MgO seed layers for CoCrPt/Cr longitudinal magnetic recording media

Li-Lien Lee, B. K. Cheong,[a] D. E. Laughlin, and D. N. Lambeth
Data Storage Systems Center, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213

(Received 17 May 1995; accepted for publication 2 October 1995)

Sputter deposited MgO thin films with the B1 crystal structure and (002) film texture are used as seed layers to improve the texture and magnetic properties of the CoCrPt/Cr magnetic thin films on glass substrates for longitudinal recording. The desired (002) textured Cr underlayers are usually obtained by sputtering Cr onto heated substrates. However, it is found that the MgO seed layers can induce the (002) film texture in the Cr underlayers without using a heated substrate and hence, the overlying CoCrPt films are formed with the $(11\bar{2}0)$ texture. Vibrating-sample magnetometry measurements show greatly improved in-plane coercivities that are suitable for future high density recording media can be easily obtained.

To fully utilize the magnetocrystalline anisotropy of HCP cobalt alloy longitudinal magnetic recording films, it is desirable to have a thin film crystallographic texture such that the easy magnetization *c* axis of the HCP Co based alloy is lying predominately in the plane of the film. This can be achieved by depositing the Co film on a texture enhancing underlayer. Many different underlayer materials have been reported in the literature.[1–6] Among them, the most successful underlayer is pure Cr. The in-plane *c*-axis texture of the Co alloy thin films can be improved by adjusting the sputtering conditions of the underlayer or by employing a seed layer. A seed layer is a thin film layer that is deposited between the substrate and the underlayer. In general, motivations for using a seed layer include the following: (1) isolation of the thin film from possible substrate contaminations; (2) facilitation of infrared heating of glass substrates; (3) modification of the topography of the substrate; (4) inducing a preferred crystallographic texture to the underlayer. For longitudinal recording, seed layers (sometimes called precoatings) such as Ti, Ti_3P, $TiSi_2$, Cr, C, Ta, W, and Zr[7–10] have been used. Varying degrees of success have been reported; however, the industry is still in the process of searching for a better seed layer.

MgO is an ionic crystal that has the B1 (NaCl-type) crystal structure with a lattice constant of 0.421 nm (Fig. 1). It has excellent high temperature chemical stability. The melting point is nearly 3000 °C. It has been shown by Nakamura and Futamoto[11] that a Cr film deposited on a single crystal MgO (002) tends to have its (002) plane lying parallel to the film plane due to the heteroepitaxial growth. Subsequently, Futamoto *et al.*[12] have demonstrated a $(11\bar{2}0)$ bicrystalline longitudinal magnetic recording medium, CoCrPt/Cr, formed on a MgO single crystal disk substrate and studied its recording characteristics. However, the disk has only limited usefulness because of its anisotropic magnetic properties around the circumference of the single crystal disk. A strong (002) textured polycrystalline MgO film with random in-plane orientation is more desirable in practice.

All films in this study were rf diode sputter deposited in a Leybold–Heraeus Z-400 system on 1 in. square Corning 7059 glass substrates without preheating. Depositions were performed at a fixed ac power of 2.3 W/cm ^{2} with a 10 mTorr Ar gas sputtering pressure. Energy-dispersive x-ray spectrometer analysis of the magnetic CoCrPt film determined the composition to be 72 at. % Co–10 at. % Cr–18 at. % Pt. All the CoCrPt films reported were maintained at a constant thickness of 40 nm by controlling the pre-calibrated deposition time. The films' thicknesses were also crosschecked with a Tencor profilometer.

Sputter-deposited MgO films can easily grow to have the (002) film texture because the closest packed (002) plane has the lowest surface energy.[13] When 20 nm thick MgO seed layers are deposited prior to Cr underlayers, the resulting texture of the underlayers is a strong (002), whether or not the substrate is heated. This is the often sought after underlayer texture because the $(11\bar{2}0)$ textured/Co alloy film tends to grow epitaxially on it. The use of MgO seed layers allows us to achieve the desired (002) texture in the Cr underlayers without resorting to an external substrate heating device.

Figure 2 shows the transmission electron microscopy (TEM) bright field micrograph of a 100 nm thick MgO film and its electron diffraction ring pattern. The ring pattern matches well with the expected diffraction pattern of a B1

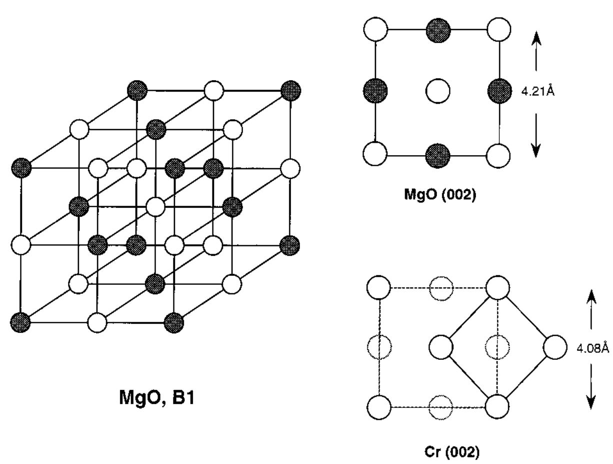

FIG. 1. Crystal structure of the MgO and the lattice match of the atomic planes MgO (002) and Cr (002).

[a]Present address: Materials Design Lab., Korean Institute of Science and Technology, Seongbuk-ku, Hawolgok-dong 39-1, Seoul 136-791, Korea.

 0003-6951/95/67(24)/3638/3/$6.00

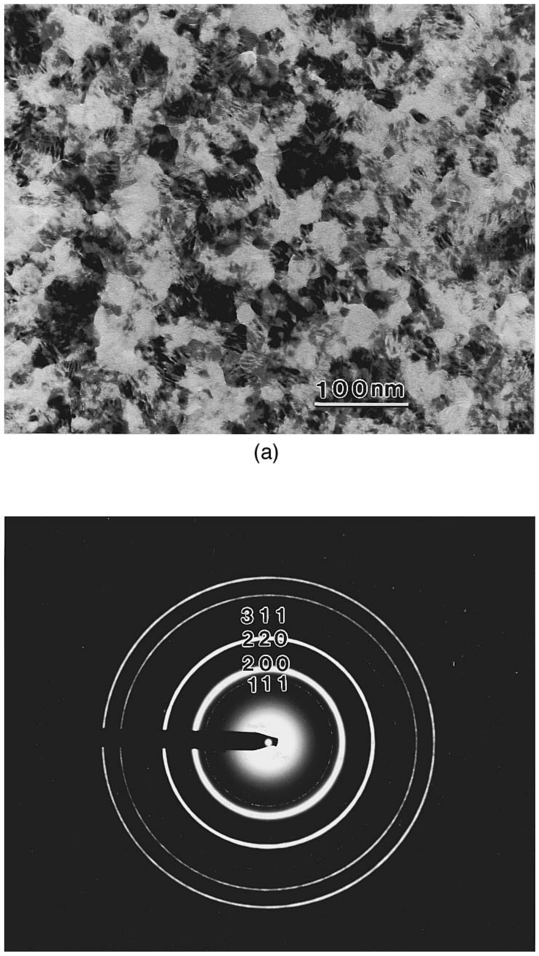

FIG. 2. TEM bright field image of a 100 nm thick MgO film (a) on a glass substrate and (b) along with its electron diffraction pattern.

polycrystalline material with a lattice constant of 0.423 nm. The grain size is estimated to be about 45 nm. The fine structures observable within the grains are defects that are abundant, indicating that there may be room for further improvement if we fine tune the sputtering processes.

Figure 3 is a plot of the x-ray diffraction spectra of the CoCrPt(40 nm)/Cr(100 nm) films with various thicknesses of

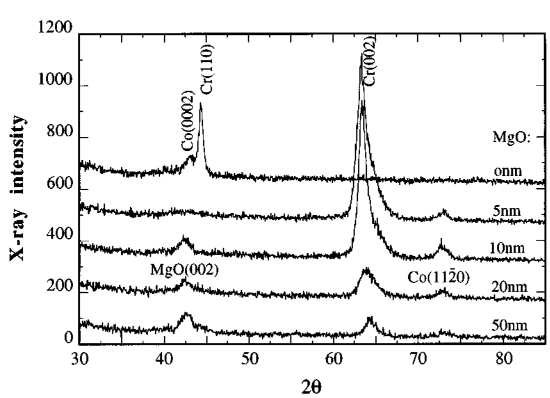

FIG. 3. X-ray diffraction spectra of the CoCrPt (40 nm)/Cr(100 nm) films with various thicknesses of MgO seed layers.

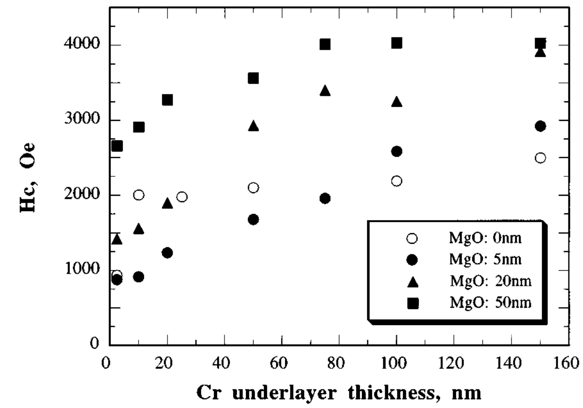

FIG. 4. Plot of the in-plane coercivity of CoCrPt(40 nm) vs its Cr underlayer thickness for MgO seed layers of 0, 5, 20, and 50 nm thick.

MgO seed layers. All film with MgO seed layers show Cr (002) and Co (1120) peaks while the film without the seed layer does not have any reflections, indicating that there is in-plane *c*-axis texture. It is well known that the high Pt content in the CoCrPt alloy causes an expanded lattice that, due to a poor atomic match with the pure Cr lattice, does not produce good epitaxial growth.[5] The visible Co (0002) peak in the diffraction spectrum of the film without a MgO seed layer is a manifestation of the large lattice misfit of Cr (110) to the Co (1010) or Co (1011) lattice plane. In spite of the poor atomic match of the high Pt content CoCrPt to the pure Cr (0002), the high quality texture of the (002) Cr grown on MgO appears to produce a good surface for epitaxial growth of Co (1120). The appearance of the Co (1120) peak and the suppression of the Co (0002) peak due to the MgO seed layer are important to achieving high in-plane coercivity, H_c.

In Fig. 3, the intensity of the Cr (002) peak, as well as that of the Co (1120) increases as the MgO thickness increases up to 10 nm. However, a further increase in the MgO thickness decreases the intensity of the Cr (002) and Co (1120) peaks. From our atomic force microscopy (AFM) studies, it is found that the MgO film roughens considerably as its thickness increases. Microbumps of up to 40 nm in height and 200 nm in diameter were observed in the 50 nm thick MgO film. This increase in roughness causes the deterioration of the epitaxy of the MgO and Cr.

Figure 4 plots the in-plane coercivity values of the CoCrPt (40 nm)/Cr films of various Cr underlayer thicknesses with and without MgO seed layers on glass substrates. Table I lists a complete set of in-plane magnetic properties of the CoCrPt (40 nm)/Cr(100 nm) films on MgO seed layers of

TABLE I. The in-plane magnetic properties of the CoCrPt(40 nm)/Cr(100 nm) films on MgO seed layers of various thicknesses.

MgO thickness (nm)	H_c (Oe)	$S(M_r/M_s)$	S^*	M_{rt} (memu/cm ^{2})
0	2286	0.83	0.84	1.2
5	2583	0.87	0.88	1.2
10	2608	0.86	0.91	1.2
20	3252	0.88	0.90	1.2
50	4036	0.88	0.88	1.1

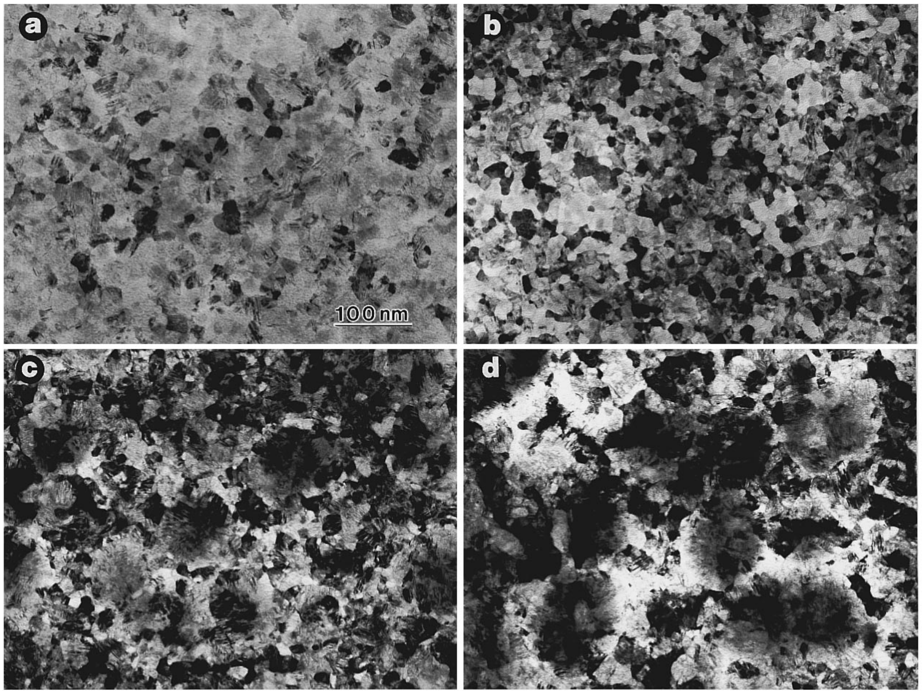

FIG. 5. TEM bright field images of plane-view CoCrPt(40 nm)/Cr(100 nm) films on MgO seed layers of various thicknesses. MgO thickness: (a) 0; (b) 5; (c) 20; and (d) 50 nm.

various thicknesses. It is found that the improvement in coercivity increases as the thickness of the Cr underlayer or the MgO seed layer increases. The coercivity reaches a value as high as 4000 Oe, if a 50 nm thick MgO seed layer is used along with a Cr underlayer thicker than 75 nm. It is known that microbumps underneath the Co alloy film can increase the physical separation between the Co alloy grains and therefore increase the coercivity value.[14] On the other hand, decreasing the Co $(11\bar{2}0)$ texture caused by the increasing roughness of the film would tend to decrease the coercivity. The continuing increase in H_c as the MgO layer thickens shows that the effect of the weakening of the Co $(11\bar{2}0)$ texture is more than compensated by the enhancement in isolation of the Co grains. However, the grain size of the CoCrPt film may also be changing because of the MgO seed layers. Larger grain size is known to be a factor that causes the coercivity to increase as long as the grains are single domains.[15] The plane-view TEM images CoCrPt (40 nm)/Cr(100 nm) films on various thicknesses of MgO seed layers are shown in Fig. 5. There is only a slight increase in the grain size of the CoCrPt films. The large dark patches in Figs. 5(c) and 5(d) are shadows of the MgO bumps, not grains.

The multilayered films in this study were made by sputtering one layer after the other without breaking the vacuum of the sputtering system. However, we have also found that glass substrates with presputtered MgO seed layers can still induce good (002) Cr epitaxial growth even though the MgO films have been intentionally exposed to air for more than a month. This may be very convenient for media production where the MgO could be deposited in a separate vacuum system.

In conclusion, it is shown that a sputter-deposited thin MgO seed layer with the (002) crystallographic texture induces the (002) texture in the Cr underlayer, which in turn induces the $(11\bar{2}0)$ texture in the CoCrPt magnetic layer. Thus, the in-plane magnetic properties can be improved without resorting to external substrate heating. By employing the MgO seed layers, the CoCrPt/Cr films and possibly other Co alloy films can become good candidates for future high density recording media.

This work was supported by the Data Storage Systems Center of Carnegie Mellon University under NSF Grant No. ECD-8907068 and ARPA Grant No. MDA972-93-1-0009.

[1] H. Suzuki, N. Tsumita, M. Hayashi, Y. Shiroishi, and Y. Matsuda, IEEE Trans. Magn. **26**, 2280 (1990).
[2] R. Ranjan, J. Appl. Phys. **67**, 4698 (1990).
[3] T. Kogure, S. Katayama, and N. Ishii, J. Appl. Phys. **67**, 4701 (1990).
[4] R. Ranjan, J. Chang, T. Yamashita, and T. Chen, J. Appl. Phys. **73**, 5542 (1993).
[5] T. A. Nguyen and J. K. Howard, J. Appl. Phys. **73**, 5579 (1993).
[6] N. Tani *et al.*, J. Appl. Phys. **67**, 7507 (1990).
[7] T. Kogure and S. Katayama, J. Appl. Phys. **67**, 4701 (1990).
[8] X. Tang, B. Reed, and R. Zubeck, IEEE Trans. Magn. **30**, 3963 (1994).
[9] S. Duan, B. Zhang, C. Gao, G. C. Rauch, and J. L. Pressesky, IEEE Trans. Magn. **30**, 3966 (1994).
[10] H. Kataoka *et al.*, Intermag 95, Paper BC-03.
[11] A. Nakamura and M. Futamoto, Jpn. J. Appl. Phys. **32**, L1410 (1993).
[12] M. Futamoto, M. Suzuki, N. Inaba, A. Nakamura, and Y. Honda, IEEE Trans. Magn. **30**, 3975 (1994).
[13] P. W. Tasker, Adv. Ceram. **10**, 176 (1984).
[14] M. Mirzamaani, C. V. Jahnes, and M. A. Russak, IEEE Trans. Magn. **28**, 3090 (1992).
[15] F. E. Luborsky, J. Appl. Phys. **32**, 171S (1961).