Noise Characteristics for Co-Cr-Ta Media and Ferrite Media

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Abstract---The effect of the residual magnetic flux density (B_r) on the media noise in Co-Cr-Ta alloy thin films has been investigated. Longitudinal media with higher B_r and thinner magnetic layer have superior media noise to signal ratio compared to media with lower B_r (below 2,000 G) and thicker magnetic layer under the constant $B_r \delta$, where δ is the magnetic layer thickness. It was revealed that media noise is proportional to fluctuations in the magnetic transition region according to analysis of the readback waveform. Furthermore, ferrite media exhibits an excellent possibility for use as a low noise media at high recording densities.

I. INTRODUCTION

Longitudinal Co-Cr-Ta alloy thin films with Cr underlayer have been widely used as recording media. In high-density magnetic recording using a magneto-resistive (MR) head, it is important to decrease the media noise as well as to increase the readback signal because of the low MR head impedance noise. Readback waveform analyzing^{1,2)} has revealed that the media noise is connected with fluctuations in the magnetic transition region. The magnetic transition length depends on the magnetic layer thickness (δ) and magnetic properties such as the coercive force (H_c) and the residual flux density (B_r). Therefore, the media noise also correlates with δ , H_c and B_r . To adjust the media noise for low MR impedance, the $B_r \delta$ product tends to become smaller. However, the B_r effect on the media noise has not been investigated over a wide range of B_r .

In addition to Co-Cr-Ta alloy thin film media, γ - Fe_2O_3 film media are also known to exhibit low noise for an inductive (ID) head³⁾. In comparison to metal films, sputtered γ - Fe_2O_3 thin films are more attractive magnetic recording media because of their excellent corrosion and wear resistance. Furthermore, from the point of film microstructure, there is interest in comparing noise characteristics for Co-Cr-Ta media and ferrite media when using an MR head.

This paper reports the noise characteristics for Co-Cr-Ta media and ferrite media at high recording densities.

II. EXPERIMENTAL METHODS

Co-Cr-Ta films and magnetite (Fe_3O_4) films were prepared on glass substrates using the rf sputtering in an argon atmosphere. The substrate temperature was about 200 °C. The base pressure was about 5×10^{-7} Torr and Ar sputtering pressure was fixed at 1.7 mTorr. The sputtering power density on the targets was fixed at 5.5 W/cm². The Cr content for Co-Cr-Ta was varied between 12 and 18 at% to control the residual magnetic

flux density. The Cr underlayer was 83 nm thick and the protection layer was 20 nm thick. The magnetic layer thickness was varied between 16 and 70 nm, to keep the value of the $B_r \delta$ products constant ($110 \text{ G} \mu\text{m}$). Ferrite films, in which 1~3 at% Co and Cu were doped, were annealed at various temperatures, from 200 °C to 400 °C, for oxidation. The Co doping element increases the coercive force (H_c) and the Cu element accelerates oxidation of Fe_3O_4 into γ - Fe_2O_3 ⁴⁾. In order to evaluate magnetic grain isolation for media films, the δM values were measured using a vibrating sample magnetometer (VSM)⁵⁾. Film structures were analyzed by X-ray diffraction.

Magnetic recording characteristics were measured with a dual-element head consisting of a thin-film inductive write head and an MR read head. The track widths for ID head and MR head were $5 \mu\text{m}$ and $3 \mu\text{m}$, respectively. The gap lengths for ID head and MR head were about $0.7 \mu\text{m}$ and about $0.5 \mu\text{m}$, respectively. The noise power for longitudinal recording media at high recording densities was correlated to the magnetic transition region shape fluctuation^{1,2,6)}. The fluctuation affects on the half-width values ($W_1, W_2, W_3, \dots$) of the readback waveform, as shown in Fig.1. The half widths were measured at ten thousand, using a time interval analyzer, and the average half width value and the standard deviation (σ) were calculated. σ was defined as the half-width fluctuation²⁾.

Figure 1 Method for measuring the fluctuation in the half-width of readback waveform at 60 kFRPI.

III. RESULTS AND DISCUSSION

A. Dependence on R/W characteristics on the Br of Co-Cr-Ta media

Under a constant $Br\delta$ condition, the R/W characteristics for Co-Cr-Ta media having different Br values were examined. Table 1 shows values of the residual magnetic flux densities (Br), film thickness (δ), coercivity (H_c) and coercivity squareness (S^*) for individual samples. As shown in the Table, H_c values gradually decrease with a decrease in Br. The change in the H_c value is probably caused by change of the grain sizes and the Cr segregation states due to a difference of the chemical affinity of the atoms. The grain sizes in the lower Br media would be larger than those for the higher Br media because the magnetic layer of the former is thicker than that of the latter. Furthermore, the low Br media with higher Cr content and thicker magnetic layer has more perpendicular component in the films. This is also one of the reason of the H_c decline in the low Br media.

Figure 2 shows the dependence of the isolated readback signal at 4kFRPI (S_0) and recording density D_{50} on Br for the media samples shown in Table 1. S_0 and D_{50} decrease with a decrease in Br, despite the $Br\delta$ value remaining constant. To investigate these S_0 and D_{50} behaviors, the relation for S_0 and D_{50} versus $Br\delta$ and H_c were estimated.

Figure 3 shows that the dependence of S_0 on $(H_c Br \delta)^{1/2}$ is strongly correlated. Since $Br\delta$ is constant, the change in $(H_c Br \delta)^{1/2}$ is equivalent to that for $H_c^{1/2}$. Figure 4 shows that the dependence of D_{50} on $(H_c/Br \delta)^{1/2}$ is also strongly correlated. Therefore, it was confirmed that the S_0 decline and D_{50} decline in low Br media is due to the low H_c value for the low Br media.

Table 1 Residual magnetic flux density (Br), film thickness (δ), coercivity (H_c), and coercivity squareness (S^*) of individual samples.

Br(G)	Hc(Oe)	S^*	δ (nm)
7,080	1,920	0.83	16
5,090	1,810	0.79	22
3,990	1,720	0.79	28
2,970	1,510	0.72	37
2,620	1,400	0.72	42
2,280	1,220	0.72	48
1,920	1,030	0.66	57
1,580	820	0.49	70

Figure 2 Dependence of isolated readback signal at 4 kFRPI (S_0) and recording density D_{50} on Br for the media samples (listed in Table 1).

Figure 3 Dependence of isolated readback signal at 4 kFRPI (S_0) on $(H_c Br \delta)^{1/2}$.

Figure 4 Dependence of D_{50} on $(H_c/Br \delta)^{1/2}$.

Figure 5 shows the dependence of the integrated media noise and DC erase noise on Br. The signal density is 100 kFRPI. The media noise values were calculated by integrating the noise spectrum over 23.2MHz bandwidth, which corresponds to the 100 kFRPI. The media noise decreases with a decrease in Br. However, the DC erase noise difference between the low Br media and the high Br media is negligible. This result shows that the DC erase noise is independent from the H_c values.

Since the media samples, shown in Fig. 5, have different readback signal values, the media noises were normalized by the readback signal (S) at each linear density. Figure 6 shows the dependence of the media noise (N) normalized by readback signal(S) on the recording density. The N/S values for all samples increase with an increase in recording density. The N/S curve slopes for the low Br media are much higher than those for the high Br media. From the longitudinal media noise to signal ratio view point, the high Br media with a thinner magnetic layer is preferable to the lower Br media with a thicker magnetic layer. However, if the H_c value for the low Br media is nearly equal to that for the high Br media, the readback signal and S/N for the former would be larger. Therefore, H_c improvement in the film preparation will be an important subject.

Figure 7 shows the dependence of the fluctuation in half-width of the readback waveform at 60 kFRPI on Br. The half-width of readback waveform depends on the magnetic transition amplitude. The half width fluctuation is almost constant, between 3,000 G and 7,000 G. However, the fluctuation value increases drastically below Br 2,000 G. This result shows that the fluctuation in the amplitude of the magnetic transition becomes large (below Br of 2,000 G).

Figure 8 shows the relationship between the N/S value and the half-width fluctuations of the readback waveforms at 60 kFRPI. The N/S values are strongly correlated to the half-width fluctuation. Therefore, it is concluded that the magnetic transition fluctuation for the lower Br media (below 2,000 G) is larger than that for the high Br media with less thickness. This result indicates that the Co-Cr-Ta films microstructure degenerates for lower Br and thicker magnetic layers. Cr segregation states in high Cr content and grain size are cited as the degeneration factors.

B. Noise characteristics of Co-Cr-Ta media and ferrite media

Noise characteristics for ferrite media were investigated and compared them with those for Co-Cr-Ta media. The H_c values for as-deposited ferrite films are

Figure 5 Dependence of integrated media noise and DC erase noise on Br for individual samples (listed in Table 1).

Figure 6 Dependence of media noise to signal ratio (N/S) on recording density for various Br media.

Figure 7 Dependence of the half-width fluctuation of readback waveform at 60 kFRPI on Br.

Figure 8 Correlation between N/S value and half-width fluctuation in the readback waveform at 60 kFRPI.

several hundred Oe and those of annealed ferrite films becomes more than 1,000 Oe. H_c increases with an increase in the annealing temperature. Ferrite film structures, which are independent of annealing temperatures, are spinel crystals with (111) preferred orientation. Ferrite media:A and ferrite media:B were annealed at 200°C and 400°C for 1 hour, respectively. The H_c values for ferrite media:A and ferrite media:B were 930 Oe and 1360 Oe, respectively. The Br for the ferrite media with 50 nm thickness is about 2,200 G.

Figure 9 shows the dependence of the media noise (N) to signal ratio at 4kFRPI (S_0) on recording density for ferrite media:A, ferrite media:B and Co-Cr-Ta media. The H_c value for Co-Cr-Ta media is 1,220 Oe, which is nearly equal to that for ferrite media:B. Ferrite film media shows superior N/S_0 characteristics to Co-Cr-Ta film media. The N/S_0 value for ferrite media:A, annealed at 200°C, is superior to that for ferrite media:B, annealed at 400°C. Therefore, low annealing temperature is effective in decreasing in media noise. DC erase noise for the ferrite media is higher than that for the Co-Cr-Ta media. With an increase in recording density, the N/S_0 values for ferrite media are almost constant. On the other hand, the N/S_0 for Co-Cr-Ta media increases with increasing recording density. These different behaviors may come from the different noise power sources. Noise power for Co-Cr-Ta media mainly comes from the magnetic transition region. On the other hand, noise power for ferrite media as well as particulate media doesn't mainly come from the magnetic transition region. This is suggested by the difference in DC erase noises between ferrite media and Co-Cr-Ta media. Therefore, the ferrite media exhibits excellent potential for use as a low-noise media at high density recording.

Figure 10 shows δM plots versus the field normalized by the remanent coercivity. These plots depend on the isolation of the magnetic grains. These samples exhibit negative interaction between crystal grains. The magnetic grains isolation for ferrite media:A, annealed at a low temperature, is weaker than that for ferrite media:B annealed at a high temperature. Furthermore, this result shows that ferrite thin films also has static magnetic interactions between grains as do Co-Cr-Ta alloy film with Cr segregation.

IV. CONCLUSION

The effect of residual magnetic flux density on the media noise for Co-Cr-Ta alloy thin films has been investigated. From the longitudinal media noise to signal ratio point view, the high Br media with a thinner magnetic layer is preferable to the lower Br

Figure 9 Dependence of the ratio for media noise (N) to signal at 4 kFRPI (S_0) on recording density for ferrite media:A, ferrite media:B and Co-Cr-Ta.

Figure 10 δM plots versus the field normalized by the remanent coercivity for individual samples.

media (below 2,000 G) with a thicker magnetic layer. It was revealed that the media noise was proportional to the fluctuation in the magnetic transition region according to analysis of readback waveform. Furthermore, the ferrite media exhibits excellent potential for use as a low-noise media at high recording densities.

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