The Application of Sputtered Thin Film in Advanced Recording Tape Media

Hwan-Soo Lee, James A. Bain, and David E. Laughlin

***Abstract*—Recording characteristics of CoCrPt-sputtered tape media with a thickness of 25 nm were investigated using an anisotropic magnetoresistive head. The sputtered tape media showed a high output, and a flat frequency response with a D_{50} value of 5500 fcmm (140 kfci) and a corresponding signal-to-noise ratio of 22 dB. Such sputtered tape media produced a sharp and symmetrical isolated pulse waveform with a PW_{50} of 0.31 μm and showed good overwrite characteristics for digital recording. The overwrite performance of the sputtered tape media was better than 30 dB for an overwriting frequency of 12 MHz or 3500 fcmm (90 kfci) and overwritten frequency ranging from 2–9 MHz or 600–2650 fcmm (15–67 kfci). In addition, the stability of the sputtered tape media was characterized exposed to an atmosphere of 65 °C and 90% RH for several weeks and showed to be highly corrosion resistive with less than 5% of their magnetization loss after 30 days of exposure.**

***Index Terms*—Anisotropic magnetoresistive (AMR) head, corrosion resistive, overwrite, recording characteristics, sputtered tape media.**

I. INTRODUCTION

IN MAGNETIC recording media, although there has been much lively debate about determining which tape medium is best suited for high density recording, there is continued demand for thinner and smoother defect-free magnetic tape media with high coercivity capable of supporting high linear densities. With present coating technologies, there is concern that shedding and dropouts might limit durability and archival stability, thus canceling the benefits of further magnetic layer thickness reduction. In particular, the migration to the very small thicknesses characteristic of rigid disks for even greater densities in future tape systems seems to be challenging even in metal evaporated (ME) tape technology.

Previously, Co-based alloys deposited at temperatures well below the glass transition temperature of polymeric substrates have been investigated [1]. In this study, the recording characteristics of these sputtered tape media are reported, showing that the sputtered tape media can offer comparable output and signal-to-noise ratio (SNR) properties to conventional tape media when an anisotropic magnetoresistive (AMR) head is used for readback. The characteristics of the sputtered tape media were also studied in terms of media stability. The corrosion resistance under elevated temperature and humidity was examined by measuring the percent change in magnetic moment (Mr).

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TABLE I
SPECIFICATIONS OF MEDIA AND WRITE/READ HEADS

<Write head>	
Type	Metal-in-gap
Gap length (μm)	0.2
Track width (μm)	17
<Read head>	
Type	Shield AMR
Bias scheme	Soft adjacent layer biased
MR element height (μm)	2.7
MR thickness (nm)	25
Track width (μm)	7
Shield to shield distance (μm)	0.23
Azimuth angle (degrees)	25
<Media>	
Type	CoCrPt sputtered
Coercivity (Oe)	2400
Thickness of mag. layer (nm)	25
Mr·δ (memu/cm^2)	1.2

II. EXPERIMENT

$Co_{62}Cr_{15}Pt_{23}$ thin films were sputter deposited on advanced polyethylene naphthalate (PEN) substrates without explicit heating for this investigation. A nonmagnetic $Co_{69}Cr_{29}Ta_2$ (15 nm) intermediate layer and NiAl (60 nm)/$Cr_{92}Mn_8$ (30 nm) underlayers were deposited on the tape prior to depositing the CoCrPt layer. Other details are described elsewhere [1]. The magnetic layer was 25 nm thick having a protective carbon nitride (CNx) layer with a thickness of 5 nm. The CNx thin film was deposited by a reactive sputtering process in an environment of pure nitrogen [2]. The measurements were done on a drum tester at a head-medium velocity of 6.8 m/s, using a metal-in-gap (MIG) write head with an effective gap length of 0.2 μm and a track width of 17 μm, and an AMR read head with a shield-to-shield distance of 0.23 μm and a track width of 7 μm. The sense current of the AMR head was 10 mA. Table I shows the details of the sputtered tape media and the write/read heads employed in the experiment. The resolution bandwidth (RBW) for the measurement was chosen to be 30 kHz for the spectral analysis. Square waves were recorded at various densities and the readback wave forms were measured using an ADVANTEST R3132 spectrum analyzer. The sputtered tape media were initially ac erased using a bulk erasure, and recording a high-density signal on the sputtered tape medium resulted in an elevation of the noise

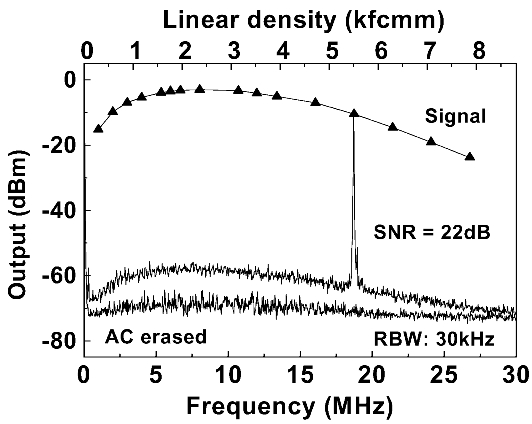

Fig. 1. Spectra of signal and noise for the sputtered tape media with the AMR head. The SNR showed about 22 dB at channel density (D_{50}) of 5500 fcmm (140 kfci).

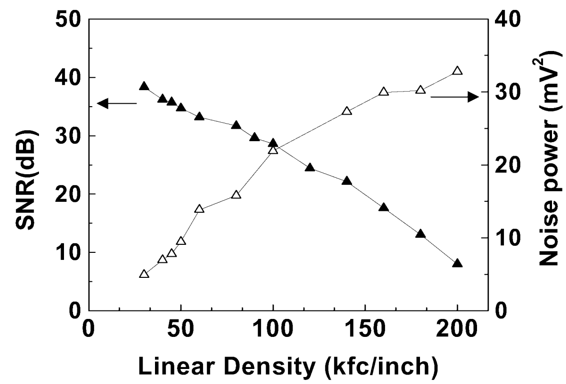

Fig. 2. SNR and integrated noise power with respect to recording density.

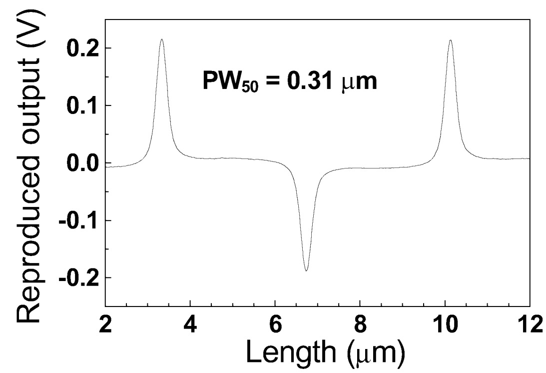

Fig. 3. Isolated pulse of reproduced output signal of the CoCrPt sputtered tape media with a thickness of 25 nm.

floor above the ac erased level. The write current utilized was optimized to produce a maximum signal amplitude at each linear density. Loss of output was seen if currents above the optimum recording current were used at short wavelengths. The output of the sputtered tape media recorded with a wavelength of 0.4 μm (120 kfci) decreased about 1.5 dB when recorded with a current above the optimum recording current. The signal power is defined as the harmonic peak, and the noise power as the area under the spectrum excluding the signal peak, as in the conventional way.

Moreover, these sputtered tape media were exposed to an atmosphere of 65 °C and 90% RH for 30 days in order to investigate their corrosion resistance. The samples for corrosion testing consisted of PEN/sputtered media/overcoat. The thickness of the protective CNx layer was 5–10 nm. After aging, the residual magnetic moment was measured to estimate the total magnetic moment loss. This included comparing a commercial DLT4 metal particle (MP) medium with a thickness of 0.3 μm that is more susceptible to atmospheric corrosion than ME tape [3]. Magnetic properties of the samples were measured by alternating gradient magnetometry (AGM) and vibrating sample magnetometry (VSM).

III. Results and Discussion

In Fig. 1, the roll-off curve for the sputtered tape media showed a D_{50} value (the density which produced 50% of the maximum output voltage from the AMR head) of 5500 fcmm (140 kfci), corresponding to an SNR of 22 dB. The maximum output from the sputtered tape media having a thickness (δ) of 25 nm was comparable to that of an experimental ME which is 40 nm thick. The similar reproduced output voltage arises from the similar value of $Mr \cdot \delta$. The studies of MP and ME tape media with the AMR heads were reported elsewhere [4], [5].

Modulation noise in the sputtered tape media was also seen to be minimal due to the smooth substrates. The use of smooth PEN substrates (mean roughness Ra: 1.3 nm) effectively eliminated modulation noise from the readback waveform. In contrast, sputtered tape media on traditional substrates (Ra: 6.1 nm) showed substantial modulation noise. In both cases, sputtered tape media were conformal with the substrate, and head-tape spacing fluctuations [6] are assumed responsible for the modulation noise. Details of the relationship between modulation noise and the surface profiles of smooth and traditional substrates will be the subject of a future publication. The measurements showed no significant modulation side bands even at narrow RBW settings.

Fig. 2 shows SNR and integrated noise power with respect to recording density. The measurements showed that integrated noise power at the erased state was very low and linearly increased with increasing recording density. This behavior suggests that the noise arises from mainly irregular domain boundaries in the transition, namely a transition noise-dominated system, as seen in media on rigid substrates for disk drives [7]. The amount of noise in the transitions increases due to magnetostatic interactions that cause percolation between adjacent transitions at high recording density. The noise power changed from 4.9 to 32.8 mV^2 in going from 30 to 200 kfci while the corresponding SNR decreased from 38.3 to 8.0 dB. The SNR of 18 dB was shown at a linear density of 6300 fcmm (160 kfci).

In Fig. 3, the isolated readback pulse from the sputtered tape media is shown to have a pulse width at 50% of maximum amplitude (PW_{50}) of 0.31 μm with a symmetrical pulse waveform. The narrow PW_{50} results from the reduced head-tape spacing. The transitions can still be reduced in length, as they appear, from analysis of this width to have a parameter of 60–70 nm. The coercive squareness S^* and squareness S of the CoCrPt films were 0.90 and 0.83, respectively.

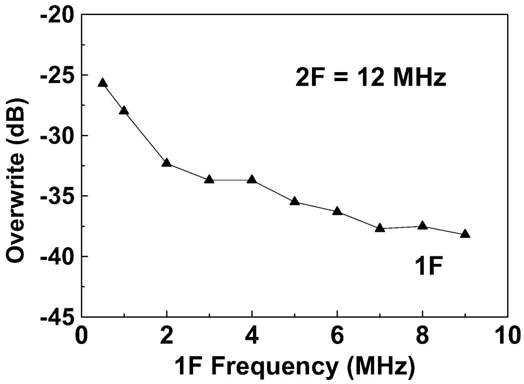

Fig. 4. Overwrite erasability of the sputtered tape media: overwrite dependence on the overwritten frequency (1F). The overwriting frequency (2F) is 12 MHz ($\lambda = 0.56\ \mu$m).

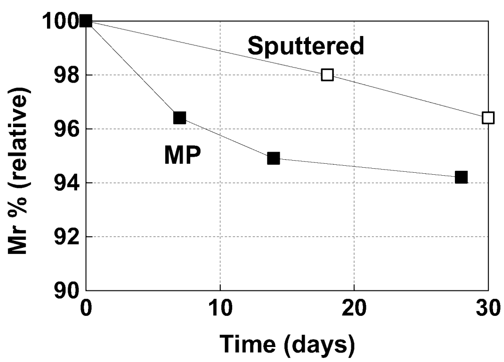

Fig. 5. Sputtered tape media stability at 65 °C and 90% RH. An MP medium is shown for comparison.

Overwrite measurements were carried out as shown in Fig. 4. Overwrite was defined as the ratio of the amplitude of the residual fundamental frequency component to the original signal of an overwritten frequency (1F) after recording with an overwriting frequency (2F). The 1F was varied and the 2F was taken as 12 MHz ($\lambda_2 = 0.56\ \mu$m). The good overwrite was present over the whole frequency range usually specified for data overwrite (two to ten times the shortest wavelength). The overwrite performance of the sputtered tape media was better than 30 dB for an overwriting frequency of 12 MHz or 3500 fcmm (90 kfci) and overwritten frequency ranging from 2–9 MHz or 600–2650 fcmm (15–67 kfci). One explanation of the good overwrite of the sputtered tape media could be the thin magnetic layer in addition to the reduced head-medium spacing.

Fig. 5 reveals that the sputtered tape media are highly corrosion resistant with only 4% magnetic moment loss after four weeks, which seems to be no worse, and, perhaps, even better, than the commercial MP tape. This was confirmed on a number of similar samples. It is considered that the high corrosion resistance was caused by two notable sample features and conditions: a protective CNx overcoat and sputtered CoCrPt film with a large content of Cr (15 at.%) and Pt (23 at.%). These contributions are in general agreement with the results reported in the literature [8], [9]. However, further investigations will be required for the detailed mechanisms of corrosion.

IV. Conclusion

The application of sputtered thin film in advanced recording tape media has been discussed. What sputtered tape media are able to exhibit in terms of recording performance include:

1) elimination of modulation noise;
2) high output and recording density limited by transition noise;
3) sharp and symmetrical waveforms;
4) good overwrite characteristics.

In addition, the sputtered tape media were stable with nearly no magnetic moment loss after exposure to the accelerated corrosion environment. Such high performance will be expected to facilitate the future applications of sputtered tape media to high density tape recording systems.

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