Ru$_x$Cr$_{1-x}$/Ta underlayer for Co-alloy perpendicular magnetic recording

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The effects of the Ru$_x$Cr$_{1-x}$/Ta underlayer on the microstructural and magnetic properties of CoCrPtB perpendicular films were investigated. The hcp Ru$_x$Cr$_{1-x}$ (0002) texture was observed to grow perpendicular to the film plane with narrow rocking curves of 2° – 3°. High-resolution transmission electron microscopy indicated epitaxial growth of the CoCrPtB on top of the Ru$_x$Cr$_{1-x}$/Ta underlayer. In-plane x-ray diffraction scans indicate that as the Cr atomic composition increases in the Ru$_x$Cr$_{1-x}$ underlayer, the a-lattice parameter was found to contract more closely matching the CoCrPtB a-lattice parameter [measured with (1120)]. In addition, the rocking curves for the CoCrPtB (0002)-texture induced by the (0002) textured Ru$_x$Cr$_{1-x}$ buffer showed narrowing peaks (4.5° – 3.5°) as the Cr concentration increased from 0% to 40%. © 2002 American Institute of Physics. [DOI: 10.1063/1.1447498]

I. INTRODUCTION

Perpendicular magnetic recording has the potential to achieve recording densities well beyond 100 Gb/in$^2$ areal density. Underlayers to enhance the Co (0002) texture growth perpendicular to the film plane are required to achieve thin Co-alloy layers with good perpendicular anisotropy. Underlayers with hcp structures, principally Ti, have been demonstrated as a means to enhance the growth of hcp Co (0002) texture. Often an amorphous-like transition region forms due to a high elastic strain energy in the initial growth of the Co alloy induced by a large a-lattice mismatch between the underlayer and Co alloy. Ru underlayers grown on freshly cleaved mica substrates by electron-beam evaporation is shown to grow epitaxially CoCr (0002) with narrow rocking curves. Transmission electron microscopy (TEM) image of CoCr$_{19}$Pt$_{10}$ grown on a CoCr$_{25}$Ru$_{25}$/Ta$_{10}$ underlayer was shown to provide a good epitaxially match. In this study Ru$_x$Cr$_{1-x}$/Ta underlayers grown on amorphous Si/SiO$_2$ substrates and the effects on the microstructural and magnetic properties of CoCrPtB perpendicular films were investigated. Cr is added to Ru to further reduce the a-lattice parameter to provide a better lattice match with the CoCrPtB and enhance the (0002) texture.

II. EXPERIMENT

The CoCrPtB and Ru$_x$Cr$_{1-x}$ films were deposited by a dc magnetron sputtering system with base pressure of 5 × 10$^{-7}$ Torr. The Ru$_x$Cr$_{1-x}$ underlayers were cosputtered from pure Ru and Cr targets. The CoCrPtB films were deposited directly from an alloy target. The substrates were 3 in. Si wafer coated with 100 nm thermally grown amorphous SiO$_2$ layer. The sputter power density of the CoCrPtB, Ta, Ru, and Cr targets was between 14 and 2 W/cm$^2$. The sputtering Ar pressure was 3 mTorr for the Ru$_x$Cr$_{1-x}$/Ta and 5 mTorr for the CoCrPtB. Substrate temperature for the film growth was kept at 280 °C by a resistive heater. Crystallographic orientations of the thin films were studied by a Philips X’Pert x-ray diffractometer (XRD) with Cu Kα radiation. The microstructures of the thin films were investigated by a Philips EM 420T transmission electron microscope (TEM). The magnetic properties were measured by a vibrating sample magnetometer (VSM).

III. RESULTS AND DISCUSSION

The symmetric 2θ/θ XRD spectra of the Ru$_x$Cr$_{1-x}$/Ta films are shown in Fig. 1. For all Cr compositions a dominant (0002) and (0004) peaks are observed. As the Cr concentration increases there is a steady shift of both peaks to higher 2θ values. The broad peak occurring at 34° is due to the Ta underlayer. The angular dispersion of the Ru$_x$Cr$_{1-x}$/Ta and the CoCrPtB (0002) orientations were investigated by

![FIG. 1. 2θ/θ XRD scans of Ru$_x$Cr$_{1-x}$/Ta 5 nm with $X = 100\%$, 70\%, and 50\%.](image)

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rocking curves. The full width at half maximum (FWHM) results from these rocking curve scans are graphed in Fig. 2. It can be seen that both Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} and CoCrPtB FWHMs steadily decrease with the addition of Cr. The CoCrPtB films have rocking curves FWHM that match the Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} underlayer FWHM indicated that heteroepitaxial growth of the CoCrPtB is occurring.

The \textit{a}-axis lattice parameter can be calculated using in-plane scans of the (11\bar{2}0), see Fig. 3. The CoCrPtB maintained a constant \textit{a}-axis length of 2.552 Å while the Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} show a shift to smaller \textit{a}-axis lattice parameter with increasing Cr. The lattice misfit between CoCrPtB and Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} improves from 7.3\% to 5.2\% as the Ru composition goes from 100\% to 60\%. The \textit{c}–axis length of the unit cell was calculated from the (0004) peak position in the 2\theta/\theta scan. The values of the \textit{a} and \textit{c}-axis lattice parameters as well as \textit{c}/\textit{a} ratio of the Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} films are listed in Table I. The decrease of the \textit{a} and \textit{c} lattice is nearly linear and maintains a \textit{c}/\textit{a} ratio near 1.58.

VSM measurements on the \textit{x}=100\%, 80\%, and 60\% were done on the same samples sent for TEM analysis. The normalized perpendicular hysteresis loops show a decrease in coercivity (\textit{H}_c) with increasing Cr, see Fig. 4. However, measurements with the field applied in the plane of the sample showed all three samples saturating (\textit{H}_k\textsubscript{eff}) near 8.5 kOe. The magnetic moment was measured at 509, 501, and 476 emu/cm\textsuperscript{3} for \textit{x}=100\%, 80\%, and 60\% respectively. The Cr diffusion from the underlayer into the Co alloy has been reported for longitudinal media\textsuperscript{8} and is expected to be the cause of the decrease in \textit{H}_c in these materials.

High-resolution cross-sectional transmission electron micrograph (TEM) images show distinct Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}}/CoCrPtB (\textit{x}=100\%, 80\%, and 60\%) interface with continuity of the (0002) plane stacking over extensive region. Figure 5 shows a representative image for \textit{x}=60\%. No initial amorphous like transition regions are seen in any of the images. The Ta layer contains small (~1–2 nm) randomly oriented body-centered-tetragonal crystallites. Columnar Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} grains are visible originating at the Ta interface. Columnar grain diameters are 12–15 nm. Continuity of the (10\bar{1}0) lattice planes across the CoCrPtB/Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} interface are seen in

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<th>\textit{a} (Å)</th>
<th>\textit{c} (Å)</th>
<th>\textit{c}/\textit{a}</th>
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TABLE I. The lattice parameters of \textit{a} and \textit{c} axes as well as \textit{c}/\textit{a} ratio for Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}}.

![FIG. 2. Angular dispersion of (0002) Ru and Co peaks for Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} (50 nm)/Ta (5 nm) and CoCrPtB (50 nm)/Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} (10 nm)/Ta (5 nm).](image)

![FIG. 3. In-plane XRD scans of CoCrPtB (50 nm)/Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} (10 nm)/Ta (5 nm) for \textit{x}=100\%, 80\%, and 60\%.](image)

![FIG. 4. Cross-sectional TEM image of Ta CoCrPtB (50 nm)/Ru\textsubscript{x}Cr\textsubscript{1-\textsubscript{x}} (10 nm)/Ta (5 nm) sample.](image)
IV. CONCLUSION

Adding up to 40% of Cr to the Ru$_x$Cr$_{1-x}$/Ta underlayers has been shown to reduce the angular dispersion in the (0002) texture. Heteroepitaxial growth of CoCrPtB layers as then successfully achieved on the Ta/Ru$_x$Cr$_{1-x}$ seed layer. The heteroepitaxial relationships have been confirmed by XRD and TEM. Improved c-axis angular dispersion of (0002) CoCrPtB magnetic layers was observed as the Cr concentration was increased from 0% to 40%. Stacking faults were observed in the hcp CoCrPtB thin films deposited onto all Ru$_x$Cr$_{1-x}$ underlayers.

**FIG. 5.** Perpendicular VSM hysteresis loops of CoCrPtB (50 nm)/Ru$_x$Cr$_{1-x}$ (10 nm)/Ta (5 nm) for $X = 100\%$, 80%, and 60%.

individual growth columns. The grains extend up through the CoCrPt layer, although interruptions in the desired hcp stacking are visible.