The read/write characteristics of Co-Cr-Ta/Ni-Fe double-layer tape for digital video recording

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Abstract --- A digital video recording experiment was conducted by using a Co-Cr-Ta/Ni-Fe double-layer perpendicular magnetic recording tape and ring heads with a track width of 5 μm . The area recording density was 1.1bit/ μm^2 , almost 8 times that of the D-3 VTR. A new equalizing method using FFT analysis was also developed for the experiment, achieving a byte error rate of 1×10^{-5} .

Key words: perpendicular recording, digital VCR, Co-Cr-Ta, equalizing method

I. INTRODUCTION

Perpendicular magnetic recording has been much studied on account of its theoretically suitability for high density recording.

The authors have been researching and developing perpendicular magnetic recording tape for high density video data storage systems for broadcasting use and have already reported on some of their works[1][2][3]. Our previous studies included a digital video recording experiment using Co-Cr-Ta/Ni-Fe perpendicular magnetic recording tape and ring heads with a track width of 10 μm [4].

In this study, we used ring heads with a 5 μm track width to raise the recording density. A new playback equalizer was also developed and added to the signal processing circuit. This paper describes the digital video recording experiment.

II. EXPERIMENT

A. Preparation of the Co-Cr-Ta/Ni-Fe tape

The Co-Cr-Ta/Ni-Fe tape was prepared by a facing target sputtering system on a 100mm-wide by 10 μm -thick polyimide sheet. Table 1 lists the deposition conditions of the double layers.

The deposited sheet was slit into 8mm wide tapes, and the surface of the tapes was oxidized at 370 degrees centigrade in air to make an oxidized protection layer. Finally the tape was coated with liquid lubricant.

Table 1 Deposition conditions of Co-Cr-Ta/Ni-Fe film.

Composition	
Co-Cr-Ta	Co _{79.5} Cr ₁₈ Ta _{2.5} at. %
Ni-Fe	Ni ₈₀ Fe ₂₀ at. %
Sputtering gas	Kr
Gas pressure	1mTorr
Temperature of base film	135 °C

Fig.1 shows the schematic structure of the Co-Cr-Ta/Ni-Fe double-layer tape. Fig. 2 shows the M-H loops of the tape measured by using a VSM. Table 2 lists the thickness and magnetic properties of the magnetic layers.

Fig. 1 Schematic structure of the Co-Cr-Ta/Ni-Fe tape.

Fig. 2 M-H loops of the Co-Cr-Ta/Ni-Fe double-layer tape.

Table 2 Thickness and magnetic properties of the Co-Cr-Ta/Ni-Fe tape.

Thickness	
Co-Cr-Ta	200 nm
Ni-Fe	50 nm
$H_{c\perp}$	1250 Oe
M_s	
Co-Cr-Ta	460 emu/cc
Ni-Fe	780 emu/cc

B. Experimental VCR for digital video recording

Fig.3 shows the tape transport system used in this study. It was based on an 8mmVCR, but improved so that the Co-Cr-Ta/Ni-Fe double-layer tape would be able to run without being damaged by changes in the material of the guide posts and the adjustment of tape tension.

Fig. 3 Tape transport system.

Fig. 4 Linear density characteristics of the output for the double-layer tape and the single layer tape.

Table 3 Specifications of the experimental VCR.

Drum diameter	40 mm
Drum rotation speed	90 rps(5400rpm)
Relative tape-to-head velocity	11.4 m/s
Total recording bit rate	126 Mbps
Maximum recording frequency	27.7 MHz
Number of simultaneous recording channels	2
Channel coding:	8-14 modulation
Number of tracks per field	6
Recording bit length	0.18 μm
Head track width	5 μm

The capstan servo with pilot signals is adopted for the ordinal 8mm VCR. However, the capstan servo system with a stationary head (CTL head) is used for the experimental VCR in order to prevent the influence from the pilot signals on the video data signal. It is very important to secure a large output from the CTL head for stable tape running and head tracking. The wavelength of the CTL signal is several hundred μm , so magnetic tapes which reproduce a large output in the long wavelength region are preferable. The authors have been researching and developing two kinds of perpendicular magnetic recording tape; the Co-Cr-Ta single-layer tape and the Co-Cr-Ta/Ni-Fe double-layer tape. Fig.4 shows the read/write characteristics for these tapes[4]. The latter has a larger output in the long wavelength region, so this was the type used in the experiment.

Table 3 lists the specifications of the VCR that was used for the experiment. A D-3 VTR signal processing circuit was chosen in order to obtain digital video data, so the bit rate, maximum recording frequency, number of simultaneous recording channels, and channel coding were the same as those for the D-3 VTR. However, the track width of the head was only 5 μm , which is one quarter of the figure for the D-3 VTR, and the bit length was 0.18 μm , or almost half that of the D-3 VTR. The area recording density was thus raised to 1.1 bit/ μm^2 , which is almost 8 times that of the D-3 VTR.

III. RESULTS AND DISCUSSION

A. Read/write characteristics

Fig. 5 shows the spectrum reproduced when recording a sinusoidal wave at the maximum recording frequency (27.7MHz), which is equivalent to the shortest wavelength. The narrow band carrier to noise ratio (N-CNR), which is the ratio of the carrier power to the noise with a band width of 100kHz in the neighborhood of the carrier frequency, is 42.5dB(rms/rms). As shown in Fig.5, the media noise is the most prominent noise. So the reduction of the media noise is necessary for the increase of the CN ratio..

Fig. 5 Reproduced spectrum and instrument noise spectrum.

Next, Fig. 6 shows the reproduced wave form when a square signal was recorded. Due to the Ni-Fe layer, the wave form resembles a rectangular one with an overshoot rather than a di-pulse, which is the typical wave form of a Co-Cr-Ta single layer tape.

It was very difficult to obtain an adequate error rate by using the conventional equalizer because of the asymmetry of the wave form and the CN ratio. The authors therefore developed an additional equalizer.

Fig. 6 Reproduced wave form.

B. Equalization

The PR5 (Partial Response class 5) equalizer is thought to be applicable to perpendicular digital recording, but it requires large and sophisticated circuits [5][6]. In the experiment, we used the equalizing circuit of the D-3 VTR. As described above, the reproduced signal of perpendicular recording could not be equalized by the circuit only. We have therefore developed a new equalizing method and added a simple RC phase equalizing circuit to the D-3 VTR's equalizer. The additional circuit is much smaller in scale than the PR5 equalizer.

The new equalizing method for perpendicular recording is as follows:

In general, circuits which have the inverse function of the transfer function of a system can equalize the output signal to produce a signal identical to the input signal. Such circuits can be realized using phase and amplitude equalizers. The transfer function of the system can be calculated from a step response signal (a pulse-reproduced signal, such as the one shown in Fig.6) by using FFT analysis. For example, the transfer function of an ordinary longitudinal recording system generally has a phase advance of 90 degrees. The D-3 VTR's equalizer has a phase delay of 90 degrees.

We calculated the transfer function of the Co-Cr-Ta/Ni-Fe tape and the ring head system from the wave form shown in Fig.6. Fig.7 shows the transfer function (amplitude and phase). The result indicated that this system exhibits a phase advance of about 50 degrees across almost the whole frequency range. In other words, it has a phase delay of 40 degrees compared with that of the longitudinal

recording system. The amplitude response displayed the same band pass characteristics as the ordinary longitudinal recording system. Based on this analysis, a phase equalizer was made by using an RC circuit with a phase advance of 40 degrees (High Pass Filter).

Fig. 8 shows the wave form after equalization of the signal shown in Fig. 6 by the RC circuit. It is almost symmetrical and resembles that of the longitudinal recording system.

Fig. 7 Transfer function of the Co-Cr-Ta/Ni-Fe tape and the ring head system.

Fig. 8 Reproduced wave form after equalization by the additional circuit.

Fig. 9 shows a typical eye pattern when digital video data are recorded. A byte error rate of 1×10^{-5} was derived. This error rate is still inadequate for practical use. To obtain a better rate, the media noise must be reduced because that is the most prominent noise, as shown in Fig. 5.

Fig. 9 Eye pattern of reproduced signal.

IV. CONCLUSION

Digital video recording was conducted using a Co-Cr-Ta/Ni-Fe double-layer perpendicular magnetic recording tape and ring heads with a track width of $5 \mu\text{m}$. The tape was prepared by means of a facing target sputtering system. The CN ratio, (the ratio of the carrier power to the noise with a band width of 100kHz), was 42.5dB(rms/rms). It was difficult to obtain an adequate error rate only by using the conventional equalizer in the D-3 VTR because of the asymmetry of the reproduced wave form and the CN ratio. A new equalizing method using FFT analysis was also developed for the experiment. An RC phase equalizer was made based on the method, and added to the conventional equalizer. As a result, a byte error rate of 1×10^{-5} was derived at a recording density of $1.1\text{bit}/\mu\text{m}^2$ which was almost 8 times that of the D-3 VTR. The reduction of media noise is now required to obtain a better error rate.

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