HITPERM soft magnetic underlayers for perpendicular thin film media

S. Kumar,[a] T. Ohkubo, and D. E. Laughlin
Data Storage Systems Center, Department of Materials Science and Engineering, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213

In this work, a class of nanocrystalline alloys, HITPERM (Fe, Co)–M–B–Cu (M=Zr, Hf, Nb, and etc.) found to exhibit excellent soft–magnetic properties in bulk were used as soft–magnetic underlayers for perpendicular thin film media. A Ti intermediate layer was used to promote a (00·2) texture and exchange de-couple the magnetic layer (CoCrPt) from the soft-magnetic underlayer. Specimens were deposited at both room and elevated temperature (~ 250 °C). The results of x-ray diffraction and transmission electron microscope structural studies, along with magnetic properties are presented. © *2002 American Institute of Physics.* [DOI: 10.1063/1.1452280]

INTRODUCTION

As recording technology progresses to higher areal bit densities, the conventional longitudinal media is predicted to suffer eventually from superparamagnetic instabilities.[1] While reducing the bit cell aspect ratio is believed to be able to extend the superparamagnetic limit up to 100 Gbit/in^2,[2] a shift to a different technology will be necessary to achieve recording densities beyond about 200 Gbit/in^2. Perpendicular recording technology, being technically close to conventional longitudinal recording and the least difficult to transition to, is a strong candidate for ultrahigh density recording.

One of the key aspects of perpendicular recording that makes it superior to longitudinal recording with respect to superparamagnetic effects is the utilization of media with a soft underlayer (SUL).[2] By exploiting the higher write fields and stronger playback signals due to the use of a SUL and due to the use of a thicker recording layer, significantly higher densities are possible than in conventional longitudinal media.

In this work, a class of nanocrystalline alloys, HITPERM $(Fe,Co)_{88}M_7B_4Cu_1$ (M=Zr, Hf, Nb, and etc.) found to exhibit excellent soft–magnetic properties[3] are used as soft–magnetic underlayers. The results of the analysis carried out on these films are reported here.

EXPERIMENTAL PROCEDURE

Soft–magnetic HITPERM films of varying thickness (50–400 nm) were deposited on glass substrates using a Leybold–Heraeus Z400 rf–sputtering system with an alloy target of composition $(Fe_{0.7}Co_{0.3})_{88}Zr_7B_4Cu_1$. 20-nm-thick CoCrPt recording layer films were deposited on the soft underlayers both with and without a Ti intermediate layer. The Ti layer serves to promote (00·2) texture[4] and exchange decouple the soft underlayer from the magnetic layer. The Ti thickness was varied (3–20 nm). The entire process was carried out under conditions of fixed substrate temperature (RT, and ~250 °C) and sputtering Ar pressure (10 mTorr). X-ray diffraction (XRD) structural studies were carried out using a Philips PW 3040 Expert X-ray machine. A DMS vibrating sample magnetometer was used to investigate the magnetic properties (coercivity, H_c and saturation magnetization $4\pi M_s$) at room temperature. A Philips TECNAI F20 transmission electron microscope (TEM) was employed to study the film's microstructure.

RESULTS AND DISCUSSION

XRD scans on the HITPERM films deposited at RT showed a broad amorphous hump indicating an amorphous phase in these films. However, films grown at 250 °C showed weakly crystalline bcc peaks in place of the amorphous hump and especially at larger thickness. This implies that the films become more crystalline at elevated temperature and at larger thickness. This was further corroborated by TEM micrographs obtained from films grown at the two different temperatures. High-resolution electron microscope (HREM) image and diffraction pattern for the RT deposited 100 nm HITPERM film is shown in Fig. 1. The HREM image shows medium range ordered regions[5] as lattice fringe regions, as shown in the encircled area. The SAED shows a halo–ring pattern, indicating the existence of the amorphous phase.

Figure 2 gives the bright–field image and SAED pattern from the film deposited at 250 °C. The bright–field image shows nanocrystalline particles in an amorphous matrix. The SAED shows the presence of bcc Fe (or FeCo) and cubic

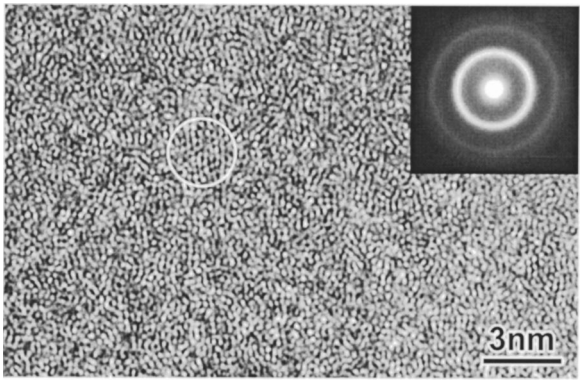

FIG. 1. HREM image and SAED pattern of RT-deposited 100 nm HITPERM film.

[a]Electronic mail: kumar2@andrew.cmu.edu

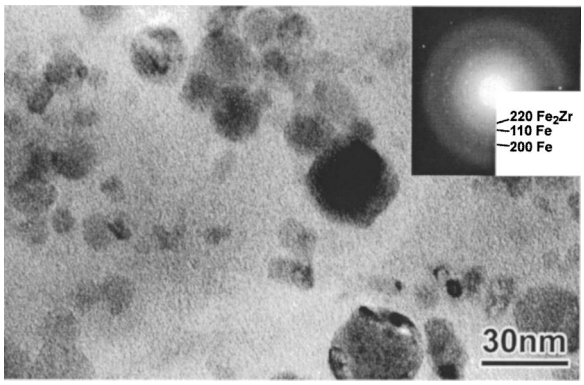

FIG. 2. Bright–field image and SAED pattern of 100 nm HITPERM film deposited at 250 °C showing nanoparticles in an amorphous matrix.

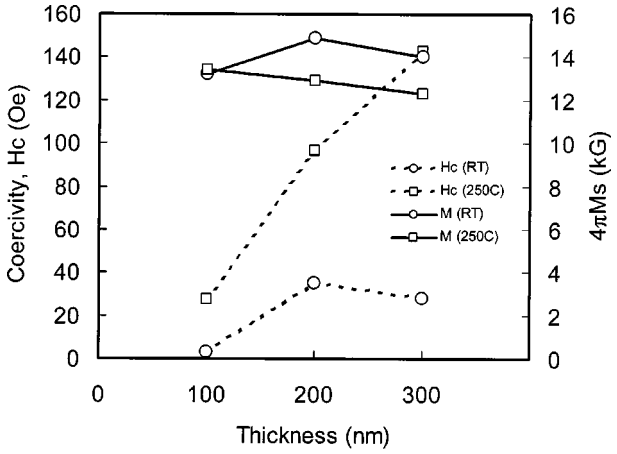

FIG. 4. Magnetic properties of sputtered HITPERM film.

Fe_2Zr. Figure 3 shows two nanoparticles and their corresponding Fourier transformed image. Bulk HITPERM alloys made by rapid solidification processing have shown crystallization to occur at a higher temperature.[3] However, surface diffusion rates are faster during sputtering. This could be the reason why we see crystallization at a lower temperature of 250 °C.

Figure 4 shows the magnetic properties of these films. The 100 nm film grown at 250 °C exhibits higher coercivity than the film grown at RT, while the saturation magnetization $4\pi M_s$, is about the same. This is attributed to the higher average magnetic anisotropy of the nanocrystalline phase compared to the amorphous phase and due to the presence of the nonmagnetic Fe_2Zr particles. For both sets of films, the soft magnetic properties degraded with increase in film thickness. This implies that as thickness increases, and the crystalline grains grew, the strong exchange coupling among the nanograins may be reduced by the increase of separation.

XRD θ–2θ scans performed on a series of Ti/HITPERM films deposited at RT, where the Ti layer thickness was varied, are shown in Fig. 5 for a HITPERM layer thickness of 100 nm. Ti remains amorphous for thickness less than 10 nm. For the films with thickness greater than 10 nm, the detectable peaks are hcp Ti (10·0) and (00·2), which indicates that the Ti grows with a bitexture on amorphous HITPERM when deposited at ambient temperatures.

Figures 6 and 7 are XRD scans for CoCrPt/Ti/HITPERM films deposited at RT and 250 °C, respectively. It was seen that CoCrPt showed good hcp (00·2) texture on Ti (on amorphous HITPERM) when grown at RT but grew poorly (on nanocrystalline HITPERM) at 250 °C. Furthermore, for the RT grown films, the peak intensity of the (00•2) texture reached a maximum at a Ti layer thickness of 5 nm

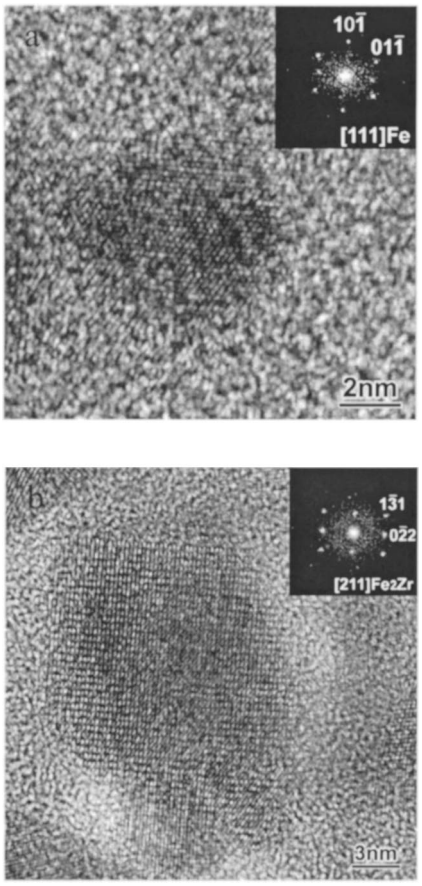

FIG. 3. HREM image and the corresponding Fourier transformed image of two nanoparticles in the 100 nm HITPERM film deposited at 250 °C. (a) Nanoparticle of Fe (or FeCo) with bcc [111] zone axis. (b) Nanoparticle of Fe_2Zr with [211] zone axis.

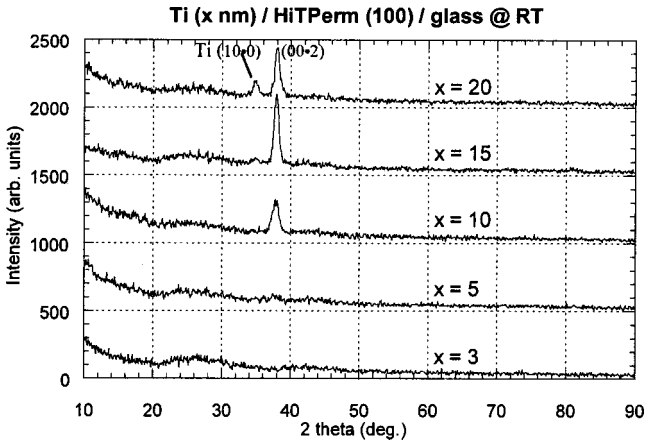

FIG. 5. XRD scans of Ti / HITPERM films deposited at RT showing bitextured Ti.

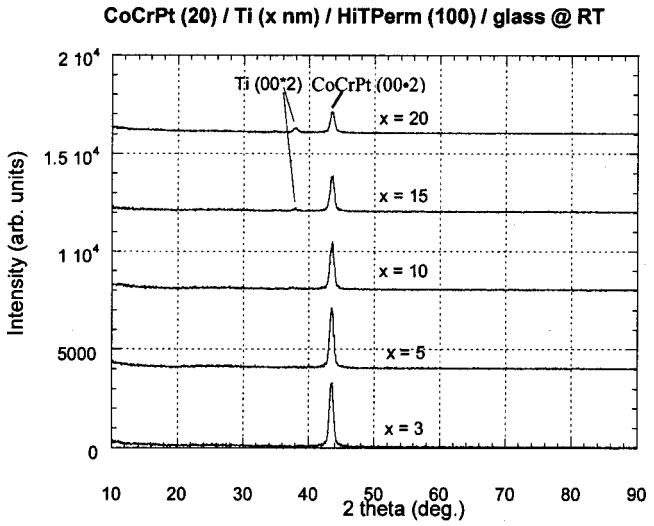

FIG. 6. XRD scans of CoCrPt / Ti / HITPERM films deposited at RT with HITPERM (nominal) layer thickness of 100 nm and varying Ti layer thickness.

and dropped thereafter. It was thus seen that an amorphous HITPERM underlayer promoted better texture than a nanocrystalline underlayer.

Without the Ti intermediate layer, CoCrPt films deposited directly over HITPERM (100–300 nm thickness) at RT, showed strong hcp (00•2) texture that remained unchanged

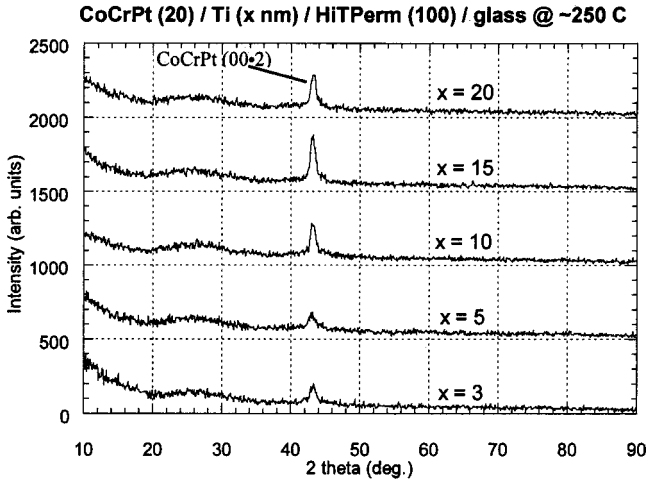

FIG. 7. XRD scans of CoCrPt / Ti / HITPERM films deposited at ~ 250 °C with HITPERM (nominal) layer thickness of 100 nm and varying Ti layer thickness.

with HITPERM layer thickness. But the same films when deposited at 250 °C exhibited very poor texture. So as in the case of the CoCrPt/Ti/HITPERM films, the CoCrPt layer grew better on amorphous HITPERM underlayer than on nanocrystalline HITPERM.

CoCrPt (40 nm)/Ti (40 nm) films were also deposited on glass substrates at both RT and 250 °C. XRD showed more strongly (00•2) oriented hcp CoCrPt on hcp (00•2) oriented Ti, when deposited at 250 °C, than at RT. Thus Ti, when deposited directly onto glass remained amorphous at RT but exhibited hcp (00•2) orientation at 250 °C.

CONCLUSIONS

HITPERM was seen to exhibit nanocrystalline particles when deposited at elevated temperature (~250 °C) but was amorphous at RT. The Ti intermediate layer was seen to grow well on the amorphous HITPERM (at RT) but not on the nanocrystalline HITPERM (at ~250 °C). This is attributed to the random distribution of the nanocrystalline alloys and the subsequent formation and random distribution of the Ti crystals. Ti was also seen to grow with a stronger hcp (00•2) orientation when deposited directly onto glass at elevated temperature (~250 °C) than at RT. The CoCrPt magnetic layer grew with strong (00•2) orientation on strongly (00•2) textured Ti. Therefore, CoCrPt exhibited strong texture when deposited onto Ti (on amorphous HITPERM) at RT or onto Ti (on glass) at elevated temperature (~250 °C). CoCrPt also showed strong (00•2) orientation when grown directly on amorphous HITPERM at RT, but very poor one on nanocrystalline HITPERM at elevated temperature (~250 °C).

We conclude that when the HITPERM underlayer has a mixed nanocrystalline microstructure consisting of amorphous and crystalline phases, or when the Ti intermediate layer is only partially crystalline, the subsequently deposited magnetic layer exhibits poor texture. But on an amorphous HITPERM underlayer and amorphous Ti intermediate layer, or on just strongly textured Ti, the Co magnetic layer grows with a strong texture.

ACKNOWLEDGMENT

The authors thank the DSSC of CMU for financial support of this research program.

[1] S. H. Charap, P.-L. Lu, and Y. He, IEEE Trans. Magn. **33**, 978 (1997).
[2] H. N. Bertram and M. Williams, IEEE Trans. Magn. **36**, 4 (2000).
[3] M. A. Willard, M. Q. Huang, D. E. Laughlin, M. E. McHenry, J. O. Cross, V. G. Harris, and C. Franchetti, J. Appl. Phys. **85**, 4421 (1999).
[4] I. S. Lee, H. Ryu, H. J. Lee, and T. D. Lee, J. Appl. Phys. **85**, 6133 (1999).
[5] Y. Hirotsu and R. Akada, Jpn. J. Appl. Phys., Part 1 **23**, 479 (1984).