Multilayer CoCrTa Thin Film Media with Cr or Ag Interlayers

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***Abstract*--The magnetic properties and recording performance of multilayer CoCrTa thin film media with Cr or Ag interlayers are investigated. It is found that the coercivities and coercivity squareness of the films with Ag interlayers could be higher than that of the films with Cr interlayers. Recording tests show that the disks with Ag interlayers are noisier than the disks without an interlayer and the disks with a Cr interlayer. It is proposed that the increase in media noise when Ag was used as an interlayer is due to the RKKY coupling among magnetic grains through Ag.**

I. Introduction

Multilayer magnetic thin film media have been reported to have higher signal to noise ratios compared to single layer magnetic thin films [1]-[3]. Recently, we reported the effects of different interlayers (Al, Ag, Cu and Cr) on the magnetic properties of double-layer CoCrTa thin film media [4]. In that study, it was found that the double-layer CoCrTa films with Ag interlayers have narrower switching field distributions but similar high coercivities, compared to films with Cr interlayers. Therefore, it is of interest to compare the recording performance of the disks with Ag interlayers to those of the disks with Cr interlayers.

In the previous work, the substrates were preheated to 260 °C and the Cr underlayer had the (002) crystallographic texture. The total thickness of the CoCrTa layers was 400 Å. In this work, the investigation of Cr or Ag interlayers was extended. In order to make multilayer thin film media suitable for MR read heads, the total thickness of the CoCrTa layers was chosen to be 200 Å. The films were deposited either with or without substrate preheating to 260 °C. The magnetic properties and recording performance of these films were studied and the results are discussed with regard to the role of interlayers on the magnetic coupling among grains in the multilayer films.

II. Experimental

Thin films were deposited onto glass substrates by RF diode sputtering in a LH Z400 system. The underlayers were 1000 Å Cr for all the films studied in this work. The magnetic layers were deposited using a Co-12 at%Cr-2 at% Ta alloy target. A 100 Å CN_x overcoat was deposited on the disk samples. The vacuum in the deposition chamber was better than $7x10^{-7}$ Torr. When the substrates were preheated to 260 °C, the Cr underlayers developed a (002) texture while on unheated substrates it had a (110) texture. The magnetic properties were measured with a vibrating sample magnetometer while spin-stand recording tests were conducted using an IBM Sawmill style MR head. The head is composed of an inductive thin film head for writing and a MR head for reading. Its write width is 7.6 μm, read width is 5.6 μm, write gap is 0.6 μm and read gap is 0.7 μm. The disks were tested at a linear velocity of 7.75 m/s (305 in/s) with estimated flying heights of 130 nm (5 μin). The noise power was measured from 0.1 to 20.1 MHz using an HP 8568B spectrum analyzer with a resolution bandwidth of 30 KHz. The total integrated noise power over a 20 MHz bandwidth was determined and the total electronic channel noise power over the same bandwidth was subtracted to obtain the intrinsic medium noise power [5].

III. Results And Discussion

A. Magnetic Properties

The effects of interlayers on the coercivity (H_c) and coercivity squareness (S^*) can be seen from Table I. Disks YC30, YC32 and YC36 were all deposited with the substrate preheated to 260 °C. Very traditional hystersis loops indicated that epitaxial growth occurred across the interlayers. Comparing the H_c and S^* values for the 200 Å film without an interlayer (YC30) to those for the film with a 20 Å Cr interlayer (YC36), we see that the values decreased substantially, while a 20 Å Ag interlayer (YC32) slightly increases the H_c and S^*. When the interlayer is used the film is composed of two separated 100 Å thick Co alloy layers which implied that the magnetic switching unit is smaller in volume. This would imply that the coercivity would decrease due to thermal relaxation [6]. The fact that the coercivity

TABLE I. Effect of Interlayer on Magnetic Properties

	Configuration	H_c (Oe)	S^*
YC30	200 Å CoCrTa/Cr	2067	0.74
YC32	100 Å CoCrTa/**20 Å Ag**/100 Å CoCrTa/Cr	2135	0.75
YC36	100 Å CoCrTa/**20 Å Cr**/100 Å CoCrTa/Cr	1654	0.54

Films deposited with substrate preheated to 260 °C.

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does not decrease when a 20 Å Ag interlayer is used implies a strong exchange coupling across the silver yielding an effective Co-alloy grain size comparable to the 200 Å thick film without an interlayer (YC30). Hence, a series of films were prepared with varying interlayer thickness. The substrates were not preheated, so as to limit diffusion of the interlayer into the Co-alloy.

Figure 1a and 1b show the dependence of H_c and S^*, respectively, on the interlayer thickness when the films were prepared without substrate preheating. The H_C and S^* decreased rapidly when a Cr interlayer was introduced. On the other hand, H_c and S^* increased when a thin Ag interlayer was used, but decreased as the interlayer thickness further increased.

B. Recording Performance

As shown in Figure 2 and 3, the medium noise of multilayer thin film media strongly depends on the interlayer material. In Figure 2, the normalized medium noise power

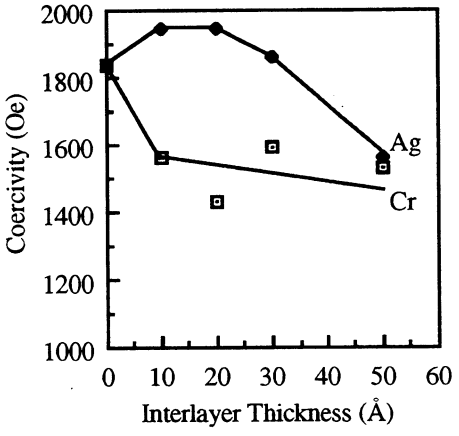

Figure 1a

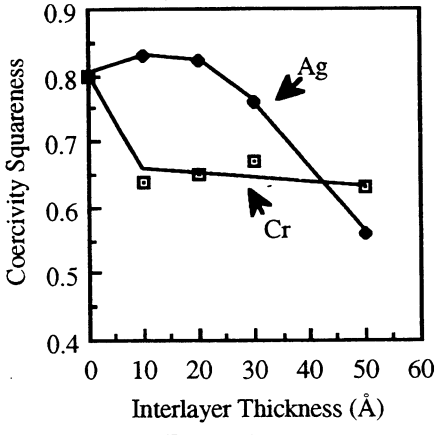

Figure 1b

Fig. 1. Dependence of a) coercivity, and b) coercivity squareness on thickness of interlayers.

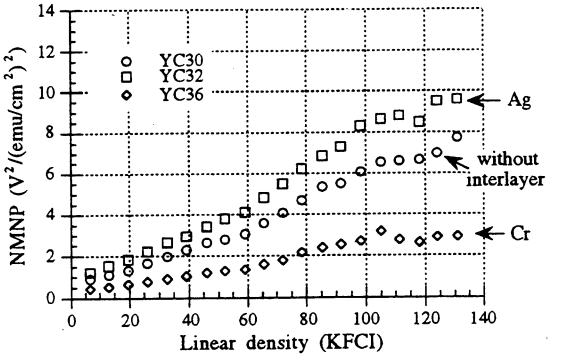

Fig. 2. Dependence of medium noise on interlayers when the films were deposited with substrate preheated to 260 °C.

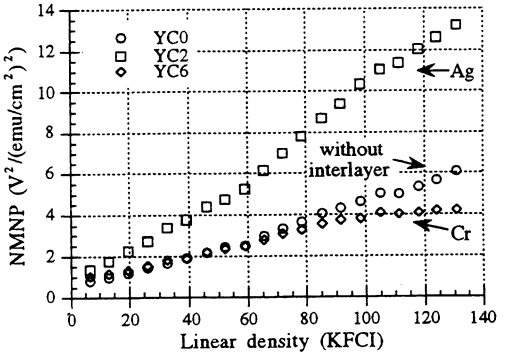

Fig. 3. Dependence of medium noise on interlayers when the films were deposited without substrate preheating.

(NMNP, normalized by M_rt) vs. recording density is shown for the disks with preheated substrates (YC30, YC32 and YC36). Comparing YC36 to YC30, it is clear that using a Cr interlayer reduces the medium noise power. On the other hand, comparing YC32 to YC30, it is seen that using a Ag interlayer increases the medium noise. Similar results were also found for the disk deposited without substrate preheating, as shown in Figure 3. YC0, YC2 and YC6 have the same configurations as disks YC30, YC32 and YC36 respectively, but were deposited at room temperature. Comparing YC2 and YC6 to YC0, it is clear that a Ag interlayer increases, and a Cr interlayer reduces, medium noise.

C. Discussion: the Role of Interlayers on Magnetic Interaction in Multilayer Films

The dependence of medium noise on interlayer materials may be understood by investigating the role of interlayers on magnetic coupling in these multilayer films. Delta M curves were measured to study the magnetic interaction. The positive part of the curve represents a magnetizing interaction (ferromagnetic coupling) and the negative part of the curve represents a demagnetizing interaction (antiferromagnetic coupling or magnetostatic interaction) [7].

Figure 4 shows the delta M curves of four films. The configurations of these films are listed in Table II. Comparing the delta M curve of the 100 Å thick CoCrTa layer (TCo1) to that of the 200 Å thick CoCrTa layer (YC0), the positive peak is lower and wider, indicating that the grains in the thinner film were more isolated. It is important to note that the delta M curve of the film with a Cr interlayer has a much lower positive peak and a larger negative part, compared to those films without a interlayer. Others have proposed that this behavior is suggestive of a lower exchange (and larger magnetostatic) interaction between particles on the two layers [7]. This could also explain why the films with Cr interlayers have smaller S^* (see Table I and Figure 1b). On the other hand, the positive peak in the delta M curve of the film with the Ag interlayer is much higher than that in the delta M curve of the film with Cr interlayer. This indicates that the ferromagnetic interaction in the film with Ag is stronger than that in the film with Cr interlayer.

The possible mechanism of the enhanced exchange coupling in the film with the Ag interlayer may be due to RKKY coupling [8]. As shown in Figure 5, the magnetic grains are coupled to each other indirectly by the conducting electrons through the Ag layer (and/or through Ag that have diffused to the CoCrTa grain boundaries). This coupling could be between two magnetic layers (Figure 5a) or among grains within the same magnetic layer (Figure 5b). However, the fact that the disks with Ag interlayers are noisier than those without interlayers can only be understood if the Ag interlayers enhance the ferromagnetic coupling among grains within a magnetic layer. The possibility of RKKY coupling among grains through the Ag interlayer also explains why the films with Ag interlayers have higher S^* and H_c.

TABLE II. CONFIGURATION AND MAGNETIC PROPERTIES OF FOUR FILMS WHOSE DELTA M CURVE ARE SHOWN IN FIGURE 4.

	Configuration	H_c (Oe)	S^*
TCo1	100 Å CoCrTa/Cr	1660	0.71
YC0	200 Å CoCrTa/Cr	1838	0.81
YC2	100 Å CoCrTa/**20 Å Ag**/100 Å CoCrTa/Cr	1945	0.82
YC6	100 Å CoCrTa/**20 Å Cr**/100 Å CoCrTa/Cr	1434	0.65

Films deposited without substrate preheating.

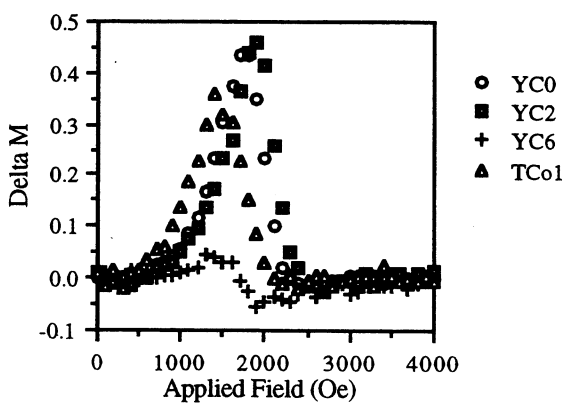

Fig. 4. Delta M curves of four films with various configurations.

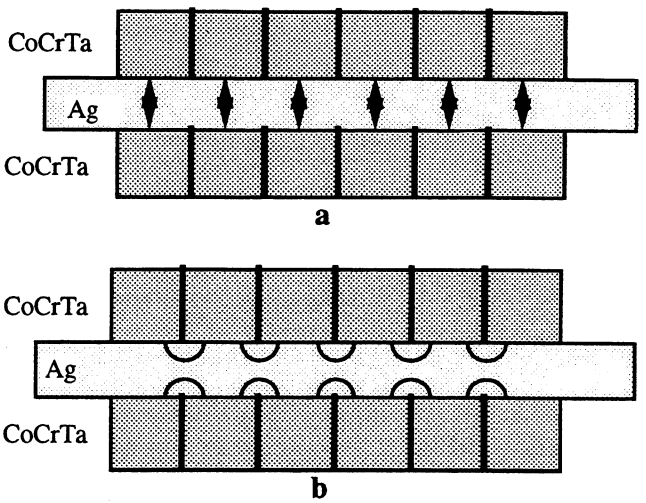

Fig. 5. Possible RKKY coupling through Ag interlayer, a) between two CoCrTa layer, and b) among CoCrTa grains within one layer.

IV. SUMMARY

The magnetic properties and recording performance of multilayer recording media with Ag or Cr interlayers were studied. The role of interlayers was investigated. The major findings are:

1) The coercivities and coercivity squareness of the films with Ag interlayers can be higher than that for films with Cr interlayers.

2) Recording tests show that the disks with Ag interlayers are noisier than disks without interlayers and the disks with Cr interlayers.

3) We propose that the increase in media noise when Ag was used as an interlayer is because of RKKY coupling among the magnetic grains through Ag interlayer.

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