Effect of Pt on the Intergranular Exchange Coupling in CoCrTaPt Thin Film Media Prepared under Ultra Clean Sputtering Process

Dept. of Electronics Engrg., Tohoku Univ., Aoba-ku, Sendai, 980-8579, Japan
*TEIJIN LIMITED, Hino, Tokyo, 191-8512, Japan
**Fujitsu Limited, Kita-Owaribe, Nagano 381-0014, Japan

(REceived ; 28 May 1998 , Accepted ; 26 August 1998)

The effect of Pt addition on magnetic properties for CoCrTaPt media with extremely thin Cr underlayer of 2.5 nm fabricated under ultra clean sputtering process are connected with the magnetic anisotropy field of grains, the microstructure, and intergranular magnetic coupling. As a results, (1) Pt addition more than 8 at% decreases the magnetocrystalline anisotropy field of the grains. (2) Pt addition more than 8 at% disturbs a formation of Cr segregated grain boundary structure, inducing intergranular exchange coupling. (3) The upper limit of Pt addition is proposed to be 5 - 6 at%.

Key word : coercive force, magnetocrystalline anisotropy field of the grains, intergranular magnetostatic coupling, intergranular exchange coupling, Cr segregated grain boundary

1. Introduction

In thin film recording media high \( H_r \) is one of the essential requirements to achieve high density magnetic recording. \( H_r \) is determined mainly by the value of the magnetic anisotropy field of grains and degree of intergranular coupling of magnetization. Pt-added Co based thin film media have been widely used because of its large magnetocrystalline anisotropy field. On the other hand, generally, for Pt-added Co based thin film media, the medium noise increases. This degradation in recording performance strongly connects with the microstructure for the thin film media.

In this study, the effect of Pt on the magnetic properties in these media is discussed in connection with their microstructure and intergranular magnetic coupling.

2. Experimental procedure

The CoCrTaPt thin film media were fabricated under the ultra clean sputtering process (UC-CoCrTaPt) with a specialized production type sputtering machine (ILC3013 ANELVA) and ultra clean Ar gas (UC-Ar). The base pressure of each process chamber is less than 3×10^{-7} Torr and the build up rate is less than 5×10^{-5} Torr·1/sec. The impurity level of UC-Ar is about 1 ppb (H₂O level) at the point of use.

In this study, CoCrTaPt (Pt=0-10 at%) targets with low impurities were used for the magnetic alloys. The films were deposited onto extremely smooth non-textured NiP/Al substrates (Ra=0.7 nm) with underlayered Cr films. The value of \( t_B \), the product of film thickness and remanence, of the media was fixed at 100 Gμm. The underlayered Cr thickness, \( d_{Cr} \), was fixed at extremely thin 2.5 nm. The substrate temperature was kept at 250°C during the film deposition. The substrate surface was cleaned by dry etching, using UC-Ar in the process chamber, just before film deposition.

The magnetization curves were measured with a vibrating sample magnetometer (VSM). The rotational hysteresis losses were measured using a high-sensitivity torque magnetometer. The microstructures were analyzed by transmission electron microscopy (TEM).

3. Results and discussion

3.1 Effect of Pt addition on magnetic properties

(a) Coercive force

Fig.1 shows the values of coercive force, \( H_c \), versus Pt content in the UC-CoCrTaPt media. According to the torque analysis, in all media, macroscopically induced uniaxial anisotropy was not observed. As seen in the figure, \( H_c \) is found to increase from about 2.3 to 2.9 kOe as the Pt content increases from 0 to 5 at%. However, with further increasing Pt more than 8 at%, \( H_c \) decreases suddenly, and shows about 1.6 kOe at 10 at% Pt.

![Fig.1 The change of \( H_c \) against Pt content in UC-CoCrTaPt media.](image_url)

Fig. 2 The change of $H_k^{\text{grain}}$ against Pt content in UC-CoCrTaPt media.

(b) Magnetocrystalline anisotropy field of the grains

Fig. 2 shows the values of magnetocrystalline anisotropy field of the grains, $H_k^{\text{grain}}$, versus Pt content in the UC-CoCrTaPt media. $H_k^{\text{grain}}$ was determined as the magnetic field at which the rotational hysteresis loss $W_r$ vanishes.\textsuperscript{11,12} As seen in the figure, $H_k^{\text{grain}}$ is found to increase from about 6.7 to 7.8 kOe as the Pt content increases from 0 to 8 at%. However, with further increasing Pt more than 8 at%, $H_k^{\text{grain}}$ decrease suddenly and shows about 6.3 kOe at Pt 10 at%.

(c) Intergranular magnetic coupling

In Fig. 3, the values of $H_i/H_k^{\text{grain}}$ for the UC-CoCrTaPt thin film media with $d_{c_r}=2.5$ nm are plotted as functions of Pt and Cr+Ta content. Here, magnetic property depend on Cr+Ta content, therefore the values of $H_i/H_k^{\text{grain}}$ and $4\pi M_i/H_k^{\text{grain}}$ are plotted as functions of Pt and Cr+Ta content in Fig. 3 and Fig. 4, respectively. In the case of the media without any intergranular coupling, $H_i/H_k^{\text{grain}}$ shows max value of 0.51. For the media with 5 at% Pt examined in this study, $H_i/H_k^{\text{grain}}$ shows almost constant values of about 0.35 against Cr+Ta content. Furthermore, $H_i/H_k^{\text{grain}}$ shows almost constant values of about 0.35 up to Pt content of 5 at%. However, with further increasing Pt content more than 8 at%, $H_i/H_k^{\text{grain}}$ starts to decrease and shows 0.26 at 10 at% Pt. This fact suggests that with increasing Pt content more than 8 at%, intergranular magnetic coupling starts to increase. The increment in intergranular magnetic coupling with increasing Pt content more than 8 at% is one of the factors of decrement in $H_k$, shown in Fig. 1. And, further more this increment also causes the decrement in $H_k^{\text{grain}}$ apparently shown in Fig. 2, through the effective-field\textsuperscript{13} overlapping the applied field.

In Fig. 4, the values of $4\pi M_i/H_k^{\text{grain}}$ for the UC-CoCrTaPt thin film media with $d_{c_r}=2.5$ nm are plotted as functions of Pt and Cr+Ta content. $4\pi M_i/H_k^{\text{grain}}$ indicates the degree of intergranular magnetostatic coupling.\textsuperscript{14} For the media with 5 at% Pt examined in this study, $4\pi M_i/H_k^{\text{grain}}$ increases with decreasing Cr+Ta content. In the UC-CoCrTaPt media with 0 - 8 at% Pt, $4\pi M_i/H_k^{\text{grain}}$ has low value less than 0.9. With further increasing Pt content, $4\pi M_i/H_k^{\text{grain}}$ increases. For thin film media with $4\pi M_i/H_k^{\text{grain}}<-1.0$, the increment of intergranular magnetic coupling by the reduction of grain diameter is expected to be suppress.\textsuperscript{15} Since the low magnetostatic coupling (low $4\pi M_i/H_k^{\text{grain}}$) is realized for the UC-CoCrTaPt media (0 - 8 at% Pt) as shown in Fig. 4, therefore, for the UC-CoCrTaPt media with 8 at% Pt, relatively higher intergranular magnetic coupling ($H_i/H_k^{\text{grain}}=0.29$) is caused by the increment in intergranular exchange coupling.

Almost the same results that the effect of Pt addition on intergranular exchange coupling for CoCrTaPt thin film media are also reported by some reseachers.\textsuperscript{16,17}
3.2 Effect of Pt addition on microstructure

In Fig. 5, TEM bright field images of CoCrTaPt media with different Pt content are shown. In every media, average grain diameter shows almost the same values of 13 nm. Concerning the grain boundary structure, with increasing Pt content, Cr segregated grain boundary structure becomes to be unclear and inhomogeneous. Here, to examine the Cr segregated grain boundary structure quantitatively, the average thickness of grain boundary, $D_{\text{boundary}}$, is introduced.

$D_{\text{boundary}}$ is defined as follows.

$$D_{\text{boundary}} = \frac{S_{\text{boundary}}}{\Sigma_{\text{length}}} \times 2$$

$S_{\text{boundary}}$: area of grain boundary

$\Sigma_{\text{length}}$: circuit length of grain

With increasing Pt content, $D_{\text{boundary}}$ decreases from 2.0 nm at 0 at% Pt to 0.8 nm at 8 at% Pt. This decrease of $D_{\text{boundary}}$ causes the increase in the intergranular exchange coupling of the magnetization.

Concerning recording performance, present authors have already reported that $S/N_m$ is improved by the reduction of grain diameter and also intergranular magnetic coupling. Therefore, the general recognition about increment in media noise by Pt addition is mainly attributable to the increment in intergranular exchange coupling. Based on these results, although Pt addition increases magnetocrystalline anisotropy field of the grains, resulting high $H_{\text{grain}}$ increment in intergranular exchange coupling is induced, resulting inhomogeneous Cr segregated grain boundary. Therefore, it is concluded that Pt content should be kept below 5 - 6 at% for high density recording media.

4. Summary

The effect of Pt addition on magnetic properties for CoCrTaPt media with extremely thin Cr underlayer of 2.5 nm fabricated under UC process are discussed in connection with the magnetic anisotropy field of grains, the microstructure, and intergranular magnetic coupling. As a results,

1. Pt addition more than 8 at% decreases $H_{\text{grain}}$
2. Pt addition more than 8 at% disturbs a formation of Cr segregated grain boundary structure, inducing intergranular exchange coupling.
3. The upper limit of Pt addition is proposed to be 5 - 6 at% for high density recording media.

Reference

5) L. Noel, Compt. Rend. 224 (1947) 1550

Fig. 5 TEM bright field images of UC-Co$_{75}$Cr$_5$Ta$_{10}$Pt$_5$, UC-Co$_{75}$Cr$_{15}$Ta$_{10}$Pt$_5$, UC-Co$_{75}$Cr$_5$Ta$_{12}$Pt$_5$, and UC-Co$_{75}$Cr$_5$Ta$_{28}$Pt$_5$ media. Average thickness of grain boundary $D_{\text{boundary}}$ is also shown.