RECORDING CHARACTERISTICS OF PARTIALLY OXIDIZED Fe-Co MEDIA WITH AN Fe-Co UNDER-LAYER

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Abstract --- Recording characteristics of partially oxidized Fe-Co media were improved remarkably by the introduction of an Fe-Co under-layer. In this paper, the effects of the coercive force of the Fe-Co under-layer on recording characteristics were investigated using a ring-type head. The stronger the coercive force of the under-layer, the higher the reproduced voltage and recording density D50, and the superior C/N and overwrite characteristics. Waveforms of a medium whose Fe-Co under-layer possessed a high coercive force were sharper than those of a medium with low coercive force. We consider that the broadening of the waveforms depends mainly on interactions between the head and Fe-Co under-layer.

1. INTRODUCTION

Perpendicular magnetic recording is promising as a key technology for high density recording systems. Co-Cr thin film media developed for these systems, however, are not durable enough for practical use. We reported previously that partially oxidized Fe-Co media (Fe-Co-O) prepared by RF reactive magnetron sputtering have a large perpendicular anisotropy, a large saturation magnetization(1) and good durability(2). We also reported the recording characteristics of Fe-Co-O media using a ring-type head(3). In addition, we reported that the reproduced voltage can be increased further for Fe-Co-O media by introducing an Fe-Co under-layer (Fe-Co-O/Fe-Co) using a ring-type head(4). The optimum thicknesses of the Fe-Co under-layer and Fe-Co-O were 500Å and 1500Å, respectively. It has already been reported that decreasing the demagnetization field enhanced the reproduced voltage by introducing a soft magnetic under-layer(5)(6). We believe, however, that the recording characteristics of this medium were influenced by the coercive force (H_c) of the Fe-Co under-layer as well as the decreasing the demagnetization field.

In this paper, the effects of H_c of Fe-Co under-layers on the recording characteristics were investigated.

2. MEDIA PREPARATION AND MEASUREMENT METHODS

Fe-Co-O layers and Fe-Co under-layers were prepared by RF reactive- and RF magnetron sputtering, respectively. The sputtering target for Fe-Co-O preparation was Fe-Co alloy, whose diameter and Co content were 6 inches and 40 at.%. The anisotropy field and coercive force in the perpendicular direction have maximum values at Co 40 at.% for an Fe-Co-O single-layered medium. The sputtering target for Fe-Co under-layer preparation was also Fe-Co alloy, whose diameter was 6 inches, and Co content was varied. Polyimide film with 50µm thickness was used as the substrate. The oxidation for Fe-Co-O layer was controlled by oxygen pressure and sputtering rate (20-30 Å/sec).

Media were prepared by rotating the substrate above the target. Thicknesses of Fe-Co-O and Fe-Co under-layer were controlled to be 1500Å and 500Å, respectively.

Recording characteristics were measured by a spectrum analyzer and a flexible disc measurement system using a Mn-Zn-ferrite ring-type head whose gap length, track width and coil turn number were 0.3µm, 30µm and 20, respectively.

Fig.1 Co content dependence of H_c

Fig.2 Sputtering power dependence of H_c of Fe-Co under-layer.

3. RESULTS AND DISCUSSION

3.1 H_c of Fe-Co under-layer

H_c of the Fe-Co under-layer depends on Co content of the target, power and pressure during sputtering. Fig.1 shows Co content dependence of H_c in the fixed conditions of Ar pressure of 1.2 mTorr and sputtering power of 200 W. H_c was measured in the track direction. The difference between H_c of track direction and that of

Fig.3 Relationship between perpendicular coercive force $H_{c\perp}$ and saturation magnetization $4\pi M_s$.

Fig.4 Relationship between anisotropy field H_k and $4\pi M_s$.

track width direction was very small. H_c depends on the Co content and becomes maximum at 40 at.%. Fig.2 shows the relationship between H_c and sputtering power for Co 60 at.%. H_c increases with increasing sputtering power. The structure of the films described above was analyzed by X-ray diffraction method. It was orientated to bcc(110).

3.2 Magnetic properties of Fe-Co-O/Fe-Co

Fig.s 3 and 4 show the relationships between perpendicular coercive force (H_{c1}), anisotropy field (H_k) and $4\pi M_s$ (oxidation degree) of the Fe-Co-O layer with varying Co content of Fe-Co under-layer, which were measured without separation of each layer. In this case, H_c of the under-layer was changed from 30 to 185 Oe by varying the Co content from 0 to 40 at.%, and under-layers possessing H_c of 260 Oe were prepared at sputtering power of 1200 W using Co 60 at.% target. Both H_{c1} and H_k of Fe-Co-O/Fe-Co double layers depend mainly on $4\pi M_s$ of Fe-Co-O.

3.3 Recording characteristics

For the measurement of recording characteristics, the recording current was selected at 4 mA, because the reproduced voltage of all media saturated at 4 mA. Fig.5 shows the relationship between normalized reproduced voltage (V) at a recording density of 25.4 kfc/i and $4\pi M_s$ of Fe-Co-O layer with varying H_c of the Fe-Co under-layer from 30 to 260 Oe. V for every H_c of the Fe-Co under-layer shows the maximum value at $4\pi M_s$ of 9000 gauss. In addition, the maximum value increases with increasing H_c of Fe-Co under-layer. Fig.6 shows the relationship between recording density D50 and $4\pi M_s$ of the Fe-Co-O layer. D50 for every H_c of the Fe-Co under-layer also shows maximum value at $4\pi M_s$ of 9000 gauss, and the maximum value increases with increasing H_c . The best V (170 μV o-p/mm/(m/sec)/turn) and D50 (82 kfc/i) were acquired for $4\pi M_s$ of 9000 gauss and H_c of 260 Oe.

The result that V increases with increasing $4\pi M_s$ proportionally is similar to that of Fe-Co-O single-layered media. Namely, V is proportional to $4\pi M_s$ for media having $4\pi M_s$ less than 9000 gauss, however, H_c is so small that V decreases for media having $4\pi M_s$ more than 9000 gauss.

It is impossible to explain the increase of V with H_c of the under-layer only by a decrease of demagnetization.

3.4 Waveform

Reproduced waveforms were investigated by varying H_c of the Fe-Co under-layer,

Fig.5 Relationship between normalized reproduced voltage V and $4\pi M_s$.

Fig.6 Relationship between recording density D50 and $4\pi M_s$.

for media possessing Fe-Co-O layers whose $4\pi M_s$ was 9000 gauss. The magnetic properties of the media are shown in Table 1. H_{c1} in Table 1 denotes the coercive force measured in a longitudinal direction for double-layered medium. Fig.7 shows the waveforms when H_c of the Fe-Co under-layer and recording current were varied. From Fig.7, the following facts are revealed.

Fig.7 Waveforms of Fe-Co-O/Fe-Co double-layered media.

Table 1 Magnetic properties of Fe-Co-O/Fe-Co double-layered media. H_c ; coercive force of Fe-Co under-layer, $H_{c\perp}$; coercive force of perpendicular direction, $H_{c\parallel}$; coercive force of longitudinal direction.

	H_c (Oe)	$H_{c\perp}$ (Oe)	$H_{c\parallel}$ (Oe)	$4\pi Ms$ (gauss)
Medium A	30	460	70	8800
Medium B	70	400	140	8700
Medium C	185	420	240	9300
Medium D	260	300	220	9000

1) The waveform becomes sharper with increasing H_c at the same recording current.

2) The waveform broadens drastically with decreasing H_c as the recording current becomes higher.

The broadening of the waveform might be caused by interaction between the Fe-Co under-layer and head. The permeability μ of the Fe-Co under-layer changes with H_c under a constant $4\pi Ms$ of Fe-Co. For low H_c , it is considered that the head field becomes broad, because of strong interaction between the Fe-Co under-layer

and head. Therefore, the magnetization transition was broadened by the effect of both broadened writing head field and low H_c , resulting in decrease of V and $D50$. On the other hand, for high H_c , it is considered that the head field does not broaden, even at high recording currents. Therefore, the magnetization transition remains narrow, so both V and $D50$ are high.

In spite of the fact that H_c of Medium D is higher than that of Medium C, the degree of V decreasing is large with increasing recording current in Fig.7. This result is due to recording demagnetization because of low $H_{c\perp}$.

Fig.8 shows waveform changes with varying recording currents and $4\pi Ms$ of a medium having a constant H_c of 260 Oe. For a recording current of 4 mA, the waveform is sharpest at $4\pi Ms$ of 9000 gauss. $4\pi Ms$ larger than 9000 gauss or less than 9000 gauss broadens the waveforms. In addition, although the waveforms broaden with increasing recording current, broadening of the waveform at $4\pi Ms$ of 9000 gauss is the smallest. It is considered that the

Fig.8 Waveforms of Fe-Co-O/Fe-Co double-layered media with varying $4\pi M_s$ of Fe-Co-O. (a) $4\pi M_s$ of 7200 gauss, (b) 9000 gauss, (c) 10200 gauss.

broadened waveform of the medium whose $4\pi M_s$ is 10200 gauss, originates from the wider magnetization transition generated by low H_{c1} . On the other hand, waveform broadening at $4\pi M_s$ of 7200 gauss might indicate that capacity of the head is insufficient for high H_{c1} or high H_k medium. It is considered that there are optimum magnetic properties for each layer of media, and an optimum combination between magnetic properties of the medium and head.

3.5 C/N and overwrite characteristics

Fig.9 shows the relationship between C/N at a recording density of 25.4 kfc/i and $4\pi M_s$ of the Fe-Co-O layer, where H_c of under-layer was varied. Resolution bandwidth was 30 kHz. The higher H_c of Fe-Co under-layer, the higher C/N. C/N obtained at $4\pi M_s$ of 9000 gauss and H_c of 260 Oe is about 42 dB. The improvement of C/N is mainly due to an increase of signal intensity.

Overwrite characteristics (O-W) were measured using the above-mentioned head at relative velocity of 2 m/sec. O-W were measured as the ratio of residual level of 2F(40 kfc/i, 1.6 MHz) signals to initial 2F level after overwriting 1F(20 kfc/i, 0.8 MHz) signals on 2F signals. Fig.10 (a), (b) show recording current dependence of O-W and recording-reproducing characteristics for H_c of 260 Oe and H_c of 30 Oe. O-W decrease with increasing recording current

Fig.9 $4\pi M_s$ dependence of C/N.

but O-W for H_c of 260 Oe increase again at 10 mA. The result closely relates to the demagnetization shown in Fig.10(b). Furthermore, O-W for H_c of 260 Oe are superior to those of H_c of 30 Oe, about -28 dB. The difference of O-W between for low H_c and for high H_c is not caused by the difference of recording sensitivity for each recording density, because it is almost same as shown in Fig.10 (b). It is considered that the difference is caused by broadening of the head field.

4. CONCLUSION

Recording characteristics for Fe-Co-O/Fe-Co media in which H_c of the Fe-Co under-layer and $4\pi M_s$ of Fe-Co-O layer were varied, were investigated. Both reproduced voltage V and recording density D_{50} for high H_c were higher than those of low H_c . V and D_{50} for H_c of 260 Oe and $4\pi M_s$ of 9000 gauss were about 170 μV_o -p/mm/(m/sec)/turn and 82 kfc/i, respectively.

C/N and O-W of the media whose Fe-Co under-layer possessed high H_c (260 Oe) and $4\pi M_s$ of 9000 gauss, were 42 dB and -28 dB, respectively, in the conditions of recording density of 25.4 kfc/i, relative velocity of 2 m/sec and track width of 30 μm .

Isolated waveforms were compared. The medium with low H_c under-layer showed the

Fig.10 (a) Recording current dependence of O-W characteristics.

Fig.10 (b) Recording-and reproducing characteristics for recording frequency of 1.6MHz and 0.8MHz.

broadening of waveform, which resulted in the decrease of V and D50. It is considered that, for low H_c , interaction between head and high permeable under-layer broadens head field, so broadening magnetization transition. On the other hand, for high H_c , the head field does not broaden even at high recording currents because of low permeability of Fe-Co under-layer. Therefore, as the magnetization transition remains narrow, both V and D50 are high. $4\pi Ms$ of Fe-Co-O layer

influenced on waveform too. The waveform was sharpest at 9000 gauss. $4\pi Ms$ larger than 9000 gauss broadens waveform because of low H_c of Fe-Co-O. $4\pi Ms$ less than 9000 gauss also broadens waveform because of the lack of head capacity for too high H_{c1} and H_k of Fe-Co-O layer.

As a result, it is necessary to increase V and D50 that H_c of the Fe-Co under-layer is higher and $4\pi Ms$ of the Fe-Co-O is the optimum value.

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