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Effects of layer thickness on orientation distribution and magnetic properties of CoCrTa/Cr films

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Evolution of orientation distribution of Co(110) crystal planes was determined by x-ray rocking curves. It has been found that: (i) The full-width at half maximum W of the Co(110) rocking curve decreases with both increasing Cr underlayer thickness d_Cr, and increasing CoCrTa magnetic layer thickness d_Co, especially in the thin layer regime. (ii) For the thin d_Co regime, the interlayer diffusion between the Cr underlayer and the magnetic layer affects the rocking curves and magnetic properties significantly. (iii) Film magnetic properties, e.g., a significant jump in coercivity with increasing magnetic layer thickness in the thin d_Co regime may be related in part to the evolution of the Co(110) orientation distribution. © 1999 American Institute of Physics. [S0021-8979(99)60608-9]

I. INTRODUCTION

Sputtered CoCrM (M=Ta, Pt, etc.) films with Cr underlayer (CoCrM/Cr) are the predominant longitudinal recording media today. It is well known that the Cr underlayer is extremely important for controlling the microstructure of the magnetic layer, including such features as the Co(110)/Cr(002) texture,\(^1\)\(^-\)\(^3\) grain size, and the intergrain interaction,\(^4\)\(^,\)\(^5\) and therefore the magnetic properties of films. Furthermore, since the magnetic layer thickness of films is getting thinner with increasing recording density,\(^7\)\(^,\)\(^8\) studies on the correlation between microstructure and magnetic properties for very thin film media is of crucial importance in surveying the future ultrahigh-density-recording media. However, to our knowledge, thus far rather few works have been published to investigate these aspects.\(^7\)\(^,\)\(^8\)

In this work, the orientation distribution of Co(110) crystal planes of the magnetic layer is studied by x-ray rocking curves,\(^9\)\(^,\)\(^10\) which helps us to understand the evolution of the Co(110)/Cr(002) texture as a function of the Cr underlayer and the magnetic layer thickness, and the correlation between microstructure and magnetic properties of the thin film media.

II. EXPERIMENTS

CoCrTa/Cr films were deposited on the NiP/Al substrate by dc magnetron sputtering. Two series of films were prepared: series A with Cr underlayer thickness d_Cr varied from 0 to 805 Å and CoCrTa magnetic layer thickness d_Co fixed at 300 Å; and series B with a fixed d_Co=350 Å and d_Cr varied from 46 to 823 Å. Magnetic properties were characterized by a vibrating sample magnetometer (VSM). Structural properties were studied by x-ray diffraction with a Cu Kα target.

III. RESULTS AND DISCUSSION

A. Effects of layer thickness and interface on orientation of Co(110) planes

In order to understand the details of the Co(110)/Cr(002) texture, it is necessary to investigate the orientation distribution of Co(110) crystal planes. The conventional x-ray θ–2θ scan only offers information on crystal planes parallel to the film surface, while the x-ray rocking curve can provide an orientation distribution pattern of Co(110) crystal planes.

Evolution of the orientation distribution of Co(110) crystal planes as a function of Cr underlayer thickness d_Cr is shown in Fig. 1. For the film without Cr underlayer, no Co(110) peak is observable in the rocking curve. The full width at half maximum W of the rocking curve narrows with increasing d_Cr, and the Cr layer thickness effect on W is plotted in Fig. 2(a). It is well known that the existence of a thin Cr underlayer (say 75 Å) is a necessary condition to epitaxially grow the Co(110)/Cr(002) texture. Figures 1 and 2(a) show that not only is the Co(110) plane intensity, but also its orientation are improved by increasing the Cr underlayer thickness d_Cr, especially in the case of very thin d_Cr.

Evolution of the orientation distribution of Co(110) crystal planes as a function of the magnetic layer thickness d_Co is shown in Fig. 3. As d_Co increases from 93 to 823 Å, W decreases accordingly, which indicates that the Co(110) planes are becoming more parallel to the film surface as the magnetic layer becomes thicker. The W value increases appreciably with decreasing d_Co from 186 to 93 Å [see Fig. 2(b)], i.e., there are more out-of-plane Co(110) components
as $d_{Co}$ decreases. This behavior is related to the interface effect in the thin $d_{Co}$ case.

Because of the atomic interdiffusion between Cr and Co alloy magnetic layers, the interface region of the magnetic layer is enriched with Cr atoms, which causes lattice strain and composition inhomogeneity because more Cr atoms diffuse along the grain boundaries. Figure 4 shows the magnetic layer thickness effect on magnetization for our films. We found that the magnetization decreases significantly in the thin $d_{Co}$ regime [Fig. 4(a)] and the so-called “dead layer” thickness is 23 Å [Fig. 4(b)]. This implies that the interface region may extend to a significant thickness of the magnetic layer if it is weakly magnetic. The thinner the $d_{Co}$,
It is essential to improve the coercivity of Co films, which are becoming thinner for future ultrahigh-density-recording media, as the magnetic properties in the thin Co regime decrease and the grain size decreases. The decrease of the grain size is associated with the preferred orientation of Co(110) planes and the magnetic layer thickness. In general, the area A under the rocking curve (see Figs. 1 and 3) is associated with the preferred orientation of Co(110) planes and the grain size. The area A tends to increase as the grain size or the preferred orientation of the Co(110) planes increases. The decrease of the grain size (volume) together with the deterioration of the Co(110)/(Cr(002)) texture with decreasing dCo leads to a rapid drop of the A value as seen in Figs. 2(b) and 3. Since the magnetic layer thickness is becoming thinner for future ultrahigh-density-recording media, it is essential to improve the Co(110)/(Cr(002)) texture and magnetic properties in the thin dCo regime.

B. Effect of layer thickness on coercivity behavior

Coercivity is essential in high-density recording and its characteristics are correlated with many factors including the Co(110)/(Cr(002)) texture. Coercivity Hc as a function of the Cr underlayer thickness is demonstrated in Figs. 5(a). This behavior may be associated with the evolution of the orientation distribution of Co(110) crystal planes as a function of dCr as shown in Fig. 1 and 2(a). The significant jump in Hc as dCr varies from 0 to 75 Å is related to the onset of the Co(110)/(Cr(002)) texture, which is confirmed by the fact that W decreases and A increases drastically in this region. As dCr changes from 75 to 805 Å, the slow increase in coercivity is related to the decrease of W and the increase of A.

Figure 5(b) shows the magnetic-layer-thickness dependence of coercivity. For thin magnetic layers, Hc increases dramatically from 460 to 2600 Oe as dCo increases from 46 to 186 Å. This feature may be connected in part with the evolution of the orientation distribution of Co(110) planes as shown in Figs. 2(b) and 3. It is clearly seen in Fig. 2(b), that W decreases (A increases) significantly in this dCo range. The slight decrease in Hc as dCo varies from 248 to 823 Å may be related to the increase of the intergrain interaction with increasing dCo.

Besides texture, coercivity behavior is affected by many other parameters such as intergranation, anisotropy, grain volume, magnetization, etc. and all these parameters change their characteristics with changing dCr and dCo, especially in the thin layer region. For thin dCo films, the interfacial magnetism is of importance in affecting the magnetic properties. The fact that the orientation of the Co(110) planes and the magnetic moment are more scattered in the thin magnetic layer region is an important concern in the design of future ultrahigh-density recording media.

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