MAGNETIC PROPERTIES OF CoPtB(O) ALLOY FILMS ON CONTINUOUS SUBSTRATE

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Abstract--- The Pt and Cr underlayer effects of CoPtB(O) alloy films are investigated on glass substrate. Films with Pt underlayer showed excellent perpendicular magnetic properties and Cr underlayer changed the magnetic properties to have in-plane magnetization with large in-plane coercivity about 2500 Oe. These are closely related to crystallinity of CoPtB(O) layer and it is very important to have well oriented film to get excellent perpendicular magnetic properties.

On a PET substrate, it is difficult to have the perpendicular magnetization because of its bad crystallinity. A Cr underlayer also effective on the PET substrate to have in-plane coercivity over 2000 Oe.

INTRODUCTION

The CoPtB(O) alloy films have excellent hard magnetic properties with remarkably large perpendicular coercivity and high saturation magnetization. The outline of the magnetic properties and the microstructure of CoPtB(O) alloy films were already reported[1][2]. To utilize these superior characteristics as the new tape medium, it is very important to understand whether do these CoPtB(O) alloy films show their excellent characteristics on continuous substrate as realized on stationary rigid substrates or not.

In the course of studying the effects of underlayer on the magnetic properties of CoPtB(O) alloy films, it revealed that the characteristics of CoPtB(O) alloy films closely depends on their underlayer. To realize excellent perpendicular magnetic properties, the underlayer play a very important role.

In this study, Pt and Cr underlayer effects on magnetic properties and film structure were investigated using stationary glass slide substrates. Magnetic properties of the films deposited onto continuous PET substrates were investigated compared to those on the glass substrates.

EXPERIMENTS

Two types of dc planar magnetron sputtering apparatus were used corresponding to the substrates. The typical sputtering conditions of CoPtB(O) alloy films are listed in the Table I.

To investigate the underlayer effects, stationary glass slide substrates were used. The substrate was attached to a water-cooled anode. Oxygen partial pressure PO_2 was changed by controlling the oxygen flow rate in the total gas (argon and oxygen). To deposit the Pt and Cr underlayer, only Ar gas was introduced to the chamber and other conditions are same as those of magnetic layer. The thickness of magnetic layer and underlayer of specimens was 100 nm, respectively.

A dc planar magnetron sputtering roll coater was used to deposit onto continuous

Table I Typical sputtering conditions

substrate	glass slide	PET
T-S distance	70 mm	
target	Co ₇₁ Pt ₂₂ B ₇ (at.%) (ϕ 100 mm) (175 × 250 mm)	
background pressure	<0.13 mPa	<0.9 mPa
total gas flow rate	50 SCCM	450 SCCM
total gas pressure	2.0 Pa	
dc-input power	0.3 kW	2.2 kW

Fig.1 The X-ray diffraction patterns of CoPtB(O)/Pt/g and PoPtB(O)/g and CoPtB(O)/Cr/g.

flexible PET substrate (thickness: 10 μ m). The PET film substrate moved along a can roll. A mask and a slit located between target and substrate limited the incident angle of sputtered particles as only vertical component available and/or allowed oblique component with vertical one. Thickness of the magnetic layer of specimens was about 100 nm.

The CoPtB(O) alloy film with Pt and Cr underlayer and without underlayer system on glass slide substrate will be written as CoPtB(O)/Pt/g, CoPtB(O)/Cr/g and CoPtB(O)/g respectively, which on PET substrate will be written as CoPtB(O)/Cr/PET or CoPtB(O)/PET.

Magnetic properties were measured by using vibrating sample magnetometry with a maximum applied field of 15 kOe. Crystal structure was analyzed by using X-ray diffraction (Cu-K α).

RESULTS AND DISCUSSION

Films on stationary substrate

Fig.1 shows the typical X-ray diffraction patterns of each types of specimens. Very strong one peak from CoPtB(O) layer is shown in CoPtB(O)/Pt/g and CoPtB(O)/g. It is difficult to decide the crystalline phase whether fcc or hcp from this figure. From TEM study of CoPtB(O) alloy film with Pt underlayer on polyimide sheet, the crystalline phase is fcc and has orientation of [111] normal to the

Fig.2 Dependence of $\Delta\theta_{50}$ on P_{O_2} .

Fig.3 Dependence of d and X-ray peak intensity on P_{O_2} .

plane[2]. $\Delta\theta_{50}$ was estimated from X-ray rocking curve of this fcc(111) main peak. Spacing of lattice planes d and peak intensity are also derived from this main peak.

Fig.2 shows the dependence of $\Delta\theta_{50}$ of CoPtB(O)/Pt/g and CoPtB(O)/g on PO_2 . When PO_2 is below 0.035 Pa, $\Delta\theta_{50}$ is nearly constant of 6 to 8 deg. in both systems. When PO_2 is over 0.035 Pa, $\Delta\theta_{50}$ increases rapidly to about 23 deg. in CoPtB(O)/g whereas $\Delta\theta_{50}$ of CoPtB(O)/Pt/g shows small increase to about 10 deg.

Fig.3 shows the dependence of d and X-ray peak intensity on PO_2 . The d s of these types films show same behavior of having minima with PO_2 increasing. The variation of d in CoPtB(O)/Cr/g is not so wide compared to those of CoPtB(O)/g and CoPtB(O)/Pt/g. The minimum point of d in CoPtB(O)/Cr/g has the different PO_2 value compared to those of the others.

The X-ray peak intensities of CoPtB(O)/Cr/g are constant up to PO_2 of 0.035 Pa and then slightly decrease with increasing PO_2 . Very strong peak intensity is observed in CoPtB(O)/Pt/g compared to that in CoPtB(O)/Cr/g. In CoPtB(O)/g, peak intensity decreases rapidly with increasing PO_2 except for 0.035 Pa which shows same intensity as CoPtB(O)/Pt/g.

Fig.4 shows the dependence of perpendicular anisotropy field H_k on PO_2 . The H_k was estimated from in-plane hysteresis loop. H_k s of CoPtB(O)/Pt/g are larger than those of CoPtB(O)/g in all PO_2 range. As saturation magnetic induction $4\pi M_s$ of CoPtB(O) film is about 12kG[1][2], it satisfied the equation of $H_k > 4\pi M_s$ in very narrow PO_2 range for CoPtB(O)/g. This film with large H_k is identical with the film having the strongest X-ray peak intensity as well as small $\Delta\theta_{50}$. This PO_2 range around 0.035 Pa is most suitable oxygen partial pressure to achieve high perpendicular anisotropy in CoPtB(O)/g. From these results, it would say that the perpendicular anisotropy is closely related to crystallinity of CoPtB(O) layer.

In Fig.4, CoPtB(O)/Pt/g satisfies the equation of $H_k > 4\pi M_s$ wider PO_2 range compared to CoPtB(O)/g. The role of Pt underlayer is to improve the crystallinity of magnetic layer. With the result that the perpendicular anisotropic films are obtained in wider PO_2 range. It should be mentioned that the d s of the films with large perpendicular anisotropy are shrunk by the oxygen incorporation. But it is difficult to tell how these small d have relation

Fig.4 Dependence of H_k on PO_2 .

Fig.5 Dependence of in-plane coercivity $H_{c//}$ of CoPtB(O)/Cr/g on PO_2 .

to the perpendicular anisotropy.

In CoPtB(O)/Cr/g, these films no more retain perpendicular anisotropy but have in-plane magnetization. From X-ray diffraction pattern of Fig.1 and X-ray peak intensity of Fig.3, the films of type CoPtB(O)/Cr/g show small intensity compared to those of the other two type. The difference of magnetic properties may due to the poor crystallinity of CoPtB(O) layer. Fig.5 shows the dependence of in-plane coercivity $H_{c//}$ on PO_2 for the films of CoPtB(O)/Cr/g. Large $H_{c//}$ of about 2500 Oe were obtained from 0.04 to 0.07 Pa of PO_2 . As these high $H_{c//}$ PO_2 region is different from PO_2 range of perpendicular anisotropy region shown in Fig.4, the mechanism of high $H_{c//}$ may be independent to perpendicular anisotropy that is realized on CoPtB(O)/g and CoPtB(O)/Pt/g.

Films on continuous substrate

Fig.6 shows the scheme of sputtering roll coater. Mask and slit limited the incident angle of sputtered particle as only vertical component available (A) and allowed oblique component with vertical one (B and C). Arrows with

Fig.6 Scheme of sputtering roll coater.

(a) CoPtB(O)/PET

(b) CoPtB(O)/Cr/PET

Fig.7 Dependence of $H_{c//}$ of (a);CoPtB(O)/PET and (b);CoPtB(O)/Cr/PET on PO_2 . A,B,C are figured in Fig.6.

Fig.8

Hysteresis loops of CoPtB(O)/PET;(a) and CoPtB(O)/Cr/PET;(b). A,B,C are incident angle of sputtered particles in Fig.6.

Fig.9 The X-ray diffraction patterns of CoPtB(O)/PET;(a) and CoPtB(O)/Cr/PET;(b). A,B,C are incident angle of sputtered particles in Fig.6.

A,B,C also represent the substrate moving direction. The incident angle of range B changed from near vertical to oblique and that of range C changed from oblique to vertical. The Cr underlayer was sputtered in the range A.

Fig.7 shows the dependence of in-plane coercivity $H_{c//}$ of (a);CoPtB(O)/PET and (b);CoPtB(O)/Cr/PET on PO_2 . All of these films have in-plane magnetization. The maximum $H_{c//}$ of CoPtB(O)/PET is about 1500 Oe at PO_2 of 0.04 Pa and then decreases with the PO_2 increase. This behavior is different from the magnetic properties of CoPtB(O) layer on the stationary glass slide substrate (CoPtB(O)/g).

The $H_{c//}$ of CoPtB(O)/Cr/PET (Fig.7 (b)) is higher in all PO_2 range compared to that of CoPtB(O)/PET. The change of $H_{c//}$ is also different from that of CoPtB(O)/Cr/g. These $H_{c//}$ dependence on PO_2 of CoPtB(O)/Cr/PET is similar to that of CoPtB(O)/PET.

Hysteresis loops of these specimens are shown in Fig.8. It can be seen that the coercive squareness S^* decreases by the Cr-underlayer. The differences of the incident angle and the substrate are not clearly recognized from Fig.8.

The X-ray diffraction patterns of these specimens are shown in Fig.9. Two peaks from CoPtB(O) layer were hcp(100) and main peak

correspond the ① and ② in the figure. All types of these films had bad crystallinity that may result in having in-plane magnetization.

CONCLUSION

The Pt and Cr underlayer effects on magnetic properties and film structure of CoPtB(O) alloy films are investigated using the stationary glass slide substrate and the continuous PET substrate. The summary is as follows.

1. The perpendicular magnetic properties are closely related to crystallinity of CoPtB(O) layer.
2. The Pt underlayer improves crystallinity of CoPtB(O) and realizes excellent perpendicular anisotropy.
3. The Cr underlayer changes the magnetic properties of CoPtB(O) to in-plane magnetization and has maximum $H_{c//}$ of 2500 Oe.
4. The CoPtB(O) alloy films without underlayer on the PET substrate show the in-plane characteristics because of bad crystallinity.

REFERENCES

- [1] K. Hayashi, M. Hayakawa, H. Ohmori, A. Okabe, K. Aso, J. Appl. Phys., "CoPtB(O) alloy films as new perpendicular recording media" 67, pp. 5175-5177, (1990).
- [2] K. Hayashi, Y. Iwasaki, A. Okabe, T. Yamamoto, M. Hayakawa, K. Aso, "Magnetic properties and microstructure of Co-Pt-B-O alloy films" Paper presented at M.R.S. spring meeting, (1991).