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Effect of MgO and Al₂O₃ on the microstructure and magnetic properties of CoCrPt-oxide perpendicular recording media

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MgO, Al₂O₃ and SiO₂ incorporated CoCrPt thin films (20 nm) have been fabricated on the Ru underlayer to study the role of different oxides on magnetic isolation of CoCrPt grains. Unlike the SiO₂ incorporated case, the MgO and Al₂O₃ incorporated specimens do not show higher coercivity and squareness. Microstructural analysis of MgO and Al₂O₃ cases shows quite different morphology than that of SiO₂. MgO and Al₂O₃ are segregated within the grains as well as grain boundaries in a patch form. The differences in magnetic properties are speculated in terms of different kinetics for the different chemical species. © 2005 American Institute of Physics. [DOI: 10.1063/1.1849051]

I. INTRODUCTION

Fine and magnetically well-isolated grain of recording layer is one of the critical requirements for the high density perpendicular recording media.¹ Though Cr is known to be segregated mainly at the grain boundaries in CoCrPt media, high Cr concentration (for example, beyond 17 at. %) is needed to promote Cr segregation into the boundary.^{2,3} Moreover, as the Cr segregation is observed only in high angle boundaries, there are many chances to have low angle boundaries due to the hexagonal symmetry in Co alloys, which will induce magnetic clusters. In order to solve these problems, CoCrPt-SiO₂ and CoCrPtO recording layers were introduced.^{4,5} Rather thick oxide boundary layers insulate CoCrPt grains almost independently regardless of relative orientations of nearest neighboring grains.

Many researchers are working on the CoCrPt-SiO₂ media for those reasons but no other oxides are reported as a proper additive material to the CoCrPt media. In this article, we have investigated the effects of such oxides as MgO and Al₂O₃ as substitute for SiO₂ on the CoCrPt media because the standard heat of formations of Al₂O₃ and MgO is similar to that of SiO₂. The CoCrPt/Ru and media were also prepared as a reference for the comparison of magnetic properties and microstructures with the MgO and Al₂O₃ incorporated CoCrPt media.

II. EXPERIMENT

Surface oxidized Si wafers were used as substrates. Ta (5 nm) and Ru (40 nm) were deposited at 3 and 10 mTorr, respectively, by dc magnetron sputtering method and the magnetic layers (20 nm) were deposited by 400 W radio-frequency (rf) sputtering method at high pressure (60 mTorr) without pre-heating. Base pressure was kept below 3×10^{-7} mTorr. The CoCrPt-Al₂O₃, CoCrPt-MgO, CoCrPt-SiO₂ and CoCrPt magnetic layers of 20 nm were deposited on Ru underlayer. The above sputtering conditions were fixed to all specimens. The content of Al₂O₃, MgO and SiO₂ was controlled by the number of oxide chips mounted on CoCrPt alloy target. Optimum doping amount of each oxide

was decided by the shape of hysteresis loops which show maximum coercivity and negative nucleation field.

The magnetic properties including perpendicular and in-plane coercivities ($H_{c\perp}$, $H_{c\parallel}$), nucleation field (H_n), and α ($4\pi \partial M / \partial H$ at H_c) were measured by a vibrating sample magnetometer at a field sweep rate of 200 Oe/s at room temperature.

The crystalline orientation of the thin films was analyzed by the $\Delta\theta_{50}$ from x-ray diffraction. Transmission electron microscope (TEM) images were observed to verify the grain isolation. Both plane-view and cross-sectional TEM samples were prepared. X-ray photoelectron spectroscopy (XPS) analyses were performed to ascertain the oxide species and energy dispersive spectroscopy was used to analyze doping contents of each oxide.

III. RESULTS AND DISCUSSION

Figure 1 shows the typical hysteresis loops of CoCrPt-_{12 mol %}MgO, CoCrPt-_{7.6 mol %}Al₂O₃, CoCrPt-_{13 mol %}SiO₂ and CoCrPt layers. When the number of oxide chips varied in MgO and Al₂O₃ incorporated layers, the hysteresis loops did not change much while that of SiO₂ incorporated layers showed sharp change. In the case of CoCrPt-SiO₂ layer, coercivity increases to 3500 Oe and the negative nucleation field increases to 1500 Oe in contrast to the CoCrPt layer. As the Ru layers were deposited at 10 mTorr and relatively higher power, the $\Delta\theta_{50}$ of the Ru layer is around 5.9°. A cross-sectional TEM of Ru layer shows some columns are discontinuous in thickness direction and these are associated with the poor *c*-axis alignments due to high sputter pressure. Due to this, there is rather large in-plane coercivity in the CoCrPt layer.

However, unlike the CoCrPt-SiO₂ layer, CoCrPt-MgO and CoCrPt-Al₂O₃ layers show lower coercivities and no negative nucleation field. The $\Delta\theta_{50}$ of CoCrPt-MgO and CoCrPt-Al₂O₃ are around 7.1–7.4° while that of the CoCrPt-SiO₂ and CoCrPt layer are kept around 6°. This indicates SiO₂ does not deteriorate the epitaxial growth. In order to understand these behaviors, TEM in-plane view of those layers has been examined and the micrographs are

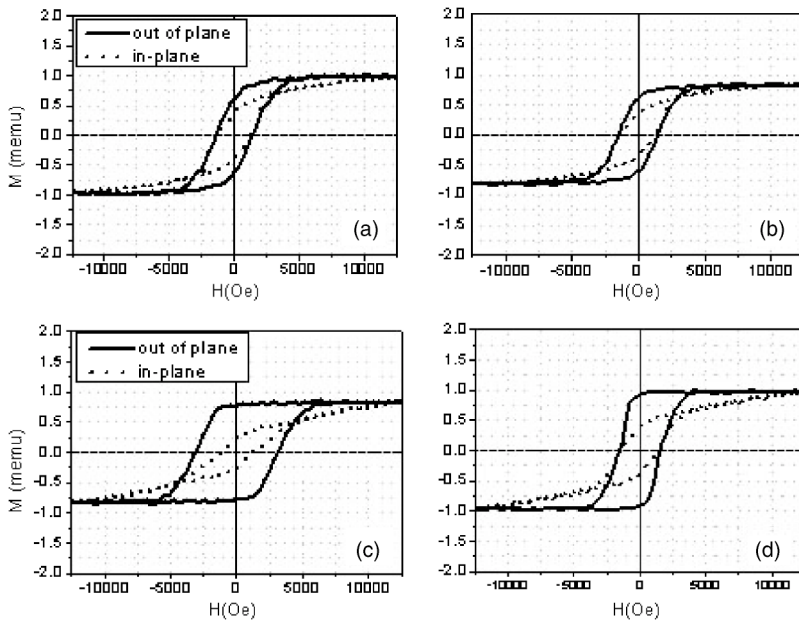


FIG. 1. Hysteresis loops of (a) CoCrPt-MgO(12 mol %), (b) CoCrPt-Al₂O₃(7.6 mol %), (c) CoCrPt-SiO₂(13 mol %) and (d) CoCrPt media.

shown in Fig. 2. In Fig. 2(d), CoCrPt grains in the CoCrPt layer are close packed in most parts and only some isolated voids are observed due to the high pressure sputtering.

As shown in Fig. 2(c), CoCrPt grains in the CoCrPt-SiO₂ layer are well separated by relatively uniform SiO₂ walls. Even in this case, a few oxides are observed inside of CoCrPt grains. However, in the CoCrPt-MgO and CoCrPt-Al₂O₃ layers, the oxides form mostly along the grain boundary and their thickness was not uniform. Moreover, many oxides are found within the grains. High resolution TEM micrographs show lattice images of CoCrPt extend even in oxide boundaries in many cases in the CoCrPt-MgO and CoCrPt-Al₂O₃ incorporated CoCrPt layers but no lattice images in SiO₂ incorporated grain boundaries.

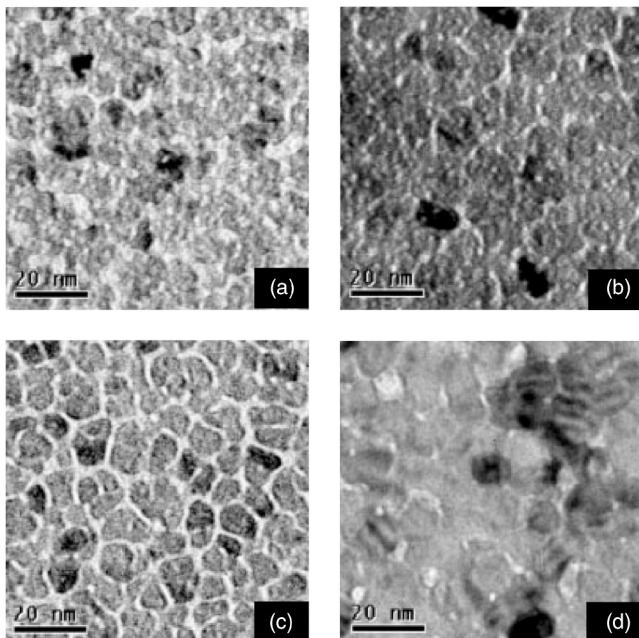


FIG. 2. Plane-view TEM images of (a) CoCrPt-MgO(12 mol %), (b) CoCrPt-Al₂O₃(7.6 mol %), (c) CoCrPt-SiO₂(13 mol %) and (d) CoCrPt media.

Cross-sectional TEM images of these layers are shown in Fig. 3. As shown in Fig. 3(d), no physical separation is observed between the CoCrPt columns in the CoCrPt layer. The CoCrPt-SiO₂ layer shows well-separated CoCrPt columns. However, the MgO and Al₂O₃ incorporated CoCrPt layers show some oxide along column boundaries with many oxides within the grains as appeared in Figs. 3(a) and 3(b). The oxides deteriorate the epitaxial growth and as a result the worse *c*-axis alignments of CoCrPt grains can be explained. Those results can explain the worse magnetic properties in the MgO and Al₂O₃ incorporated layers.

The heat of formation energies (ΔH°) as a measure of stability of the oxides appear in Table I together with free surface energy. ΔH° of SiO₂ is the highest among those and is comparable with that of Al₂O₃. These ΔH° values are normalized to one metal atom. XPS analysis shows almost

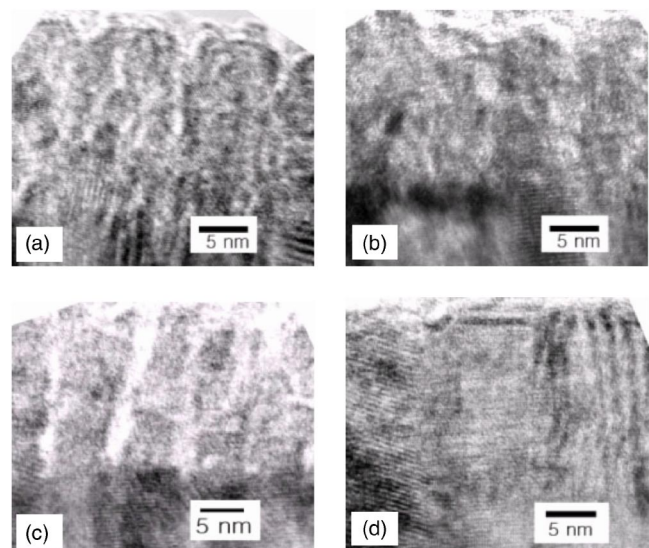


FIG. 3. Cross-sectional TEM images of (a) CoCrPt-MgO(12 mol %), (b) CoCrPt-Al₂O₃ (7.6 mol %), (c) CoCrPt-SiO₂ (13 mol %) and (d) CoCrPt media.

TABLE I. Free surface energy and heat of formation (ΔH°) of several oxides. The free surface energy refers to crystalline state value. ΔH° is normalized to one metal atom (see Refs. 6 and 7).

	MgO	Al ₂ O ₃	SiO ₂	Cr ₂ O ₃
Surface Energy (J/m ²)	1.2*	1.7–2.6*	1.5*	N/A
Heat of formation (J/mol)	–602 229	–837 850	–910 900	–567 350

all Si and Al exist as oxide form. However, in the case of MgO incorporated layer, only 40% of Mg exists as oxide and 60% of Mg exists as metal atom. The reasons may be as follows. ΔH° of MgO is comparable to that of Cr₂O₃. Therefore, Mg and Cr may compete during oxidation. In the MgO incorporated film, about 40% of Cr exists in oxide form while less than 30% of Cr exists in oxide form in the SiO₂ and Al₂O₃ incorporated films. Those results suggest that more stable oxide is preferable in an oxide incorporated CoCrPt layer.

However, these results do not explain the formation of the different oxide morphologies in these layers. The free surface energies of these oxides are not much different as shown in Table I. There are no available data for interface energy between these oxides and CoCrPt metal. The oxide formation during sputtering may be controlled not by thermal equilibrium but by kinetic process. If diffusion processes of Si, Al and Mg are different on CoCrPt surface, the different oxide morphology may occur as appeared in the present case. Further research is needed to understand these different behaviors.

IV. CONCLUSION

MgO, Al₂O₃, and SiO₂ incorporated CoCrPt media have been fabricated and their magnetic properties and micro-

structures were compared to understand the role of different oxide materials. The SiO₂ incorporated CoCrPt layer had higher coercivity and squareness than those of MgO and Al₂O₃ cases. That would be attributed to the well-isolated CoCrPt grains. The different behaviors are thought to be associated with different kinetics of diffusion for the different oxide elements rather than thermodynamic energy.

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¹K. Ouchi and N. Honda, IEEE Trans. Magn. **36**, 16 (2000).

²Y. Hirayama, M. Futamoto, K. Kimoto, and K. Usami, IEEE Trans. Magn. **32**, 3807 (1996).

³H. Uwazumi, T. Shimatsu, Y. Sakai, A. Otsuki, I. Watanabe, H. Muraoka, and Y. Nakamura, IEEE Trans. Magn. **37**, 1595 (2001).

⁴S. Okiwa, S. Takeo, T. Hikosaka, and Y. Tanaka, IEEE Trans. Magn. **36**, 2393 (2000).

⁵T. Oikawa, M. Nakamura, H. Uwazumi, T. Shimatsu, H. Muraoka, and Y. Nakamura, IEEE Trans. Magn. **38**, 1976 (2002).

⁶Q. Jiang, H. M. Lu, and M. Zhao, J. Phys.: Condens. Matter **16**, 521 (2004).

⁷D. R. Gaskell, *Introduction to the Thermodynamics of Materials*, 3rd ed. (Taylor & Francis, London 1995).