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Recording properties of CoCrPt tape media sputter-deposited at room temperature on polymeric substrates

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Recording properties of CoCrPt thin films sputter-deposited on polymeric substrates at room temperature were investigated. Typical frequency spectra of the readback signal from sputtered tapes at various recording densities revealed an appreciable amount of modulation noise, despite the fact that the sputtered tape is expected to be smooth and conformal with the substrate. Atomic force microscopy images suggest the modulation noise, present as side bands about the signal peak, is primarily due to the roughened polymeric substrate. The nonlinear partial erasure method was used to measure the sharpness of recorded transitions via the frequency domain one-dimensional/three-dimensional method. Intertransition interactions occurred at a linear density of 130 kfci, which corresponds to a transition length parameter (πa) of 195 nm. This rather large value of transition length is attributed to exchange coupling between grains in the media, suggesting inadequate Cr segregation due to the low-temperature deposition needed to avoid substrate damage. [DOI: 10.1063/1.1557335]

I. INTRODUCTION

With the introduction of magnetoresistive and eventually giant magnetoresistive multitrack heads in both linear and helical tape recording systems, media noise-limited performance will continue as densities increase. Thus, future data tape recording systems will require the tape magnetic layers to migrate to the very small thicknesses characteristic of rigid disks. Sputtering is invariably employed in the fabrication of rigid disk media, and offers an alternative method for producing the next generation of high-density tape media in response to the continued demand for thinner and smoother defect-free magnetic layers.

Previously, Co-based alloys have been investigated as candidates for sputtered thin film magnetic tape media. We have reported that magnetic media on polymer substrates having high coercivity (well above 2000 Oe) were obtained by applying NiAl/CrX underlayers prior to CoCrPt deposition with a CoCrTa interlayer.[1] In the present study, reading and writing on these sputtered tape media with a magnetic layer thickness of 25 nm and a coercivity of 208 kA/m (2600 Oe) were examined using a drum tester. The physical properties of the sputtered tape as well as its recording characteristics will be discussed, and compared to an experimental MP+++ media.

II. EXPERIMENTAL PROCEDURE

Films of CoCrPt were sputter-deposited onto polyimide tape (Kapton™) of 30-μm thickness. Kapton is used as an exploratory substrate because it can withstand high temperatures, when necessary. Ultimately, though, this technology will need to be transferred to polyethylene teraphthalate and/or polyethylene naphthalate substrates. A nonmagnetic CoCrTa interlayer and NiAl/CrV underlayers were deposited on the tape prior to depositing the CoCrPt layer. Other details of the sputtering conditions are described elsewhere.[1] It is important to note that the substrate is preheated to 130 °C to drive off adsorbed water before allowing it to cool in vacuum and depositing at room temperature. Magnetic properties of the samples were measured by alternating gradient magnetometry and vibrating sample magnetometry. Surface roughness was measured using an atomic force microscope (AFM). The gap and the track width of the read/write head were measured using a scanning electron microscope. The details of the media and the head used in the experiment are shown in Fig. 1. Square waves were recorded at various densities and the playback wave forms were measured using an HP 8568B spectrum analyzer. For the spectral analysis, the resolution bandwidth (RBW) was chosen to be 2–10 kHz.

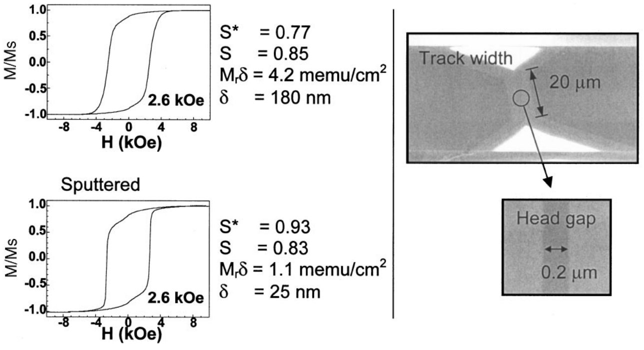

FIG. 1. Specifications of media and read/write head used in the experiment.

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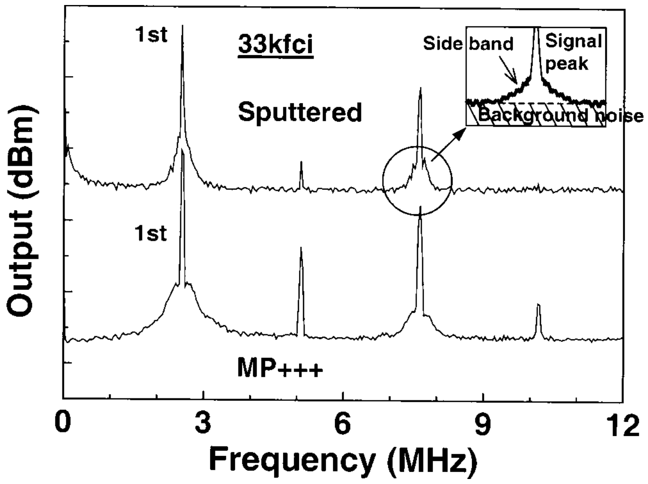

FIG. 2. Output amplitude vs recording density for sputtered and MP+++ media.

The narrow RBWs are needed in order to resolve the modulation side band, and correspond, at a head–medium speed of 4 m/s (see Sec. III) and 2 kHz to a maximum spatial wavelength of approximately 1 mm. Spacing fluctuations longer than this are not sensed in this measurement. An experimental MP+++ tape with a thickness of 180 nm and a coercivity of 2600 Oe was measured for comparison with the sputtered thin film media, also shown in Fig. 1.

III. RESULTS AND DISCUSSION

The measurements were performed on a drum tester using a sputtered tape and an experimental MP+++ tape. A MIG head with an effective gap length of 0.2 μm, a track width of 20 μm, and a relative head-to-tape velocity of 4 m/s were used in the experiments. Figure 2 shows the typical spectrum of the readback signal components for sputtered and MP+++ tapes at 33 kfci, revealing an appreciable amount of modulation noise for both. The similar modulation side band was observed at various recording densities. The inset to Fig. 2 indicates, schematically, the relevant features in the spectrum: a signal peak, a side band, and a background noise having a broad band. The side-band modulation noise of the sputtered media extends about 0.5 MHz on either side of the signal peak, while that of the MP+++ media covers a broader bandwidth, which is nearly double this. This corresponds a minimum sensed spatial modulation wavelength of 8 μm for the sputtered tape and about 4 μm for the MP+++ tape. Head–medium spacing fluctuations introduce this modulation, creating the side bands about the signal peak. In advanced tape media, fluctuation of the head–medium spacing dominates the noise introduced during the recording of transitions, which accounts for the tone noise phenomena.[2] The long wavelength fluctuations during writing create the sidebands, while short wavelength fluctuations create a broad band noise source (tone noise). Head–medium spacing fluctuations can result from the surface roughness of tape media, or asperities that produce variations in the record-head–tape separation. However, the modulation from sputtered media is rather surprising since the sputtered tape is expected to be smooth and conformal with the substrate.

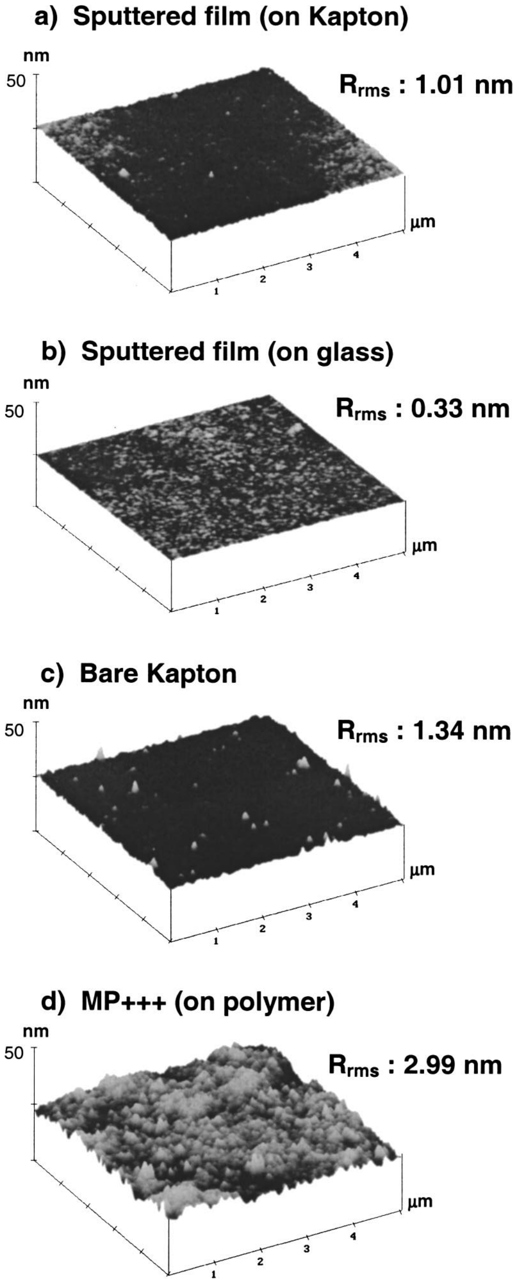

FIG. 3. Measured roughness properties of sputtered medium on (a) polymer, (b) glass, (c) bare Kapton, and (d) MP+++ medium.

AFM measurements were performed to examine the morphology of sputtered film surfaces on tape substrates. MP+++ tape and sputtered film stacks on glass substrates were measured as well, in order to compare with the films directly deposited on tape substrates. The typical measurement area was 5×5 μm. Figs. 3(a) and 3(b) show that the measured rms of the surface roughness of a sputtered medium on polymer (Kapton) and glass substrate is 1.01 and 0.33 nm, respectively, within a 5 μm$\times$5 μm region. The roughness of bare Kapton in Fig. 3(c) was of the same order of magnitude (1.34 nm) as the roughness of the sputtered media. Note that the surface roughness was improved about 30% when the stack of NiAl(100 nm)/CrV(30 nm)/

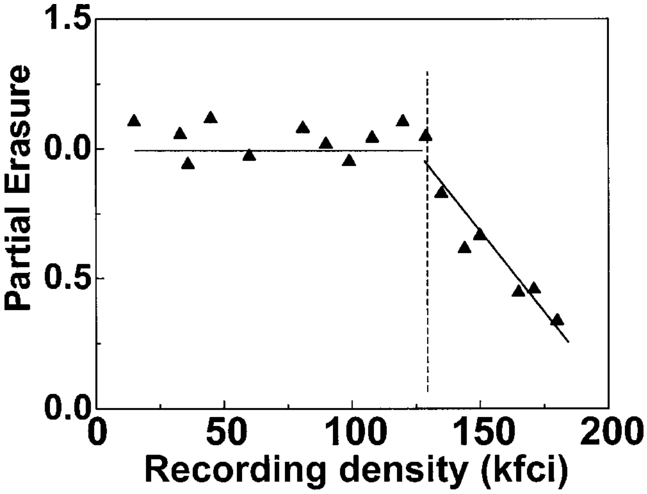

FIG. 4. Partial erasure vs linear density for the sputtered tape media.

CoCrTa(20 nm)/CoCrPt(20 nm) was deposited on the polymeric substrates. Thus, the results suggest that the appearance of side bands in sputtered media is primarily due to the roughened surface morphology of polymeric substrates since sputtered films are smooth and conformal with substrates. Note that these AFM scans are not large enough to encompass the shortest spatial wavelengths seen in the sidebands, so the correlation must be taken as suggestive rather than definitive. However, it is certain that whatever the contributions from surface roughness to modulation noise, they arise from the substrate, not the film. Similarly, texture-induced modulation noise in thin-film disk media has been addressed in the previous studies.[3,4] In Fig. 3(d), an MP+++ medium with magnetic particle size of 75-nm length by 12-nm diameter is shown to have the surface roughness of 2.99 nm. While this MP tape is not on a 30-μm-thick Kapton substrate, which would allow a direct comparison of roughnesses, we nonetheless conclude that the roughness of sputtered media is controlled by the roughness of polymeric substrates, while the roughness of MP media seems likely to be dominated by the size of particles (since 1-μm-thick particulate undercoat is typically used in the dual coating process).

The roll-off curves for these samples were measured to estimate a maximum system operating density from this combination of a sputtered medium and a conventional MIG head. The record current utilized was optimized to produce a saturated signal amplitude at 7.7 MHz (100 kfci). However, the roll-off curve of the sputtered tape and the MP+++ proved not to be good indicators of density capability, because the read-head gap was dominant in determining partial write PW_{50} in both cases. This resulted in channel density at 50% of the maximum (D_{50}) of 110 kfci in both the sputtered and MP+++ tapes.

Consequently, the nonlinear partial erasure method was used to measure the sharpness of recorded transition via the frequency domain one-dimensional/three-dimensional method.[5] The ratio is defined as $V_{3\mathrm{D}}$ (first harmonic)/$3V_{1\mathrm{D}}$ (third harmonic). Figure 4 shows the onset density of the partial erasure in the sputtered tape, indicating intertransition interactions occurred at a linear density of 130 kfci, which corresponds to the transition length parameter πa (i.e., the average width of the zigzag domain wall) of 195 nm. Transmission electron microscope revealed that the average grain size of the CoCrPt magnetic layer is 20 nm, which indicates the effective transition extends about 10 grains. This rather large value is due to exchange coupling between grains in the media. The measured S^* and the $\Delta M/M_r$ peak in the sputtered media were 0.93 and 0.40, respectively, indicating that grains are highly exchange-coupled. This coupling likely results from inadequate Cr segregation due to the low-temperature deposition needed to avoid substrate damage.[6] To confirm whether elevated temperature will produce the level of decoupling that is desired, similar films were sputter-deposited with the CoCrPt layer deposited at elevated temperatures. Consistent with the conjecture of insufficient Cr segregation, the S^* was decreased with increasing temperatures. Coercivity H_c in those elevated-deposition-temperature films remained largely unchanged.

IV. CONCLUSIONS

The typical readback spectrum from sputtered tape media presented a significant amount of modulation noise. The modulation noise about the carrier frequency was attributed to the morphological features of polymeric substrates as revealed by AFM measurements, in which the surface roughness was dominated by the substrate, not the sputtered film. Additionally, the CoCrPt tape media sputter-deposited at room temperature showed a large transition width ($\pi a = 195\,\mathrm{nm}$), indicating that grains are highly exchange-coupled. The interaction between grains appears to be the result of insufficient elemental segregation due to the low temperature deposition.

ACKNOWLEDGMENTS

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