Co-Pt Clusters on a Highly Oriented Fe-Co Soft Underlayer in a Co-Pt-TiO₂ Perpendicular Medium

K. Shintaku

Akita Research Institute of Advanced Technology (AIT), 4-21 Sanuki, Araya, Akita 010-1623, Japan

A granular-type medium with a highly oriented high-B_s Fe-Co soft underlayer (SUL) and a thin Ru intermediate layer of 4 nm was prepared. It displayed low H_{ch} (H_c in the hard axis direction) value of 1.1 Oe in the SUL and high H_c of 6.0 kOe in a Co-Pt-TiO₂ recording layer. The recording layer in the medium has a novel granular structure, namely, well-isolated clusters composed of 5–15 pieces of small Co-Pt grains 4–7 nm in diameter segregated by TiO₂. The clusters were oval, with an average area of 213 nm². At present, the shape and arrangement of the clusters cannot be controlled successfully.

Key words: perpendicular recording media, granular film, cluster, Fe-Co soft underlayer, Ru intermediate layer, Ta underlayer.

1. Introduction

Perpendicular magnetic recording was proposed about 30 years ago¹⁾, and perpendicular recording hard disk drives were first produced commercially last year. Co-Pt based granular film has been used as a recording layer in perpendicular recording media. For high-density perpendicular recording, media require low noise (high S/N), a moderate saturation field, and high thermal stability. However, it is thought to be very difficult to satisfy the desired conditions for future high recording density by reducing the grain size of a granular film. Consequently, composite media or patterned media are being investigated as an alternative solution.

Reduction of the film thickness of the intermediate layer between the recording layer and the SUL is important for saturation recording. A high-B_s SUL is also needed to reduce the film thickness from the viewpoint of industrial production. To solve these problems simultaneously, I prepared an Fe-Co soft underlayer with a high-B_s of 2.45 T and a high crystal orientation and found a novel granular structure in the recording layer.

2. Experiment

Samples were prepared in an UHV sputtering system by dc and rf magnetron methods in an Ar gas atmosphere. The composition of the alloy targets was (Co₈₀Pt₂₀)-(TiO₂) (CoPt:TiO₂ = 70:30 vol%, CoPt-TiO₂), Ru, Fe₇₀Co₃₀ (FeCo), Ir₂₀Mn₈₀ (IrMn), Pt, Ta, and C. The substrates were φ 2.5-inch glass disks. A magnetic field of about 100 Oe in the radial direction of the disk was applied to induce an in-plane magnetic anisotropy during deposition. The base pressure was around 1–3 × 10⁻⁷ Pa. The substrate temperature was 22°C.

The film structure was investigated by X-ray diffraction (XRD) using the θ-2θ scan method with Cu-Kα radiation. Magnetic properties were measured by means of a vibrating sample magnetometer (VSM)

calibrated by using standard samples (pure Ni and Fe) and a polar Kerr effect magnetometer. The microstructure was observed by using a transmission electron microscope (TEM).

3. Results and Discussion

Figure 1 shows a schematic illustration of a prepared medium. The designed film structure was C (6 nm)/CoPt-TiO₂ (15 nm)/Ru (4 nm)/FeCo (50 nm)/IrMn (10 nm)/Pt (10 nm)/Ta (5 nm)/glass substrate. The B_s of an FeCo SUL was 2.45 T. IrMn was used as an fcc underlayer to obtain soft magnetic properties in the FeCo film²⁾⁻⁴⁾, and an antiferromagnetic layer to pin the FeCo film⁵⁾. A Pt underlayer is effective in increasing the crystal orientation of the IrMn, which is necessary in order to enhance the exchange coupling energy between the FeCo and the IrMn films. It is reported that a CoPt-TiO₂ recording layer on a Ru/Pt film has a well-isolated fine granular structure⁶⁾.

The crystal orientation of the medium was greatly enhanced by using a thin Ta underlayer. As shown in Fig. 2, a medium with such a Ta underlayer has a very

Fig. 1 Schematic illustration of a medium.

Fig. 2 XRD pattern of the medium.

Fig. 3 Rocking curve of the FeCo (110) peak.

large peak intensity in the XRD pattern. The $\Delta\theta_{50}$ value of the FeCo bcc (110) peak was 2.9° , as shown in Fig. 3, while that of the CoPt-TiO₂ hcp (002) peak was 4.5° . The orientation of the CoPt-TiO₂ layer was lower than that of the FeCo layer.

Figure 4 shows the M-H curve of this medium. As the in-plane signal from the recording layer was negligibly small from the measurement of a CoPt-TiO₂ perpendicular single-layered media, this indicates a clear in-plane magnetic anisotropy and good soft magnetic properties of the FeCo SUL. The values of H_{ch} , H_c in the easy axis direction (H_{ce}), the anisotropy field (H_k), and the exchange coupling field (H_{ex}) were 1.1 Oe, 28.0 Oe, 48.7 Oe, and 24.8 Oe, respectively. The exchange energy (J_{ex}) was estimated to be 0.24 erg/cm² from the formula $J_{ex} = M_s H_{extFeCo}$, where M_s is the saturation magnetization and t_{FeCo} is the film thickness of the FeCo.

As shown in Fig. 5, the magnetic properties of the CoPt-TiO₂ recording layer were estimated by a Kerr loop. The values of the squareness ratio (SQ), H_c , the nucleation field (H_n), and the saturation field (H_s), were 0.92, 6.0 kOe, -0.51 kOe, and 14.0 kOe, respectively. Large H_c and squareness ratio were obtained for a medium with a Ru intermediate layer thickness of 4 nm.

Figure 6 shows an in-plane TEM image of the CoPt-TiO₂ recording layer in the medium. Well-isolated clusters with small grains were observed.

Fig. 4 M-H curve of the medium.

Fig. 5 Kerr loop of the medium.

From ref. 6, it seems that the small grains are composed of CoPt, and that TiO₂ is segregated in the grain boundaries. The small grains were 4–7 nm in diameter. The separation of the small grains was incomplete. A cluster included 5–15 of small grains. The clusters were generally oval. However, the uniformity of the shape was not good. The average area of the clusters was 213 nm², which is much smaller than the maximum bit area of 1 Tbit/in² (645 nm²).

Figures 7(a) and 7(b) show cross-sectional TEM images of the medium. A clear columnar structure was observed. Large columns were formed from the Pt layer to the CoPt-TiO₂ layer, whose grain sizes in the lateral direction were constant as the film thickness was increased. Moreover, small columns with narrow grain boundaries were observed in the CoPt-TiO₂ recording layer. Wide grain boundaries between the large columns were also observed in this region.

On the basis of the TEM observations, a schematic illustration of the cross-section of the medium is shown in Fig. 8. The small grains of the CoPt film were separated due to the presence of a Ru intermediate underlayer. On the other hand, wide boundaries surrounding the clusters with the small grains were formed at the positions of the columnar boundaries of the highly oriented SUL.

Fig. 6 In-plane TEM image of the medium.

Fig. 8 Schematic illustration of the cross-section.

Fig. 7 Cross-sectional TEM images of the medium. (a) The whole film. (b) The CoPt-TiO₂/Ru/FeCo (thinner sample).

4. Conclusions

A granular-type medium with a highly oriented

high-B_s FeCo SUL was prepared. Although the Ru intermediate layer thickness was only 4 nm, the CoPt-TiO₂ recording layer had a high crystal orientation. The magnetic properties of the SUL and the recording layer were also good.

The CoPt-TiO₂ recording layer in the medium has a novel granular structure, namely, well-isolated clusters composed of 5–15 small CoPt grains 4–7 nm in diameter segregated by TiO₂. The clusters were generally oval, with an average area of 213 nm².

At present, the shape and arrangement of the clusters cannot be controlled successfully. However, it seems that this new granular structure has the potential to enable high perpendicular recording densities.

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