Recording characteristics of Co-γFe_2O_3 perpendicular magnetic recording media

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The recording characteristics of Co-γFe_2O_3 perpendicular magnetic recording hard disk media were investigated. Sliding contact recording was performed to evaluate the intrinsic high-density recording performance of the media with using a metal-in-gap-type ring head. The half-voltage density D_{50} of 176 kFRPI and low-density reproduced voltage E_p of 143 $nV_{p\text{-}p}$/[turn μm (m/s)] were obtained for the optimal medium whose Co-γFe_2O_3 layer thickness was 0.13 μm and perpendicular coercivity was 1800 Oe. The pass wear durability test was performed at 2 m/s, or at a disk rotation of 830 rpm. The reproduced voltage did not decrease with time, and scratches and damage were not observed on the tested track even after 18 000 000 passes. The Co-γFe_2O_3 medium is one of the candidates for ultrahigh-density recording media because of its specific advantages; superior high density recording performance and hardness tolerable for sliding contact use. [S0021-8979(96)14508-7]

I. INTRODUCTION

After the invention of perpendicular magnetic recording, various types of perpendicular magnetic recording media were proposed.[1–7] It has been proven experimentally that an extremely high density recording exceeding 500 kFRPI is possible in perpendicular magnetic recording using a Co–Cr perpendicular media.[8,9] Contact recording is essential to achieve such a high density recording with suppressing spacing loss. There are two ways to achieve contact recording: One is to develop superior overcoat materials, and the other is to develop magnetic thin films for recording layers with sufficient hardness. In the case of Co–Cr medium, an overcoat layer, such as amorphous carbon and SiO_x, is necessary for contact recording because of its insufficient hardness. Oxidized magnetic material is expected to be one of the candidates in the latter approach described above because it is essentially harder than the metallic magnetic materials.

We have already reported that the spinel Co-γFe_2O_3 films obtained by annealing the sputtered CoO/Fe_3O_4 multilayers have a large perpendicular magnetic anisotropy, which originates from preferential crystalline orientation of the [100] axis.[10,11] The perpendicular coercivity of these Co-γFe_2O_3 films can be controlled in the wide range from 0.8 to 5.0 kOe. From the viewpoint of magnetic properties, the Co-γFe_2O_3 films are applicable to perpendicular magnetic recording media. However, the recording performance for the Co-γFe_2O_3 recording media fabricated by this process has never been measured.

In this study, therefore, the feasibility of these films as perpendicular magnetic recording hard disk media in contact recording use was investigated with respect to recording characteristics and pass-wear durability.

II. EXPERIMENT

In the fabrication of Co-γFe_2O_3 perpendicular magnetic recording hard disk media, at first, a 0.2 μm thick NiO layer was deposited on 2.5 in. glass substrate by reactive rf sputtering. Successively, CoO/Fe_3O_4 multilayers were deposited on the NiO underlayer at a substrate temperature of 200 °C. Finally, the disks were annealed at the temperatures from 280 to 350 °C to obtain perpendicular anisotropy.[11] No overcoat layers were prepared on any of the disks.

The specification of the tested Co-γFe_2O_3 hard disks is shown in Table I. In sample series A, the thickness of Co-γFe_2O_3 recording layer δ, varies from 0.10 to 0.17 μm. In series B, perpendicular coercivity $H_{c\perp}$, varies from 1472 to 2506 Oe. The metal-in-gap (MIG) ring heads with a gap length of about 0.2 μm designed for the Hi-band 8 mm VCR were used to measure the recording characteristics. The sliding contact method was introduced to evaluate the intrinsic high-density recording performance of the media.[12]

III. RESULTS AND DISCUSSION

The thickness and perpendicular coercivity dependence of recording characteristics was measured using series A and B samples, respectively, to optimize the media parameters. For all the media, the isolated reproduced pulse shape was di-pulse showing that the perpendicular magnetization mode was realized.

TABLE I. Specification of Co-γ Fe_2 O_3 perpendicular magnetic recording hard disks.

		δ (μm)	$H_{c\perp}$ (Oe)
Series A	Sample A1	0.10	1930
	Sample A2	0.13	1861
	Sample A3	0.17	1900
Series B	Sample B1	0.13	1472
	Sample B2	0.13	1630
	Sample B3	0.13	1710
	Sample B4	0.13	1861
	Sample B5	0.13	2323
	Sample B6	0.13	2506

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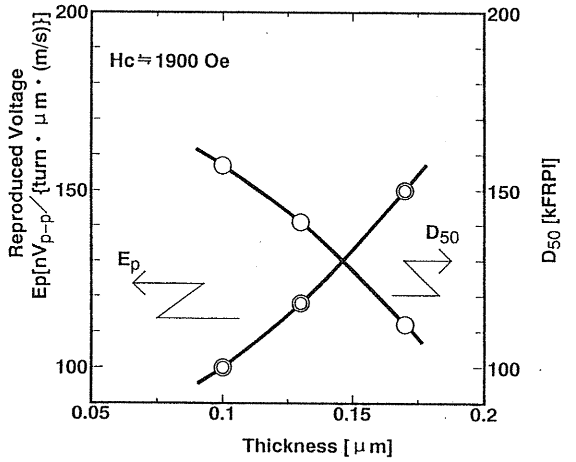

FIG. 1. Co-γFe_2O_3 layer thickness dependence of half-voltage density (D_{50}) and low density reproduced voltage E_p.

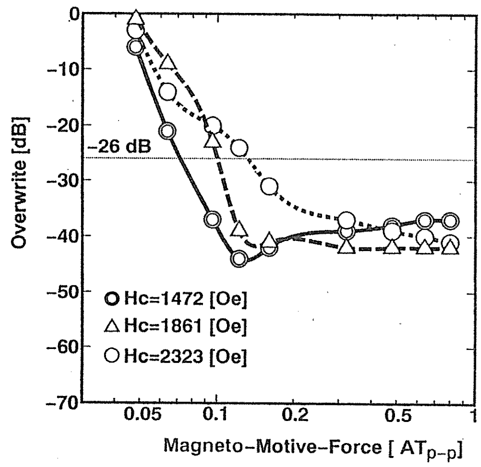

FIG. 3. Overwrite characteristics for 0.13 μm thick Co-γFe_2O_3 disks.

The Co-γFe_2O_3 layer thickness dependence of the D_{50} and E_p is shown in Fig. 1. As the Co-γFe_2O_3 layer thickness decreases from 0.17 to 0.1 μm, the half-voltage density D_{50}, increases. On the other hand, the peak voltage of the isolated reproduced pulse E_p, decreases with decreasing Co-γFe_2O_3 layer thickness. It is necessary to optimize the Co-γFe_2O_3 layer thickness according to the density because a tradeoff relation exists between D_{50} and E_p. At densities over 100 kFRPI (kilo flux reversals per inch), the highest reproduced voltage was obtained by using a 0.13 μm thick Co-γFe_2O_3 disk.

The perpendicular coercivity dependence of the D_{50} and E_p is shown in Fig. 2. These data were obtained using 0.13μm thick Co-γFe_2O_3 disks. Both for the D_{50} and E_p, the maximum value obtained at the perpendicular coercivity was about 1700 Oe.

Overwrite characteristics were also measured for the 0.13 μm thick Co-γFe_2O_3 disks to check the performance for saturation recording. The 36 kFRPI signal was overwritten by a 58 kFRPI signal. Overwrite value, which is defined as the ratio of the 36 kFRPI reproduced signal voltage after and before overwrite operation, was plotted against the recording magnetomotive force in Fig. 3. For all the disks with perpendicular coercivity from 1750 to 2338 Oe, the ultimate overwrite value becomes close to -40 dB. This result shows that the recording magnetic field generated by the MIG head is strong enough to perform saturation recording on the 0.13 μm thick disks.

The bit density response curves were shown in Fig. 4. For comparison, the commercialized 2.5-in. longitudinal recording hard disk was also tested. In the longitudinal hard disk, a CoNi recording layer and the 20 nm thick overcoat layer were deposited on a glass substrate. The longitudinal coercivity and the remanent magnetization and thickness product $M_{r\delta}$, of the CoNi layer were 1370 Oe and 2.5×10^{-3} emu/cm^2, respectively. The D_{50} of 176 kFRPI and E_p of 143 n$V_{p\text{-}p}$/[turn μm (m/s)] were obtained for the Co-γFe_2O_3 perpendicular hard disk whose Co-γFe_2O_3 thickness was 0.13 μm and perpendicular coercivity was 1800 Oe. These values of D_{50} and E_p were 1.9 and 1.2 times higher than those of the CoNi longitudinal disk.

The pass wear durability test was performed at 2 m/s, or

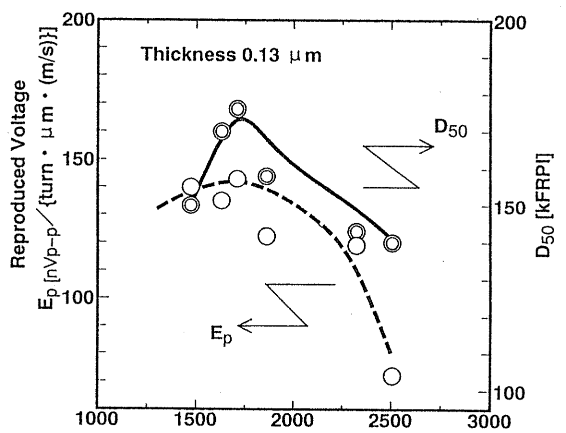

FIG. 2. Perpendicular coercivity dependence of D_{50} and E_p.

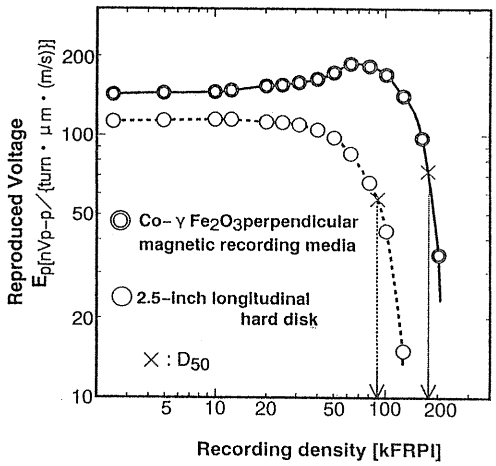

FIG. 4. Bit density response curves for Co-γFe_2O_3 perpendicular magnetic recording disk (◎) and CoNi longitudinal magnetic recording disk (○).

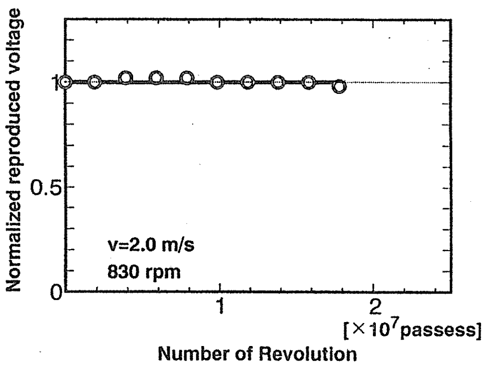

FIG. 5. Pass wear durability test.

a disk rotation of 830 rpm. The liquid lubricant was applied on the Co-γFe_2O_3 disk. After the 50.7 kFRPI signal was recorded, reproduction operation was continued with monitoring the reproduced signal voltage. In Fig. 5, the reproduced signal voltage was plotted against the number of disk revolutions. For comparison, a sputtered Co–Cr perpendicular hard disk without an overcoat layer was also tested. The Co–Cr disk was damaged just after the pass wear test started. On the contrary, for the Co-γFe_2O_3 hard disk, deviation of the reproduced voltage from the initial state was within a few percent, and no scratches or damage were observed even after 18 000 000 passes.

IV. CONCLUSION

A D_{50} of 176 kFRPI and E_p of 143 $nV_{p\text{-}p}$/[turn μm (m/s)] have been obtained for the Co-γFe_2O_3 hard disk with optimized thickness and coercivity. It was found that the Co-γFe_2O_3 disk has pass wear durability over 18 000 000 revolutions in spite of no overcoat.

From these experimental results, it is concluded that the Co-γFe_2O_3 medium is one of the candidates for ultrahigh-density recording media because of its specific advantages; superior high density recording performance and hardness tolerable for sliding contact use.

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