

Magnetic and Crystallographic Properties of Co–Cr–Pt Longitudinal Media Prepared on MgO Seedlayers Deposited by ECR Sputtering

Nobuyuki Inaba and Masaaki Futamoto

Abstract—Crystallographic and magnetic properties are investigated for Co–Cr–Pt/Cr–Ti longitudinal media fabricated on MgO seedlayers ($t = 0 - 20$ nm) prepared by Electron Cyclotron Resonance (ECR) sputtering method. The MgO layer deposited at room temperature shows well developed {100} texture. Highly (100)-oriented Cr–Ti and (11.0)-oriented Co–Cr–Pt layers are epitaxially grown on the seedlayers. The media coercivity is enhanced by about 15% compared with that with no MgO seedlayer.

Index Terms—Electron cyclotron resonance sputtering, longitudinal recording medium, MgO, seedlayer.

I. INTRODUCTION

CRYSTALLOGRAPHIC orientation and grain distribution controls are important to develop high density longitudinal recording media with low noise characteristics and enhanced thermal stability. It is necessary to realize the media consisting of small but controlled magnetic crystal grains with c -axes parallel to the film plane. CoCr-alloy thin films epitaxially grown on MgO(100) single crystal substrates through Cr-alloy underlayers have the easy magnetization axis parallel to the substrate surface [1]. MgO seedlayers deposited by RF sputtering are reported to be useful to control the crystallographic orientation of CoCr-alloy polycrystalline thin films [2]. Electron cyclotron resonance (ECR) sputtering is reported to be effective to prepare high quality insulator thin films with smooth surfaces at relatively low substrate temperatures [3]. In this study, we employed ECR sputtering to deposit MgO seedlayers to prepare Co–Cr–Pt/Cr-alloy/MgO longitudinal thin film media with well controlled crystallographic properties.

II. EXPERIMENTAL PROCEDURE

A. ECR Sputtering System

We used a custom-made sputtering system (NTT AFTY Corp.) composed of a loading chamber, two deposition chambers, and a transfer chamber which connects the loading and the deposition chambers. Background pressure in the deposition chambers of less than 10^{-9} Torr is achieved by using

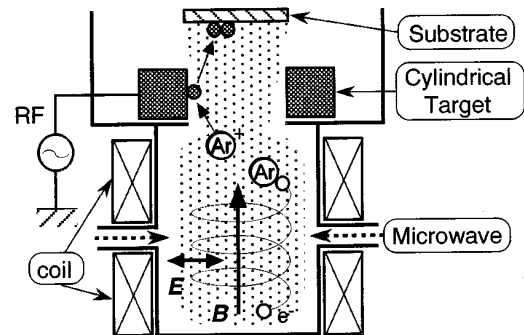


Fig. 1. Schematic picture of electron cyclotron resonance (ECR) sputtering apparatus.

a turbo-molecular pumping system. The sputtering system is equipped with six conventional magnetron sputtering cathodes and one ECR sputtering cathode in the deposition chambers. Two of the magnetron sputtering cathodes can be operated either in DC or RF mode. So, seven different kinds of thin films can be deposited on a substrate without breaking vacuum.

Fig. 1 shows a schematic picture of the ECR sputtering apparatus. Two magnetic coils apply a magnetic field B of 875 Gauss, which satisfies the electron cyclotron resonance condition, in the discharge chamber. When a microwave (frequency: 2.45 GHz) is introduced into the discharge chamber perpendicular to the chamber side wall through a microwave guide, high density plasma is generated at Ar gas pressure as low as 10^{-4} Torr under the ECR condition. As shown in Fig. 1, the plasma stream occurs from the discharge chamber toward the substrate along magnetic force lines. A film deposition is carried out by applying RF power to the cylindrical target set around the plasma stream. In the present study, we used a MgO cylindrical target for ECR deposition. The microwave and the RF powers were set to be 0.7 kW and 0.5 kW, respectively.

B. Sample Preparation

We prepared $\text{Co}_{73}\text{Cr}_{15}\text{Pt}_{12}$ (25 nm)/Cr–Ti(50 nm) bi-layer thin film specimens on MgO seedlayers ($t = 0 \sim 20$ nm) deposited on glass substrates. The deposition of MgO layer was carried out by using the ECR sputtering at an Ar pressure of 0.4 mTorr. The deposition rate is 0.5 nm/s. Co–Cr–Pt/Cr–Ti bi-layer film was sequentially deposited on the MgO layer by DC magnetron sputtering at an Ar pressure of 3 mTorr with the sputtering rate of 2 nm/s. We also prepared Co–Cr–Pt/Cr–Ti specimens fabricated on MgO seedlayers deposited by using

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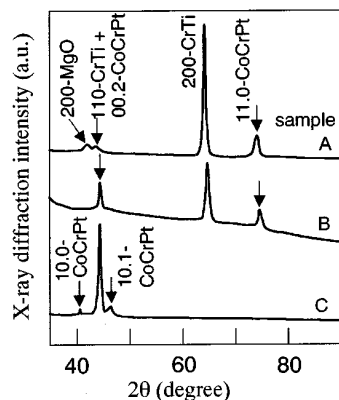


Fig. 2. X-ray diffraction spectra of Co-Cr-Pt/Cr-Ti specimens with MgO seedlayers deposited by ECR (sample A) and RF sputtering methods (B), and with no MgO layers (C).

RF conventional sputtering at an Ar pressure of 16 mTorr with the sputtering rate of 0.06 nm/s.

Crystallographic structures of media specimens were investigated by using an X-ray diffractometer and a high spatial resolution transmission electron microscope (TEM). Magnetic properties were measured by using a vibrating sample magnetometer.

III. RESULTS AND DISCUSSION

A. Crystallographic Structure

The crystallographic properties of thin film media were compared between the specimens with 10 nm-thick MgO layers prepared by ECR and RF sputtering methods. Specimens with no MgO layers were also prepared. The specimens A, B, and C are the Co-Cr-Pt/Cr-Ti thin films deposited at room temperature with the ECR-sputtered MgO seedlayer, the RF-sputtered MgO seedlayer, and no MgO layer, respectively. Fig. 2 shows the X-ray diffraction spectra of these specimens. The specimen C shows the 110-CrTi reflection peak from the underlayer and the 10.1-CoCrPt and the small 10.0-CoCrPt peaks from the magnetic layer. The 00.2-CoCrPt peak also seems to exist with overlapping the 110-CrTi peak. The *c*-axes of Co-Cr-Pt grains are out of the film plane. When the substrate temperature was increased up to 300°C, the 200-CrTi peak from an underlayer was also observed in addition to the 110-CrTi peak. The intensity of the 200-CrTi peak was about a half of that of the 110-CrTi peak. The sample A with the ECR-deposited MgO seedlayer shows strong 200-CrTi and 11.0-CoCrPt peaks, even when the film was deposited at room temperature. The intensities of 110-CrTi and 10.1-CoCrPt peaks are less than one tenth of those of 200-CrTi and 11.0-CoCrPt peaks, respectively. The 200-MgO peak is also observed from the seedlayer. These results mean that the 10 nm-thick MgO seedlayer deposited by ECR sputtering shows well developed {100} texture, on which Cr-Ti (100) and Co-Cr-Pt (11.0) planes can grow epitaxially to lie the *c*-axis on the film plane. On the contrary, the sample B with the RF-sputtered MgO layer shows both 110-CrTi and 200-CrTi peaks with 200-CrTi intensity twice as large as that of the 110-CrTi peak.

In order to understand the crystallographic structure of ECR-deposited MgO seedlayer, we observed high resolution

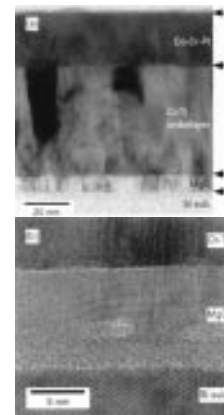


Fig. 3. (a) Cross-sectional TEM image of Co-Cr-Pt/Cr-Ti with ECR-deposited MgO layer. (b) Lattice image around interface between MgO seedlayer and Cr-Ti underlayer.

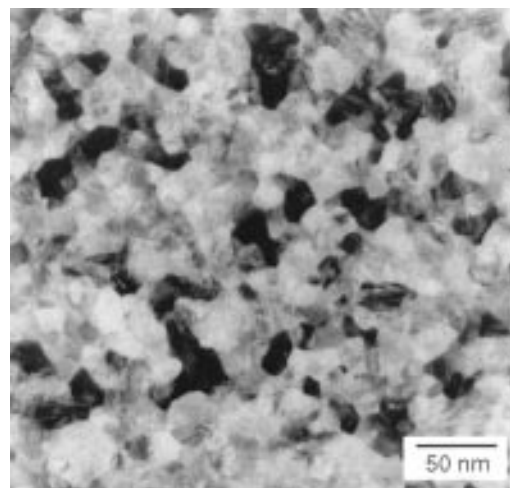


Fig. 4. Plan-view magnetic layer TEM image of specimen with ECR-deposited MgO seedlayer.

TEM images. Fig. 3(a) shows a cross-sectional TEM image of Co-Cr-Pt(25 nm) / Cr-Ti(50 nm) / MgO(10 nm) specimen deposited on Si(100) wafer. Fig. 3(b) shows the cross-sectional lattice image around the MgO seedlayer. The Co-Cr-Pt/Cr-Ti bi-layer thin film consists of columnar crystal grains grown on the MgO seedlayer. An MgO initial layer shows no clear crystallographic structure up to around a few nm from the Si substrate, while the upper part of the MgO layer shows well developed crystal grains with {100} texture. The interface between the MgO and the Cr-Ti layers is very sharp. The cross-sectional TEM data suggest that the (100)-oriented Cr-Ti columnar and the (11.0)-oriented Co-Cr-Pt crystal grains are epitaxially grown on the MgO (100) crystal grains.

Fig. 4 shows a plan-view TEM image of the magnetic layer. The crystal grain size distribution was investigated by counting 365 crystal grains in the TEM image. The average diameter and the standard deviation are determined to be 13.9 nm and 4.0 nm, respectively. The average diameter and the standard deviation of Co-Cr-Pt(16 nm)/Cr-Ti(50 nm) bi-layer specimen without MgO seedlayers are already determined to be 15.1 nm and 5.4 nm, respectively [4]. Those of the specimen with 8-nm

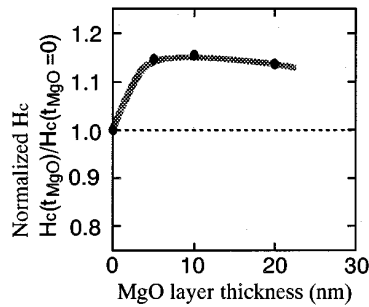


Fig. 5. Variation of normalized H_c on MgO layer thickness when deposited by ECR method.

thick magnetic layer without MgO seedlayer are also determined to be 14.8 nm and 5.5 nm, respectively. By comparing the average grain size and the standard deviation between the thin film specimens with and without MgO seedlayer, it is found that the magnetic grain size of the specimen with MgO seedlayer is about 7% smaller than those without MgO seedlayers, and the standard deviation is 20% smaller. These results suggest that the MgO seedlayer is useful to obtain small grains and sharp grain distribution.

B. Magnetic Properties

The effect of MgO seedlayer thickness on medium coercivity of specimens with ECR-deposited seedlayer is shown in Fig. 5. The coercivities for the specimens with the MgO seedlayers are enhanced by about 15%, when compared with no MgO seedlayer samples. The X-ray diffraction spectrum of the specimen with 5 nm-thick MgO layer shows a very strong 200-CrTi peak. Highly (11.0)-oriented Co-Cr-Pt magnetic layers are epitaxially grown on MgO seedlayers through (100)-oriented Cr-Ti underlayers. The improvement in the

crystallographic orientation of Co-Cr-Pt layer prepared on the MgO seedlayer seems to increase of the coercivity. The low energy ion irradiation during ECR sputtering [3] seems to have favored the formation of high-quality very thin MgO seedlayers with strong (100) preferred growth orientation even at low substrate temperatures. On the contrary, the conventional RF sputtering seems to require elevated substrate temperature to get highly oriented MgO seedlayers. The ECR deposition is proved to be useful to get highly oriented MgO seedlayers which are useful to prepare Co-Cr-Pt thin films with small crystalline grain diameters and small standard deviations.

IV. CONCLUSION

Crystallographic and magnetic properties are investigated for Co-Cr-Pt/Cr-Ti longitudinal media with MgO seedlayers ($t = 0 - 20$ nm). When deposited by ECR sputtering, MgO layers show well developed {100} texture even at room temperature deposition. Highly (100)-oriented Cr-Ti and (11.0)-oriented Co-Cr-Pt layers are epitaxially grown on the MgO seedlayers. The thin film media coercivity is enhanced by about 15% compared with the sample which has no MgO seedlayer.

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