text{Ni}_{1-x}$ alloy layers, we first prepared an alloy ingot and used it as a source. Subsequently the composition was determined on a film of $\text{Co}_x\text{Ni}_{1-x}$ about 150 nm thick. No difference in the composition between the source and the layer could be detected. Both glass and silicon were used as substrates. First Pt, Au buffer layer 100 Å thick was deposited at room temperature and then annealed at 200°C for 2 hours. The multilayers were then grown on this buffer layer at room temperature. The Pt, Au layer thickness $t(\text{Pt, Au})$ was kept constant at 15 Å and that of Co-Ni varied in the range 4 to 30 Å. The growth parameters will be designated as $\{t(\text{Co,Ni}), t(\text{Pt, Au})\} \times N$ where N stands for the number of bilayers. The top layer was either Pt or Au layer 20 Å thick which also served as a protective layer.

Low and high angle X-ray diffraction studies were made to verify the periodic structure and to calculate the layer thicknesses. Magnetization was measured using a vibrating sample magnetometer (VSM) and the anisotropy was determined by a home made sensitive torque meter. The above properties were measured in the temperature range 6 to 300K. The M-H and magneto-optical loops were also taken at the laser wavelength of 6323 Å. Magneto-optical polar Kerr spectra were studied at 295 K in the photon energy range from 1.5 to 5.2 eV.

3. RESULTS AND DISCUSSIONS

3.1 Magnetic anisotropy

Let us first discuss the anisotropy in these multilayers. The effective anisotropy K_{eff} in the multilayers can be expressed by the well known phenomenological model by the relation, $K_{\text{eff}} = K_V + 2K_s/t$, where, K_V and K_s represent the bulk and surface anisotropies and t the magnetic layer thickness. The term K_V contains the contributions from the demagnetization energy $2\pi M^2$ and the crystalline and magnetoelastic anisotropy energies. Plotting $K_{\text{eff}} \times t$ as a function of t yields both K_V and K_s . The results were analysed on the basis of the above model. Fig. 1 shows the variation of K_s as a function of Co (x) concentration in Co-Ni/Pt at 5 K.

Fig. 1 The variation of K_s as a function of Co content in Co-Ni/Pt at 5K.

Fig. 2 The variation of K_s as a function of Co content in Co-Ni/Au at 5K.

We discuss the results at 5 K to eliminate the effects of relatively low T_C on the properties. The experimental points show the linear variation of K_s with the Co content. The straight line is calculated based on the relation which assumes the one ion contribution and which can be written as $K_s^{\text{alloy}} = K_s^{\text{Co}}(x) + K_s^{\text{Ni}}(1-x)$, where K_s^{Co} and K_s^{Ni} are surface anisotropy for Co/Pt and Ni/Pt multilayers and which have been determined by us by studying the respective multilayers. So taking $K_s^{\text{Co}} = 0.6 \text{ erg.cm}$ and $K_s^{\text{Ni}} = 0.17 \text{ erg.cm}^{-2}$ we calculated the straight line in fig. 1. The excellent agreement confirms our assumption. Fig. 2 shows a similar result for Co-Ni/Au system. It is seen that K_s which is negative for $x=0$, starts becoming more and more positive with the addition of Co. The increase in K_s could be modelled as before. $K_s^{\text{alloy}} = K_s^{\text{Co}}(x) + K_s^{\text{Ni}}(1-x)$, where, K_s^{Co} and K_s^{Ni} are now surface anisotropies found for Co/Au and Ni/Au multilayers. $K_s^{\text{Ni}} = -0.1 \text{ erg.cm}^{-2}$ at 5 K from our earlier work on Ni/Au [10] and $K_s^{\text{Co}} = +0.52 \text{ erg.cm}^{-2}$ at 295 K (T_C being very high this value is expected to be the same at 5 K) from ref. 8. The straight line in Fig. 2 calculated using the above values explain the experimental points very well. These results also show that the contribution from magneto-elastic effects to K_s is negligible if not absent. Because the magnetostriction in Co-Ni alloys vary in a complex manner and even changes sign [10], therefore if there is any contribution from this then one can hardly expect a linear variation. So we are led to conclude that the surface anisotropy in these systems arises mainly from crystal field effects (Néel type) and can be treated as single ion anisotropy. It is noteworthy that the modification of the band structure of Ni by the addition of Co and vice versa does not seem to influence the contribution of the surface atoms to the anisotropy. More theoretical work in this area would probably be welcome.

3.2 M.O. loops

Let us discuss the hysteresis loops taken using polar Kerr rotation at 295 K. With the addition of Co and with decreasing layer thickness, the loops get more and more rectangular and the coercivity also increases.

Fig. 3 and 4 show a typical loop for the $\text{Co}_{0.3}\text{Ni}_{0.7}/\text{Pt}$ sample $(4.5\text{\AA}/15\text{\AA}) \times 10$ and $\text{Co}_{0.7}\text{Ni}_{0.3}/\text{Au}$ sample $(5.4\text{\AA}/15\text{\AA}) \times 16$. However, for the same modulation when the Au buffer layer thickness was increased to 300 $\text{\AA}$, then the coercivity almost doubled and increased to 800 Oe. Detailed structural studies using X-ray diffraction also showed that the interface quality improved significantly when the buffer layer thickness was increased from 100 to 300 $\text{\AA}$ [11]. So some optimisation is needed to improve further the loop characteristics. One can nevertheless notice in Fig.3, the rectangularity of the loop for the Pt system, which is interesting for application in information storage.

Fig. 3 Kerr loop of $\text{Co}_{0.3}\text{Ni}_{0.7}/\text{Pt}$, $(4.5\text{\AA}/15\text{\AA}) \times 10$.

Fig. 4 Kerr loop of $\text{Co}_{0.7}\text{Ni}_{0.3}/\text{Au}$, $(5.4\text{\AA}/15\text{\AA}) \times 16$

3.3 Magneto-optical studies

3.3.1 Co-Ni/Pt system

As we have published already on this system we will give only a very brief description here [12]. Fig. 5 shows the Kerr spectra in $\text{Co}_{0.3}\text{Ni}_{0.7}/\text{Pt}$ for $t = 14$ and $4.5\text{\AA}$. One can notice the large negative peak in the rotation near 4 eV. This peak has been attributed to the effect arising from Co-Pt interactions in Co/Pt and also been observed by us in Ni/Pt [12]. The peak position shifts to lower energy as the Ni concentration increases.

Fig. 5 PKR and PKE spectra in $\text{Co}_{0.3}\text{Ni}_{0.7}/\text{Pt}$ for $t = 14$ and $4.5\text{\AA}$. Inset PKR loop for the latter

Fig. 6 PKR and PKE spectra in Ni/Au, $(6.4/15) \times 25$ (triangles); $x = 0.7$ $(6.4/15) \times 16$ (circles)

It is noteworthy that the rotation of 0.28° at 3 eV (wavelength of interest for high density magneto-optical information storage) of the thinner sample is much higher than that of even Co/Pt with similar magnetic layer thickness and furthermore the T_C is close to 200°C . All these characteristics make this material a very interesting candidate for application.

CONCLUSION

In conclusion, Co-Ni/Pt, Au multilayers have been prepared by evaporation, their magnetic and magneto-optical spectra studied. The Co concentration dependence of the surface anisotropy can be explained by a single ion model. The Au system sample with $x = 0.7$ and $t(\text{Co-Ni}) = 5.4 \text{ \AA}$, shows a rectangular perpendicular loop with coercivity as high as 800 Oe and with polar Kerr rotations close to 0.14° near 2.8 eV. However in the Pt system the multilayer with $x = 0.3$ and $t(\text{Co-Ni}) = 4.5 \text{ \AA}$ shows a perfect rectangular loop with $H_c = 1.2 \text{ kOe}$, a Kerr rotation of 0.28° at 3 eV and a T_C close to 200°C . These characteristics make this material a potential candidate for magneto-optical storage applications in the blue light. In the MO spectra for thin Co-Ni layers the interband transition of Au can be seen but for thicker layers the behaviour is Co-Ni like. The spectra can be well explained in terms of the model proposed.

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