ANISOTROPY AND MAGNETO-OPTICAL PROPERTIES OF SPUTTERED Co/Ni MULTILAYER THIN FILMS

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ANISOTROPY AND MAGNETO-OPTICAL PROPERTIES OF SPURRED CO/Ni MULTILAYER THIN FILMS

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Abstract—Several series of sputtered Co/Ni multilayer thin films have been investigated. The volume and interface contributions to the magnetic anisotropy were determined from magnetization measurements, and the interface anisotropy, \( K_\parallel = 0.23 \pm 0.03 \text{ erg/cm}^2 \), was found to support perpendicular magnetic anisotropy. The anisotropy constant, \( K \), increased with the Au buffer layer thickness, indicating the buffer layer was crucial to the perpendicular magnetic anisotropy. The polar Kerr rotation and coercivity as a function of temperature, and room temperature magneto-optical figure of merit are presented in this paper.

INTRODUCTION

Multilayered structures have attracted much attention in many fields of materials science owing to the possibility of creating new structures and physical properties. One interesting phenomenon observed in magnetic multilayered thin films is the preference for magnetization perpendicular to the film plane: perpendicular magnetic anisotropy (PMA). This property is displayed by several Co/X multilayers, where X is a noble non-magnetic metal such as Pd, Pt, Au, or Ir.\(^1\)\(^2\) Large perpendicular magnetic anisotropy shown in these multilayers makes them potential candidates for MO recording media.

Recently, Co/Ni multilayer thin films were also predicted to have perpendicular magnetic anisotropy,\(^3\) and this was confirmed in e-beam evaporated\(^4\) and sputtered\(^5\) samples. The perpendicular magnetic anisotropy is due to the positive interface anisotropy,\(^6\) and is strongly buffer layer dependent.\(^7\) Our previous paper showed perpendicular magnetic anisotropy for Co/Ni multilayers on Au buffer layers, while the same films on Ag buffer layers showed in-plane anisotropy.\(^8\) This paper reports the anisotropy of sputtered Co/Ni multilayer thin films with Au buffer layers as a function of Co and Ni layer thicknesses. The effect of Au buffer layers is discussed in terms of the anisotropy constant and x-ray measurements. The polar Kerr rotation (as a function of temperature) and the magneto-optic figure of merit are also reported to investigate the possibility of using Co/Ni multilayer thin films as MO recording media.

EXPERIMENTS

Several series of Co/Ni multilayer thin films were prepared by magnetron sputtering. The system was evacuated to below \( 5 \times 10^{-7} \text{ Torr} \) before sputtering, and Ar gas \( (5 \times 10^{-3} \text{ Torr for Au target and } 15 \times 10^{-3} \text{ Torr for Co and Ni targets) } \) was used in the sputtering process. The source to substrate distances were fixed at about 10 cm. A series of \( \times (2 \text{ Å Co/8 Å Ni}) \) multilayers was made with Ni thickness, \( t \), ranging from 2 Å to 40 Å. A second series of \( 8 \times (t \text{ Å Co/8 Å Ni}) \) multilayers was made with Co thickness varying from 1.2 Å to 20 Å. These two series were deposited on 450 Å thick Au buffer layers, which were deposited on glass substrates at room temperature. In the third series, \( 8 \times (2 \text{ Å Co/8 Å Ni}) \) multilayers were deposited onto Au buffer layers of varying thicknesses. (50 Å to 650 Å) The deposition rates for Co, Ni and Au were 0.9 Å/s, 1.3 Å/s and 3.4 Å/s, with corresponding input powers of 30W, 75W, and 40W respectively. Multilayered structures were realized by rotating the substrates above separate guns.

The magnetic anisotropy was determined from the area within the perpendicular (i.e., \( \vec{H} \perp \text{film plane} \)) and parallel (i.e., \( \vec{H} \parallel \text{film plane} \)) magnetization curves\(^1\). An X-ray diffractometer was used to determine the sample and buffer layer textures. Kerr rotation, \( \theta_K \), and Kerr ellipticity, \( \epsilon_K \), were measured at normal incidence over the wavelength range from 3000 Å to 8000 Å.

RESULTS AND DISCUSSION

A. Anisotropy

Magnetic anisotropy can be written as:

\[
KD = K_{V,Co} t_{Co} + K_{V,Ni} t_{Ni} + 2K_i.
\]

where \( K \) is the anisotropy of the sample. \( D \) is the bilayer thickness, \( K_{V,Co} \) and \( K_{V,Ni} \) are volume anisotropies corresponding to the Co and Ni layers respectively, \( K_i \) is the Co/Ni interface anisotropy constant, and \( t_{Co} \) and \( t_{Ni} \) are the Co and Ni layer thicknesses. It follows that \( KD \) changes linearly with \( t_{Co} \) when \( t_{Ni} \) is fixed, that is,
\[ K_D = K_N^{A} t_{Ni} + K(t_{Co}), \]
\[ K_N^{A} = K_N^{A} + 2K_i, \]
\[ K(t_{Co}) = K_N^{A} t_{Ni} + 2K_i. \]

Variation of anisotropy constant \( K \) with Au buffer layers thickness for \( 8 \times (2 \, \text{A} \, \text{Co/8} \, \text{A} \, \text{Ni}) \) multilayers

<table>
<thead>
<tr>
<th>Samples No.</th>
<th>Au buffer layer thickness (Å)</th>
<th>( K ) (10^4 \text{ erg/cm}^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au-1</td>
<td>50</td>
<td>-37</td>
</tr>
<tr>
<td>Au-2</td>
<td>150</td>
<td>-3</td>
</tr>
<tr>
<td>Au-3</td>
<td>250</td>
<td>50</td>
</tr>
<tr>
<td>Au-4</td>
<td>350</td>
<td>60</td>
</tr>
<tr>
<td>Au-5</td>
<td>450</td>
<td>78</td>
</tr>
<tr>
<td>Au-6</td>
<td>550</td>
<td>89</td>
</tr>
<tr>
<td>Au-7</td>
<td>650</td>
<td>100</td>
</tr>
</tbody>
</table>

The 50 Å and 150 Å Au buffer layers could not provide sufficient (111) texture, so the films had in-plane anisotropy, similar to Co/Ni multilayers on Ag buffer layers.\[6]\] Co/Ni multilayers on thick or annealed Au buffer layers\[6]\] had perpendicular magnetic anisotropy, due to the buffer layer's better (111) texture. X-ray measurements support this argument.

X-ray diffraction from Co/Ni multilayer samples showed Au (111) and CoNi (111) peaks. The intensity of these peaks increased with increasing Au buffer layer thickness.
Fig. 3 shows the rocking curve near the Co/Ni (1 11) peak. The peak intensity of the Co/Ni on the 550 Å film is much stronger, and the half width is smaller (less than 80%) than on the Au 150 Å film. This result is used to explain the increase in anisotropy constant, \( K \), with increasing buffer layer thickness. Thicker Au buffer layers provide stronger <111> direction perpendicular to the film plane in the Co/Ni multilayer, which increases the perpendicular anisotropy, \( K \).

C. Magneto-optical Properties

The peak intensity of the Co/Mi on the 550 Å film is much stronger, and the half width is smaller (less than 80%) than on the Au 150 Å film. This result is used to explain the increase in anisotropy constant, \( K \), with increasing buffer layer thickness. Thicker Au buffer layers provide stronger <111> direction perpendicular to the film plane in the Co/Ni multilayer, which increases the perpendicular anisotropy, \( K \).

CONCLUSIONS

Sputtered Co/Ni multilayer thin films show perpendicular magnetic anisotropy when deposited on Au buffer layers. The perpendicular magnetic anisotropy arises from the interface anisotropy, where \( K_i = 0.23 \pm 0.03 \text{ erg/cm}^2 \) for our sputtered samples. Thicker Au buffer layers have better (1 11) texture which improves the (1 11) texture of the Co/Ni multilayers, and consequently increase the perpendicular magnetic anisotropy. The measured magneto-optical properties indicate the Co/Ni multilayers on Au buffer layers are similar to those of other Co-based multilayers, but are not as large in the blue wavelength region as for Co/Pt multilayers.

REFERENCES