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Bidirectional recording performance of a perpendicular evaporated Co–CoO tape

K. Motohashi *, N. Ikeda, T. Sato, D. Shiga, H. Ono, S. Onodera

Sony Corporation, 3-4-1 Sakuragi, Tagajo-shi, Miyagi 985-0842, Japan

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ABSTRACT

It is the first report on the recording performance of a perpendicular metal evaporated (ME) tape measured with a giant magnetoresistive head. To solve the application difficulty of oblique evaporated tape media to linear scan tape systems, a perpendicular evaporated Co–CoO tape was proposed instead. The prepared sample showed perpendicular anisotropy with coercivity of 107.3 kA/m, M_rt of 3.9 mA and squareness of 0.25. Identical recording characteristics were obtained for both head-media moving directions, which enables the application of perpendicular evaporated Co–CoO tape to linear scan tape systems. The better carrier-to-noise ratio was also confirmed by comparison with a current advanced product of metal particulate tape, which can realize the higher recording density of linear scan tape systems using ME tape.

1. Introduction

Following an increase of recording density of hard disk drives (HDD), there have been increasing demands for the higher-capacity tape storages. To improve its recording density, some demonstrations have been reported about an application of giant magnetoresistive (GMR) heads to tape storages. Using metal evaporated (ME) tape media, which have been widely used for consumer videotape, Motohashi et al. [1] demonstrated its capability of 23.0 Gb/in^2 in an areal recording density with an improved 35 nm-thick Co–CoO tape by measuring recording performance using a GMR head. On the other hand, the feasibility of high recording density tape storage was demonstrated using a barium ferrite particulate tape and GMR heads, in which its track-following test and error rate were investigated, as well as the signal-to-noise ratio. Then, the areal recording density of 6.7 Gb/in^2 was confirmed in a prototype linear tape system [2].

Linear scan tape systems have become a major system in a tape storage market, and have been adopted in some tape storage technologies such as linear tape-open (LTO), digital linear tape (DLT), and so on. In linear scan tape systems, read/write heads scan the tape surface bidirectionally along with a tape-moving direction to improve the data-transferring rate. Oblique evaporated tape media, however, require a one-directional recording use because of its anisotropy of recording performance related with the head-media movement direction. Therefore, oblique ME tape has not been used for linear scan tape systems, despite its potential for higher capacity and its history as consumer videotape for more than 18 years since the first production of ME tape for a high-band 8 mm video system in 1989.

In this research, a perpendicular ME tape was developed to apply it to linear scan tape systems. To meet this objective, symmetric perpendicular evaporated tape media are proposed to obtain the identical bidirectional recording performance. Some researches on tape media of perpendicular anisotropy have been already reported since 1982. However, heating process was indispensable for perpendicular evaporated Co–Cr tape; the signal output of perpendicular evaporated Co–CoO tapes was poorer than that of oblique evaporated tapes [3–6]. These results were crucial disadvantages for the practical application at that moment. Meanwhile, recent rapid development on GMR heads has enabled detecting the smaller magnetic flux from recording media and changed their layer design. We prepared a 60-nm-thick perpendicular evaporated Co–CoO tape that was optimized for GMR heads. The magnetic properties and recording performance were investigated.

2. Experiment

The perpendicular evaporated Co–CoO recording layer was prepared by web-coating-type evaporation in a vacuum chamber. A 60 nm-thick recording layer was deposited directly on a polyethylene telephthalate (PET) base film without a soft magnetic underlayer that is commonly used for perpendicular

* Corresponding author. Tel.: +81 22 367 2460; fax: +81 22 367 2589.
E-mail address: Kazunari.Motohashi@jp.sony.com (K. Motohashi).

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Table 1
Head specifications

Recording head structure	Metal-in-gap inductive
Write width (μm)	16
Write gap length (μm)	0.2
Reproducing GMR head structure	Shielded spin-valve
Effective read width (μm)	0.5
Read shield-to-shield length (μm)	0.1
Reproducing AMR head structure	SAL-biased FeNi
Effective read width (μm)	6.8
Read shield-to-shield length (μm)	0.23

recording HDD media. For a Co–CoO layer, ferromagnetic metal cobalt was evaporated by introducing oxygen to control the magnetic properties of a Co–CoO layer. The cobalt incident angle to a film surface was defined by a slit opening above an evaporation source of a crucible. Then, cobalt vapor reaching the film surface perpendicularly was considered to consist of a perpendicular columnar structure. The major difference between perpendicular evaporated and oblique evaporated Co–CoO tape is the incident angle during evaporation; the incident angle of oblique evaporated tape has been designed to be around 45° from an in-plane direction. After the perpendicular evaporation, a sample tape was completed with subsequent deposition of a 4 nm-thick carbon protective layer and a lubricant coating for its measurement durability.

Magnetic hysteresis loops, angular dependences of coercivity and squareness were measured with a vibrating sample magnetometer. Coercivity distribution was estimated by measuring $\Delta H_c/H_c$ [7].

Recording performances were measured using a drum tester in which a recording head and a reproducing head approach the surface of a sample tape wound around a rotating drum. The relative recording speed was set at 3.5 m/s. We used a GMR head and an anisotropic magnetoresistive (AMR) head, respectively, for different purposes. The shielded GMR head was used for a comparison of the perpendicular evaporated Co–CoO tape and the oblique evaporated Co–CoO tape. The latter tape was used for 23 Gb/in^2 demonstration in Ref. [1]. For comparison with a metal particulate (MP) tape for LTO-4, only an AMR head was applicable to avoid sensing layer saturation caused by the relative large stray field of an MP tape. For recording, metal-in-gap (MIG) heads were used for both measurements. The head specifications used in this research are summarized in Table 1.

To investigate writing capability on perpendicular evaporated Co–CoO tape, signal output dependence on write gap length was compared from a write gap length of 0.12 to 0.8 μm using different MIG heads. Then, overwrite was confirmed with the gap lengths of 0.12, 0.15 and 0.2 μm, respectively. For the overwrite measurement, a comparatively long signal wavelength of 1.6 μm was overwritten by a signal wavelength of 0.4 μm, and residual signal output of 1.6 μm was compared with that before the overwriting.

3. Results and discussion

Fig. 1 shows a cross-sectional image of a perpendicular evaporated Co–CoO layer by high-resolution transmission electron microscopy (HRTEM). Perpendicular columnar growth is observed from the beginning of crystalline growth of the Co–CoO layer. Each column width is around 5 nm. The columnar boundary is much clear at the bottom half of the Co–CoO layer, and rather unclear at its top half. However, any specific orientation of cobalt particles is not observed in this image.

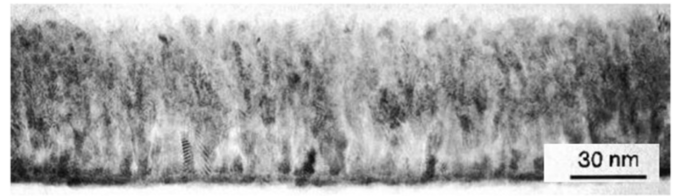

Fig. 1. A cross-sectional HRTEM image of a perpendicular evaporated Co–CoO layer.

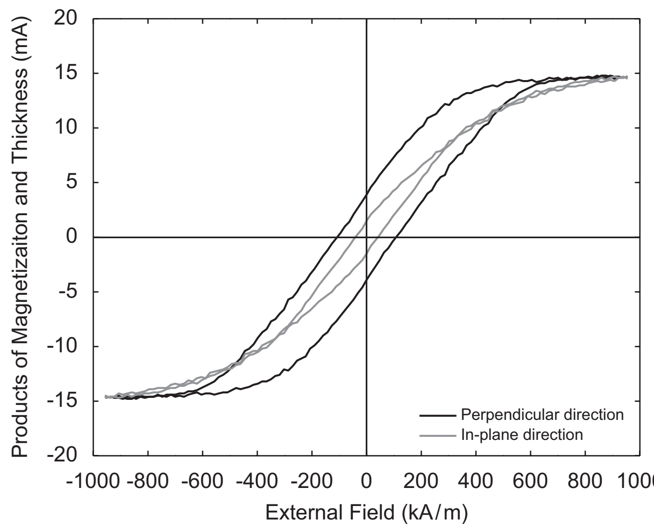

Fig. 2. Hysteresis loops of the perpendicular ME tape.

Magnetic hysteresis loops indicate the perpendicular anisotropy of the prepared sample as shown in Fig. 2. In the perpendicular direction, sample shows a coercivity of 107.3 kA/m and squareness of 0.26, while coercivity and squareness are 40.2 kA/m and 0.10, respectively, in the in-plane longitudinal direction. The product of remanent magnetization and thickness M_rt is 3.9 mA in the perpendicular direction, which can be utilized only by GMR heads. Angular dependence of the coercivity and squareness reveals its perpendicular orientation (Fig. 3), where a sample was rotated from an in-plane longitudinal reference direction of a tape. Both coercivity and squareness have a peak around a perpendicular direction to the sample plane, when a sample film is rotated in an out-of-plane direction against a magnetic field. It is considered that a slight shift of the peak angle from a perpendicular direction is due to the tilt of the columnar structure as observed by HRTEM. This was caused by an incident angle shift during the deposition, when a transferred base film is exposed to cobalt vapor from a crucible source. It is because that vapor from point source should have angular distribution at an opening slit. On the other hand, isotropic magnetic properties were observed when a magnetic field was rotated in an in-plane direction. From these results, we concluded that perpendicular evaporated Co–CoO tape has perpendicular anisotropy without specific orientation to an in-plane direction, and that the identical recording performance in any head-media moving direction can be obtained.

From ΔH_c measurement, coercivity distribution of cobalt particles in a perpendicular evaporated Co–CoO layer was estimated. An orientation factor $\Delta H_c/H_c$ was 0.52 for this perpendicular ME tape, which indicates that the coercivity distribution is rather large compared with the value measured