Original

Perpendicular Recording Performance of Co-Cr Film Prepared by Newly Developed Sputter-deposition

by

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ABSTRACT

Recording and noise properties were studied by using a ring type head for a Co-Cr medium prepared by a new sputtering method at room temperature with a high Ar pressure of 70 Pa. Reproduced waveform for the medium was a dipulse which suggested that a perpendicular recording mode has been realized. The new medium exhibited as a high density response performance as that of a conventionally prepared medium, namely, deposited at a high temperature of 250°C with a low Ar pressure of 0.2 Pa. The noise level of the new medium was lower than that of the conventional one. It is suggested that the low noise properties are attributed to an isolated microstructure of the medium.

Key Words: perpendicular magnetic recording, Co-Cr film, high Ar pressure sputtering, room temperature deposition, noise, microstructure

1. INTRODUCTION

Co-Cr films by sputtering have been extensively investigated as ultra high density recording media. In order to obtain a large perpendicular magnetic anisotropy and a high coercivity for such the deposited films, sputtering conditions with high substrate temperatures and low Ar gas pressures have been preferentially used. However, these conditions impose difficulties such as high cost of the sputtering apparatus or instability of discharge for the sputtering process. We have recently proposed a new preparation method for Co-Cr films with high perpendicular coercivities by sputter-deposition at room temperature and high Ar pressures. It was found that the Co-Cr films of the new preparation method had an isolated microstructure which was very different from as continuous structure observed for conventional method films. Therefore some advantages in recording and noise properties are expected for the new media. In this paper, recording properties for the new Co-Cr medium of a disk type were investigated. The recording performance at ultra high densities was compared with that of a conventional Co-Cr medium as well as with a commercial Co-Cr system longitudinal medium. Relationship between the noise property and the microstructure for these Co-Cr media was also studied.
2. Experiments

The Co-Cr films were prepared by DC magnetron sputtering using targets of 75 mm in diameter. A 17 wt% Co-Cr alloy target was used for the Co-Cr films. Sputter-deposited Ti was used as underlayer. All depositions were made on glass disk substrates of 60 mm in diameter. The Ar pressure was set at 70 Pa to obtain a high coercivity for the Co-Cr film deposited at room temperature (medium # 1). The conventional Co-Cr film (medium # 2) was deposited at a condition of 0.2 Pa and 250 °C. A commercial longitudinal Co-Cr-Ta disk (medium # 3) was also used as a reference.

Perpendicular orientation of the hcp c axis for the Co-Cr films was evaluated by full half height width of the rocking curve for (00 2) x-ray diffraction line using CuKα radiation. Coercivities of the Co-Cr films were measured using a vibrating sample magnetometer (VSM). The deposition conditions and the magnetic properties are shown in Table I.

Recording specifications of the media were measured by using a disk tester with a MIG (metal in gap) type ring head whose specifications are shown in Table II. A contact head-supporting mechanism, which is called self-weight type supporting mechanism, was used for reducing the head-medium spacing. The relative velocity between the head and the medium was 2.09 m/s for all recording measurements.

Microstructure of the films was observed by a field-emission scanning electron microscope (FE-SEM).

3. Results and discussions

3.1 Recording properties

Figure 1 shows reproduced waveform at a recording density of 4 kFRPI (Flux Reversals Per Inch). Reproduced waveforms for the medium # 1 as well as the medium # 2 were similarly dipulse shape showing opposite subpulses followed by the each main pulses. However, the waveform for the longitudinal medium # 3 exhibited a single peaked shape. It is well known that the dipulse is a typical reproduced waveform for perpendicular recording media when a ring head is used. Therefore, it is indicated that the waveform of the medium # 1 prepared by new method is of perpendicular recording.

Recording density response of reproduced voltages (Ep) is shown in Fig. 2. Output voltage for the medium # 1 was higher than that for the medium # 2 at low recording densities, and slightly lower at high recording densities. The medium # 1 exhibited a second peak in it's response curve around 320 kFRPI similar to the curve for the medium # 2. However, no such a peak was observed for the

<table>
<thead>
<tr>
<th>Medium</th>
<th>Substrate temp.</th>
<th>Ar pressure</th>
<th>Δ θ, (00 2)</th>
<th>Hc(∥/⊥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>room temp.</td>
<td>70 Pa</td>
<td>5.8 deg</td>
<td>500/942 Oe</td>
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<tr>
<td>#2</td>
<td>250 °C</td>
<td>0.2 Pa</td>
<td>7.5 deg</td>
<td>470/990 Oe</td>
</tr>
<tr>
<td>#3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1438° Oe</td>
</tr>
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</table>

Table I Deposition conditions and magnetic properties of media

<table>
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<tr>
<th>Type</th>
<th>Gap length</th>
<th>Track width</th>
<th>Coil turns</th>
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<tbody>
<tr>
<td>MIG</td>
<td>0.23 μm</td>
<td>25 μm</td>
<td>20</td>
</tr>
</tbody>
</table>

Table II Specifications of head
Fig. 1 Reproduced waveforms recorded at 4 kFRPI, for (a) medium #1, (b) medium #2, (c) medium #3.
Fig. 2 Density response of reproduced voltage $E_p$ for various media, ○ for medium #1 (r. t., 70 Pa), ▲ for medium #2 (250°C, 0.2 Pa) and ■ for medium #3 (longitudinal).

Therefore, it is indicated that a high density property accompanied by above mentioned reproduced waveforms for the medium #1 is a typical property for perpendicular recording media. The reproduced voltages for the perpendicular media #1 and #2 were lower than that for the longitudinal medium #3 in a low density region. However, reproduced voltage for a Co-Cr medium could be increased using a thin high permeable back layer. The reproduced voltage for the medium #1 could be, therefore, raised to a level comparable with that of medium #3 by introducing a soft magnetic back layer.

3. 2 Noise properties

Noise spectra for the above tested three media were measured with a recorded signal. Figure 3 shows a noise spectrum for the medium #2 with a signal at a density of 320 kFRPI. The noise spectra were measured by a spectrum analyzer with conditions of the frequency range of 0 to 10 MHz, the resolution band width of 100kHz, and the video band width of 10kHz. The medium noise ($N_m$) was evaluated by subtracting the system noise ($N_s$), which was measured with the same head but apart from the medium, from the total noise ($N_t$) in a non-correlated manner, i.e. $N_m = (N_t^2 - N_s^2)^{1/2}$.

The medium noise spectra for the media are shown in Fig. 4. The noise spectrum for the medium #1 exhibited a peak at a low frequency around 2 MHz (Fig. 4 (a)). The noise spectrum for the medium #2 was widely spread and shifted slightly toward a higher frequency region comparing with the medium #1 (Fig. 4 (b)). Figure 4 (c) shows that remarkable peak in the noise spectrum for the longitudinal medium #3 can be seen at around 1 MHz, clearly differing from both the perpendicular medium #1 and #2.

Relationships between the medium noise level and the recorded signal density are shown in Fig. 5. The noise level was evaluated from the medium noise spectra for various recorded signals. The noise
Fig. 3 Noise spectra for medium #2 recorded at 320 kFRPI, measured by spectrum analyzer with RBW: 100 kHz, VBW: 10 kHz.

Fig. 4 Spectra of medium noise recorded at 320 kFRPI, for (a) medium #1 (r. t., 70 Pa), (b) #2 (250 °C, 0.2 Pa) and (c) #3 (longitudinal). Spectrum analyzer set is RBW: 100kHz, VBW: 10kHz.
level at 1 MHz are plotted in Fig. 5 (a), where the noise level for the media #1 and #2 do not depend on the recording density at low densities and decrease at higher densities. While the noise level drastically increases with increasing the recording density for the medium #3 at low densities below 100 kFRPI. The change of noise for the longitudinal medium #3 is a typical character of recording transition noises\(^{3,13}\). Figure 5 (b) shows the wide band noise averaged in 0 to 5 MHz, where the noise level for the medium #1 is the medium #2 (190 nm to 150 nm), the noise level for the medium #1 was substantially lower than that for the medium #2. The wide band noise levels in Fig. 5 (b) are lower than the levels at 1 MHz in Fig. 5 (a) for the media #1 and #3, this is because those media exhibit relatively narrow noise spectra.

3. 3 Microstructure

SEM images for the deposited film surfaces are shown in Fig. 6. The air gap like narrow grooves are observed as grain boundaries for a new method film (Fig. 6 (a)). On the other hand, a continuous structure with no clear grain boundaries is seen for a conventional method film (Fig. 6 (b)). It is suggested that the above mentioned low noise property for the new method medium is due to the microstructure of the film with magnetic isolations between the grains. Namely the well isolated grain structure plays an important role for providing the low noise property.
4. Conclusions

Recording and noise properties were investigated for the Co-Cr medium prepared by a new sputtering method. A new medium exhibited superior recording and noise properties to a longitudinal medium, and lower noise than a conventional perpendicular medium does with a comparably high density response. The low noise property of the new method medium can be related to a pronounced isolated microstructure of the film.

Since a low noise medium is very essential for a ultra high density recording, this new deposition method has advantage for a high density recording medium with a high potential for mass-production.

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References