CoCrPtTa/Ti Perpendicular Media Deposited at High Sputtering Rate

Bin Lu, Timothy Klemmer, Sakhrat Khizroev, J. Kent Howard, Dmitri Litvinov, Anup G. Roy, and David E. Laughlin

***Abstract*—CoCrPtTa/Ti bilayer thin films have been sputter deposited onto both glass and Al substrates under high sputtering rate in a manufacturing environment. From microstructure and magnetic property studies, it is found that Cr segregation and stacking fault density are the two major issues in obtaining high quality perpendicular media. (0002) texture orientation spread and c lattice parameter remain almost constant within the variation range of the deposition parameters, though there is a small distinction between the media on glass and those on Al substrates.**

***Index Terms*—Co-alloy, magnetic properties, microstructure, perpendicular media, sputtering rate.**

I. INTRODUCTION

CO-ALLOY/Ti BILAYERS have been studied for two decades for perpendicular magnetic recording media [1], [2] To obtain desirable magnetic and recording properties, many materials and process issues have to be considered. From a compositional point of view, Cr has been found to exchange de-couple the magnetic grains at elevated temperature [3], [4] as it does in longitudinal media, while Pt was used to slow the decrease of $K\mathrm{u}$ caused by adding more nonmagnetic elements [5]. Therefore a CoCrPtTa alloy is believed to have low $M\mathrm{s}$ and relatively high $K\mathrm{u}$ to give squareness $(S = M\mathrm{r}/M\mathrm{s})$ close to one, which is very critical to media thermal stability and noise reduction.

On the other hand, deposition parameters, such as, sputtering power (rate), substrate temperature, and film thickness, etc. can significantly influence the microstructure and consequently vary the properties of the magnetic layer. In order to enhance Cr segregation and epitaxial growth of CoCr-alloys on Ti, while reducing angular distribution of the (0002) texture, fcc phase, stacking fault density, and the volume of the initial layer, CoCr-alloy films should be deposited at very low sputtering rate [6]. However, this is not practical in a manufacturing process, where sputtering power can be as high as 4 kW for a 84 mm-diameter disk.

In this research, CoCrPtTa/Ti thin films are DC-magnetron sputter deposited at high rates. X-ray diffraction (XRD) and Transmission Electron Microscopy (TEM) were used to study the microstructure of the films. A polar magneto-optical Kerr effect (PMOKE) looper was used to study the magnetic properties. The purpose of this study is to develop practical approaches of making CoCrPtTa thin film at high sputtering rate.

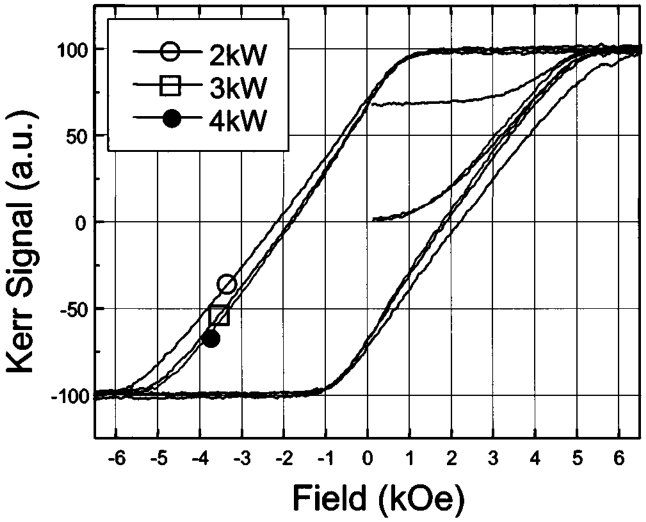

Fig. 1. Hysteresis loops of CoCrPtTa films deposited at different rate.

II. EXPERIMENT

Ti and CoCrPtTa films were sputter deposited onto 84 mm glass substrates by DC magnetron sputtering. Ar pressure was maintained at approximately 20 mTorr for all the samples. The substrate temperature varied from 100 to 300°C and the sputtering power varied from 2 to 4 kW. To study the effect from the underlayer, the Ti thickness was changed from 3 to 10.5 nm. Hysteresis loops were measured by a home made PMOKE looper. Crystallographic texture was investigated by a Philips X'pert diffractometer. A Philips EM420 TEM was used for plan-view and cross-section imaging and electron diffraction.

III. RESULTS AND DISCUSSION

For the sputtering power study, bilayers of CoCrPtTa(50 nm)/Ti(15 nm) were made on NiP plated Al substrates at 250°C. The deposition rate at 3 kW is about 12.8 nm/s. Fig. 1 shows PMOKE loops of the three samples, while Fig. 2 plots the variation of coercivity $(H\mathrm{c})$ and squareness (S) as a function of the sputtering power.

It can be seen that an increase of deposition power causes a large drop of $H\mathrm{c}$. On the other hand, S does not drop much. From Fig. 1, it can also be seen that coercive squareness increases. This suggests that inter-granular exchange coupling is

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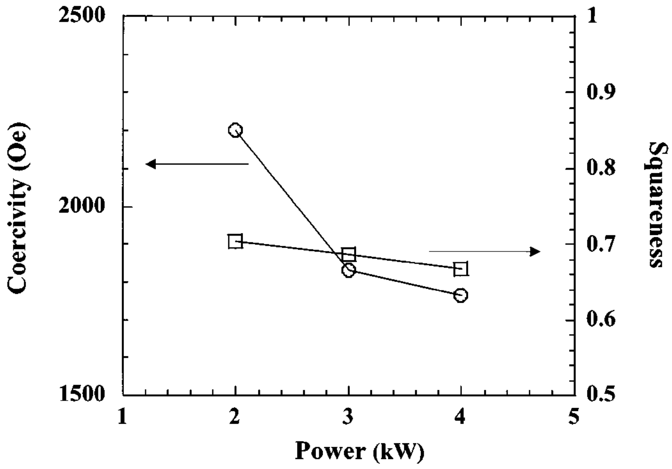

Fig. 2. Change of coercivity (Hc) and squareness (S) with deposition rate.

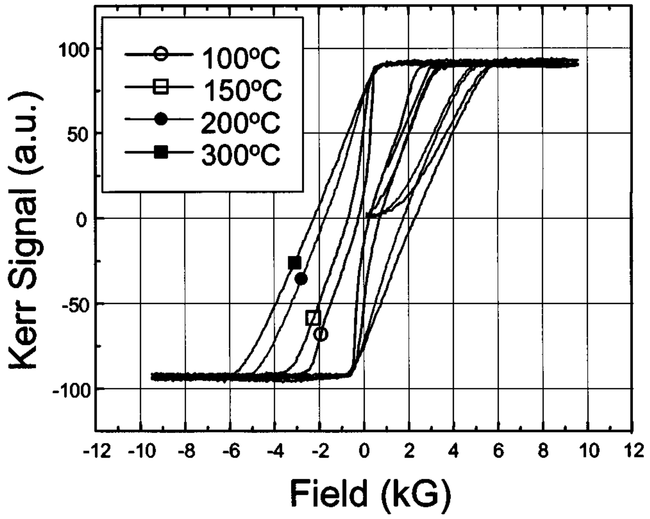

Fig. 3. Hysteresis loops of CoCrPtTa films deposited at different temperature.

enhanced as the sputtering rate increases. The FWHM of the XRD rocking curves of the CoCrPtTa (0002) peak only varies from 7.1 to 6.8 degrees. Also, the (0002) peak position and intensity in a θ–2θ scan remains almost the same, in which case, the c lattice parameter changes only from 0.4174 to 0.4176 nm. This indicates that the deterioration of the magnetic properties is not due to weakening of (0002) texture or crystallinity. It is most likely due to a lower degree of Cr segregation. An increase of stacking fault density might be another reason for the coercivity decrease because when the CoCrPtTa is deposited at a faster speed there is not only less time for Cr to diffuse to the grain boundaries but also more chance of atomic misplacement.

CoCrPtTa (50 nm)/Ti (15 nm) films have also been deposited at different temperatures on glass substrates at 3 kW sputtering power. Fig. 3 shows the hysteresis loops of the four samples. At the temperatures below 200°C the loops curve inward demonstrating reluctance of the film to be demagnetized, which is a strong indication of inter-granular exchange coupling. This is because Cr segregation is not complete at low temperature, as it can be seen that the loop is moving toward having constant coercive squareness at 300°C. At this temperature the Cr segregation is good enough to magnetically decouple the grains, therefore the film has the highest Hc.

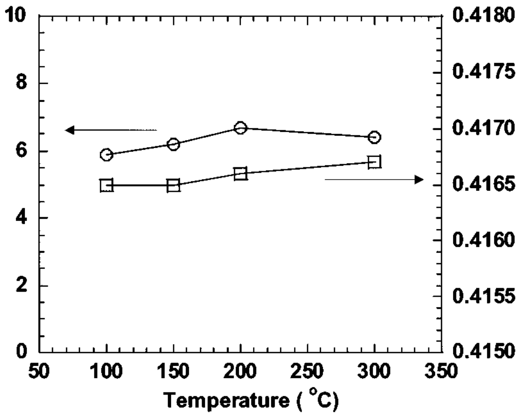

Fig. 4. Dependence of FWHM of XRD rocking curves and c lattice parameter on substrate temperature.

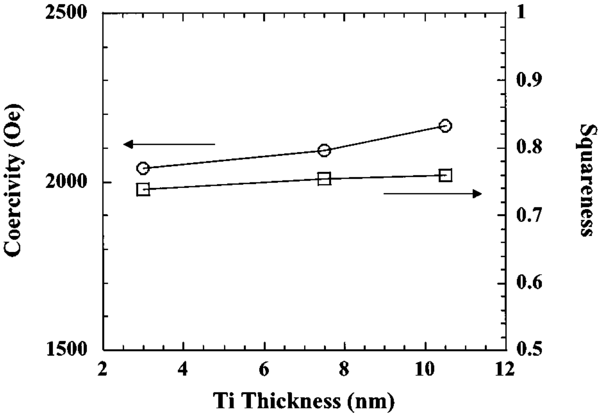

Fig. 5. Dependence of Hc and S with Ti layer thickness.

Fig. 4 plots the dependence of orientation spread and c lattice parameter on substrate temperature. Both of them keep quite constant through the temperature range. This indicates that the curvature of the hysteresis loop is not due to misorientation of the Co-alloy grains. In this case the degree of (0002) texture and crystal structure is less related to the magnetic property variation. It seems that chemical segregation plays a dominant role.

It is interesting to notice that the c lattice parameter of CoCrPtTa is always about 0.4166 nm on glass substrates, while it is around 0.4175 nm on NiP/Al substrates. This could result from the difference in thermal expansion coefficient of the two substrates. Hence the stress level is different after thermal cycling during deposition. It is also interesting to observe that the FWHM of the film on NiP/Al substrates is always 1° larger than that of the film on glass substrates. This is most likely because the surface of the former is a little rougher than the latter.

Fig. 5 shows the variation of Hc and S with the Ti layer thickness. Samples were deposited at 2 kW and 250°C on glass substrates with the magnetic layer kept at a thickness of 50 nm.

The plot shows that the Ti thickness has a weaker impact in improving the magnetic properties of the CoCrPtTa layer as compared with sputtering power and substrate temperature. It

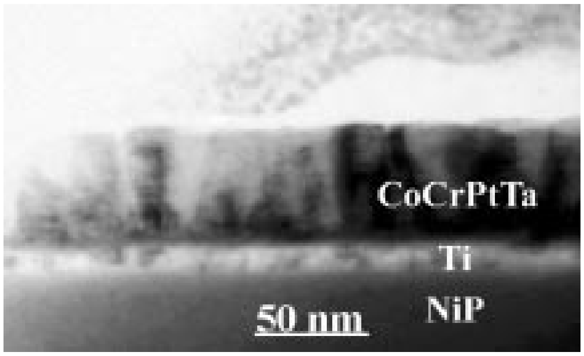

Fig. 6. Cross-section TEM image of the bilayer.

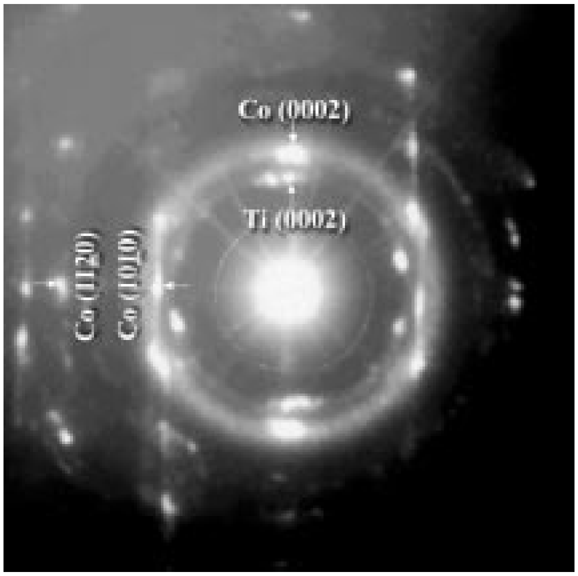

Fig. 7. Cross-section electron diffraction pattern (EDP) of CoCrPtTa/Ti on NiP/Al substrate.

is also found that Ti thickness has little influence on the shape of the hysteresis loop. The XRD results consistently show that there is almost no change in orientation spread (6.1°) and c lattice parameter (0.4166 nm). All these data suggest that the magnetic layer can barely see the difference in Ti layer, whose texture is believed to improve as it grows thicker, as reported previously [6]. This indicates that there is no epitaxial growth of CoCrPtTa on the Ti layer, i.e., CoCrPtTa grains re-nucleate at the Ti-CoCrPtTa interface.

The re-nucleation can be observed from a cross-sectional TEM image as shown in Fig. 6. The sample is made at a power of 2 kW on NiP/Al substrate. Its MOKE loop has been plotted in Fig. 1. From the image it can be seen that the diffraction contrast is not continuous across most of the Ti/CoCrPtTa interfaces. This indicates that there is almost no orientation relationship between the CoCrPtTa grains and Ti grains right underneath.

The corresponding cross-sectional electron diffraction pattern (EDP) in Fig. 7 also shows that Ti grains are more randomly oriented than CoCrPtTa grains. The diffusive ring next to Co (0002) reflection is from the amorphous NiP. The streaks superimposed on CoCrPtTa (101L) (where $L = 0, 1, 2\ldots$) and (202 L) reflections are caused by stacking faults. Hence, they are parallel to the (0002) direction and there are no streaks on (1120) and (0002) diffraction spots, as predicted by Warren[7]. It is worth noting that there are no streaks on Ti (101L) reflections. This is consistent with the stacking fault energy being much higher in Ti than in the Co-alloy, which may be somewhat beneficial for the Co-alloy to nucleate on a hcp Ti layer rather than on an amorphous or fcc (111) surface.

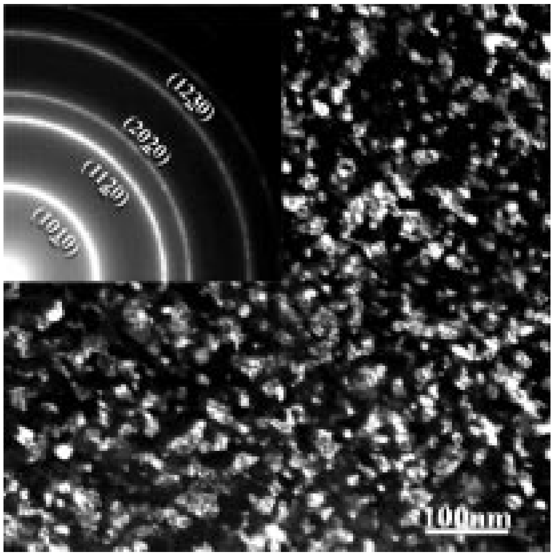

Fig. 8. Plan-view dark field image and EDP of CoCrPtTa/Ti on NiP/Al substrate.

There are no Co-alloy fcc $\{200\}$ reflections present in the cross-section EDP suggesting that the film contains very few fcc grains. However, the strong intensity of stacking fault streaks confirms that even at the lower sputtering power (2 kW) there is inevitably a large amount of stacking faults inside the CoCrPtTa grains.

Fig. 8 shows the plan-view TEM dark field image and EDP of the same sample as in Figs. 6 and 7. The grain size can be estimated as 13 nm, which is quite small for a 50 nm thick film. This is due to the high sputtering rate, which gives rise to a high nucleation rate at the CoCrPtTa and Ti interfaces. The plan-view EDP shows very clearly that only the diffraction rings perpendicular to the (0002) texture axis are present indicating that there are no randomly oriented CoCrPtTa grains in the magnetic layer.

IV. CONCLUSION

In conclusion, CoCrPtTa/Ti bilayer thin films deposited at high sputtering rate have been studied. The grain size is about 13 nm for a 50 nm thick film due to the high deposition rate. Stacking faults are found to exist in the Co-alloy grains. It is found that magnetic properties are very sensitive to the sputtering power and substrate temperature, but less sensitive to Ti layer thickness. At this high deposition rate, there is less time for Cr segregation and a higher chance for stacking faults to form inside the Co-alloy. Therefore, temperature and sputtering power should be optimized carefully to obtain the best quality of perpendicular media.

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