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Recording Performance of CoCrPt-(Ta, B)/TiCr Perpendicular Recording Media

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***Abstract*—The magnetic properties, microstructure and the recording performances of CoCrPt-(Ta, B)/TiCr perpendicular magnetic recording media were studied in conjunction with the effect of thermal agitation. The addition of Ta or B to CoCrPt media significantly improves its low noise performance, mainly due to the reduction of grain size and intergranular magnetic interactions. However, adding Ta or B also reduces the value of perpendicular magnetic anisotropy, K_u, especially in the initial growth layer, resulting in the degradation of thermal stability. In order to achieve high thermal stability without degrading the low noise performance of these media, an M_r/M_s value of nearly 1.0 is required. This may be achieved by suppressing of the reduction of K_u and the reducing intergranular magnetic interactions, whilst maintaining their small grain size.**

***Index Terms*—CoCrPt-(Ta, B), media noise performances, microstructure, perpendicular recording media, thermal agitation.**

I. Introduction

LOW MEDIA noise performance and high thermal stability are strongly required for perpendicular recording media to achieve recording densities of greater than 100 Gbit/in^2. CoCrPt based material is one of the promising candidates for the recording layer due to its large magnetocrystalline anisotropy, which results in media that is resistant to thermal agitation. However, it is well known that the addition of Pt to CoCr based media gives rise to relatively large media noise because the intergranular magnetic interactions and also the grain size may become larger due to insufficient Cr segregation to the grain boundaries [1]. Several studies were carried out to control the microstructure of the CoCrPt based perpendicular media by adding another element such as Ta [2], Nb [3] and Y [4].

In this paper, Ta and B are focused on as the additives to CoCrPt alloy films to reduce intergranular magnetic interactions and grain size. The relations between the magnetic properties, microstructures and the recording performances of CoCrPt-(Ta, B)/TiCr perpendicular recording media are discussed in conjunction with the thermal agitation to reveal the effect of adding Ta or B to CoCrPt.

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II. Experimental

CoCrPt-(Ta, B)/$Ti_{90}Cr_{10}$ perpendicular media were prepared on 2.5″ glass disks using a dc magnetron sputtering system. Three kinds of sputtering target, $Co_{70}Cr_{20}Pt_{10}$, $Co_{68}Cr_{20}Pt_{10}Ta_2$ and $Co_{66}Cr_{20}Pt_{10}B_4$ were used for sputtering the recording layer. The thickness of the recording layer was varied from 10 to 50 nm, while the thickness of TiCr underlayer and carbon overcoat was fixed at 15 nm and 8 nm, respectively.

The coercivity H_c, the squareness M_r/M_s and the saturation magnetization M_s were measured using a vibrating sample magnetometer (VSM). The perpendicular magnetic anisotropy K_u was measured by a torque magnetometer. The "intrinsic" remanence coercivity H_0, which is the remanence coercivity without the effect of thermal agitation, and the thermal stability parameter K_uV/kT were obtained by using a pulse field magnetometer [5], [6]. The microstructure of the film was analyzed using X-Ray Diffraction (XRD) and Transmission Electron Microscopy (TEM).

Recording performance was characterized using a MIG head for recording (track width 2.7 μm, gap length 0.17 μm) and a GMR head for read back (shield gap length 0.14 μm and track width 0.75 μm). Media noise was estimated as an integrated read back power in the spectrum from 0 to 90 MHz, subtracting the other noise source.

III. Results and Discussions

A. Magnetic and Structural Properties

Fig. 1 shows the dependence of H_c of the CoCrPt-(Ta, B) media on the magnetic layer thickness. For thicknesses greater than 30 nm, the addition of Ta or B significantly reduces the value of H_c from more than 3 kOe to ~1.8 kOe when Ta is added, and to ~2.2 kOe when B is added. Moreover, for all the media studied, below a thickness of ~30 nm H_c is seen to reduce with thickness: H_c of the CoCrPtTa and CoCrPtB at the thickness of 20 nm drops to ~1.0 kOe, while that of CoCrPt at the same thickness remains at more than 3 kOe.

M_r/M_s also shows similar thickness dependence for these media, and the values of M_r/M_s of the CoCrPt, CoCrPtTa and CoCrPtB at the thickness of 30 nm were 0.8, 0.5, and 0.5, respectively.

Structural analysis was carried out for these media. The XRD patterns show only hcp(002) and (004) peaks, indicating c-axes orientations normal to the film plain for all media examined here.

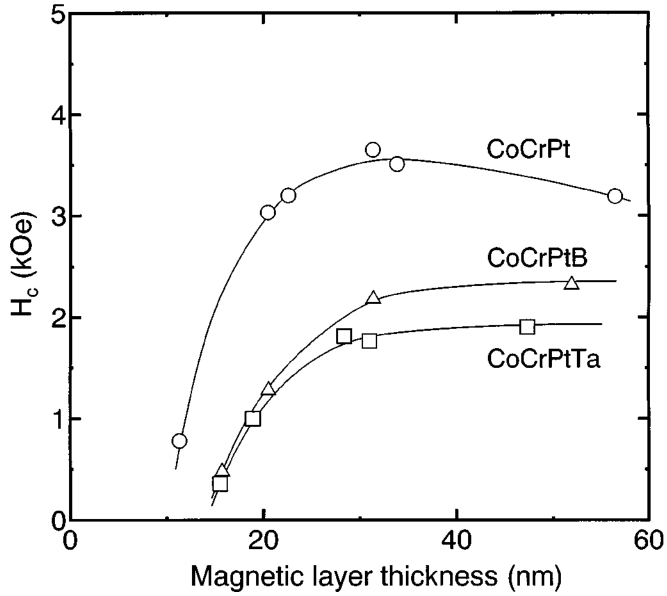

Fig. 1. The dependence of H_c of the CoCrPt-(Ta, B) media on the magnetic layer thickness.

TABLE I
GRAIN SIZE OF THE CoCrPt-(Ta, B) MEDIA

Magnetic Layer	Grain size (nm) from TEM	Grain size (nm) from XRD
CoCrPt	~ 14	12.2
CoCrPtTa	~ 10	8.2
CoCrPtB	~ 8	— [a]

a diffracted peak was too small to calculate the grain size.

Table I shows the average grain size of the magnetic layer of CoCrPt-(Ta, B) media, obtained from the TEM images and from the grazing incidence XRD using Scherrer's formula to the FWHM of hcp-(100) peak. Measured values of grain size obtained from XRD and from TEM were in good agreement qualitatively, though the size obtained from XRD is smaller than that from TEM because of the effect of the lattice distortion. Grain size obtained from TEM observation decreases from 14 nm of CoCrPt to 10 nm and 8 nm by adding Ta and B, respectively. These results indicate that the addition of Ta or B is very effective in reducing the grain size of the magnetic layer.

B. Perpendicular Anisotropy, Intergranular Magnetic Interaction and Thermal Stability

Fig. 2 shows the dependence of K_u and M_s of the CoCrPt-(Ta, B) media on the magnetic layer thickness. The addition of Ta or B significantly reduces the value of K_u, and the K_u of all media drastically decreases in the thickness region of less than 20 nm. While the M_s of all media decrease slightly in the thin thickness region. The anisotropy field H_k, calculated as $2K_u/M_s$, of CoCrPt, CoCrPtTa and CoCrPtB at the thickness of 30 nm were 11.1, 9.1 and 9.0 kOe, respectively. It is considered that the degradation of K_u in the thin thickness region is caused mainly by the structural imperfection of the initial growth layer of the magnetic layer, such as stacking faults or the effect of the lattice misfit with the underlayer.

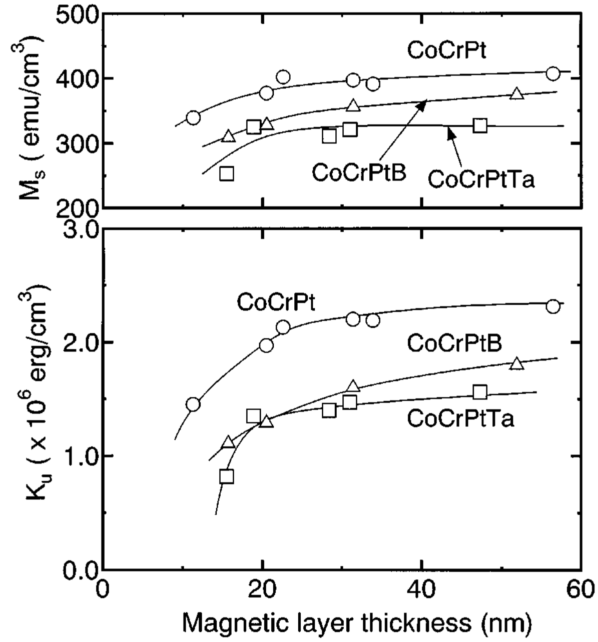

Fig. 2. The dependence of K_u and M_s of the CoCrPt-(Ta, B) media on the magnetic layer thickness.

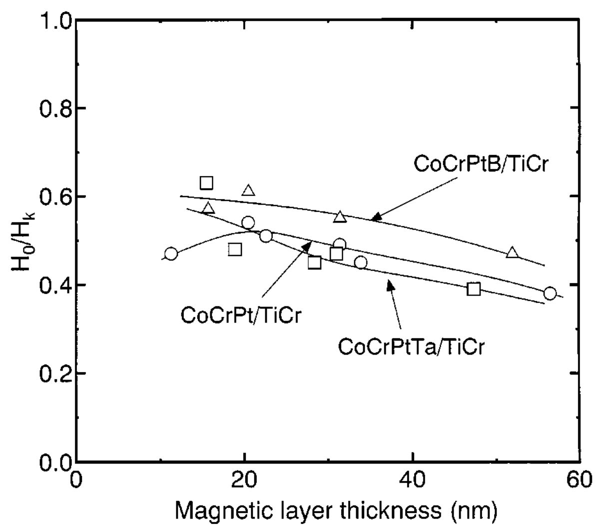

Fig. 3. The dependence of H_0/H_k of the CoCrPt-(Ta, B) media on the magnetic layer thickness.

Fig. 3 shows the thickness dependence of H_0/H_k of the CoCrPt-(Ta, B) media. H_0/H_k for all media gradually increases with decreasing thickness because of the reduction of intergranular magnetic interactions [5]. The value of H_0/H_k of $\sim$0.55 for CoCrPtB at the thickness of 30 nm is the largest value of all samples discussed here. The addition of B is likely to be effective in the reduction of the intergranular exchange interaction, which must be caused by the enhancement of the Cr segregation to the grain boundaries.

Fig. 4 shows the thickness dependence of K_uV/kT of the CoCrPt-(Ta, B) media. The K_uV/kT for all media decreases monotonically with decreasing thickness. The value of K_uV/kT of CoCrPt was more than 300 at a thickness of

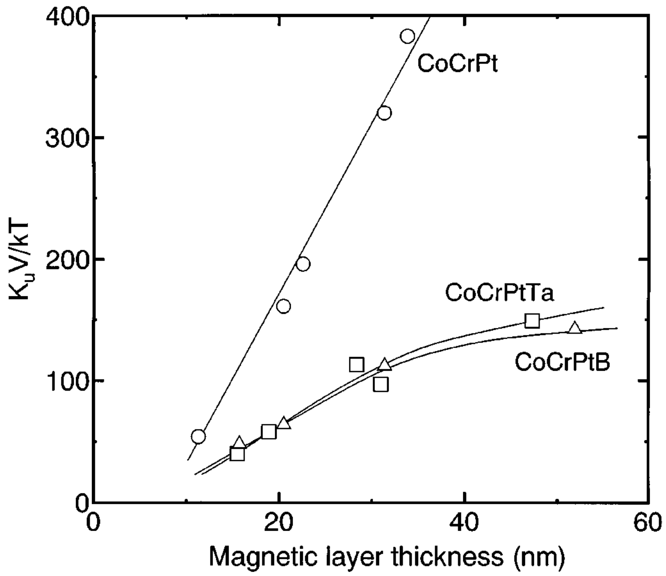

Fig. 4. The dependence of K_uV/kT of the CoCrPt-(Ta, B) media on the magnetic layer thickness.

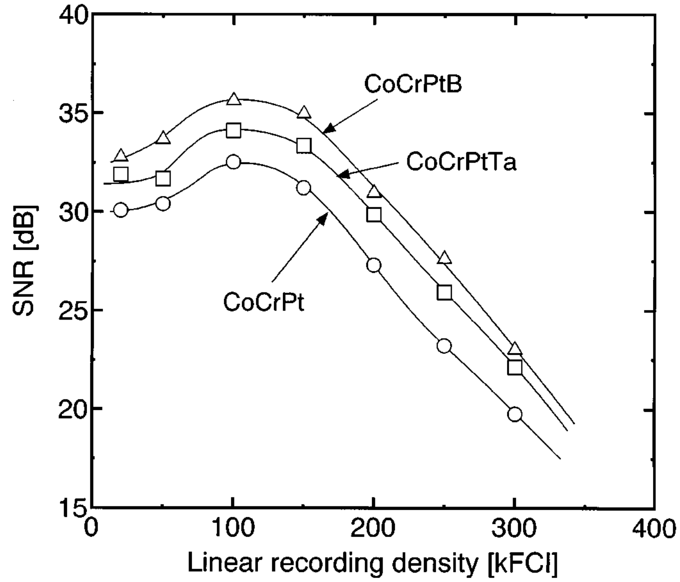

Fig. 5. The recording density dependence of SNR of CoCrPt-(Ta, B) media.

30 nm indicating its high thermal stability, while those of CoCrPtTa and CoCrPtB were almost same at ~100 for the same thickness. It is considered that the reduction of K_uV/kT resulting from the addition of Ta or B is caused mainly by the reduction of the grain size, and by the reduction of the K_u shown in Fig. 2. Activation Volume V_{act} was calculated from the measured values of K_uV/kT and K_u, and the activation grain diameter D_{act} was also estimated from V_{act} by assuming a cylindrical grain with a height equal to the thickness of the film. The value of D_{act} at the thickness of 30 nm was 16.0 nm for CoCrPt, 11.4 nm for CoCrPt and 10.8 nm for CoCrPtB, which were qualitatively in good agreement with the actual grain size obtained from TEM observation, however, estimated D_{act} for all media is slightly larger than the actual grain size. In this study, K_uV/kT is measured at the field of the remanence coercivity H_r, in Fig. 4 The dependence of K_uV/kT of the CoCrPt-(Ta, B) media on the magnetic layer thickness which the magnetostatic dipole interactions can couple some grains together, resulting in the enhancement of the thermal stability of the grain. Therefore, the measured value of K_uV/kT and calculated value of V_{act} at the H_r state can be larger than those at the remanent state. Moreover, the activation volume is likely to consist of a few coupled grains by the residual intergranular exchange interactions.

C. Recording Performances

Fig. 5 shows the recording density dependence of SNR of CoCrPt-(Ta, B) media. The value of SNR at 200 kFCI was ~24 dB for CoCrPt, ~30 dB for CoCrPtTa, and ~32 dB for CoCrPtB, respectively. It is clear that the addition of Ta or B is significantly effective in the reduction of media noise. SNR improvement by adding Ta or B is considered to be mainly due to the reduction of the grain size and the intergranular magnetic interactions.

Time decay of the read back signal of CoCrPtTa and CoCrPtB media was measured at a recording density of 2 kFCI, however, almost 20% of the signal reduction was observed within 100 seconds after the recording. This fact indicates that the recorded bits on the media discussed here are thermally unstable, especially at low recording densities.

It is thought that the thermal instability of the media that results from the addition of Ta or B is mainly due to the low M_r/M_s value of ~0.5, which means the large demagnetizing field strongly affects the magnetization at the remanent state. In order to realize high thermal stability, i.e. to realize the value of M_r/M_s of ~1.0, the following must be effective for CoCrPt based media:

i) K_u should be much more increased against the demagnetizing energy $2\pi M_s^2$. Improvement of the structural imperfection of the initial growth layer of the magnetic layer by changing the sputtering conditions or the underlayer material should be effective to suppress the reduction of K_u caused by the addition of Ta or B. Moreover, the choice of suitable compositions to get much larger K_u value must be important in CoCrPt based material.

ii) H_0/H_k should be increased, that is, the intergranular magnetic coupling should be much more reduced. The slope of the magnetization curve of CoCr based media having well-segregated grains is likely to be ~1/4π [7] due to the demagnetizing field normal to the film plain, therefore the large H_0/H_k value leads to a large M_r/M_s value directly. The values of H_0/H_k of the media studied here are smaller than the achievable maximum value, ~0.7, [5], [7] and further reduction of the intergranular exchange coupling is necessary for CoCrPt based media.

IV. Conclusions

The magnetic properties, microstructures and the recording performance of CoCrPt-(Ta, B)/TiCr media were discussed in conjunction with the effect of thermal agitation. Addition of Ta or B significantly improves the recording performances due to the reduction of the grain size and the intergranular magnetic interactions. On the other hand, the value of K_u and K_uV/kT also reduces with adding Ta or B resulting in poor thermal stability, especially of recorded bits at low recording densities. In order to achieve both high thermal stability and low-noise performances for CoCrPtTa and CoCrPtB media, suppression of the reduction of K_u and reduction of the intergranular magnetic interactions must be the key issues.

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