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Influence of gas pressures on the magnetic properties and recording performance of CoCrPt–SiO_2 perpendicular media

J.Z. Shi*, S.N. Piramanayagam, C.S. Mah, J.M. Zhao

Data Storage Institute, 5 Engineering Drive 1, Singapore 117608, Singapore

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Abstract

CoCrPt–SiO_2-based granular perpendicular media with dual-Ru intermediate layers were studied in the paper. The effects of gas pressures, such as argon pressure for the top Ru layer, oxygen partial pressure ratio and the total gas pressure for the magnetic layer, on the magnetic properties and recording performance of the media were systematically investigated. The results show that all these gas pressure parameters have significant effects on the magnetic properties and recording performance of the media to different extents. Combined with the results by X-ray diffraction, transmission electron microscopy, magnetic force microscopy, magneto-optical polar Kerr magnetometer and Guzik spin-stand tester, the growth mechanism of the perpendicular media and the functions of the gas pressure parameters for certain individual layer were demonstrated.

Keywords: Perpendicular media; Pressure; Magnetic properties; Recording performance

1. Introduction

High-density perpendicular recording medium requires a well-isolated grain structure to reduce the intergranular exchange effect so as to get low noise and achieve high signal-to-noise ratio (SNR) [1–3]. It has been reported that the oxygen/silicon ratio of 2 is critical to achieve high Hc in CoCrPt–SiO_2 layer [4]. It has also been reported that there is an optimized argon pressure for intermediate layer (Ru) to achieve a high Hc in Co–Pt–Ta_2O_5 film [5]. In our previous study, we used dual-Ru layers as intermediate layer for CoCrPt–SiO_2-based granular media. The bottom Ru layer (Ru_b) deposited under a high-mobility condition, i.e. low working gas pressure and bias on substrate, was helpful to provide a narrow *c*-axis orientation dispersion, while the top Ru layer (Ru_t) deposited under a low-mobility deposition condition, i.e. high working pressure, provided an isolated template for the magnetic layer [6]. In this paper, we systematically study the effects of gas pressures, such as argon pressure for the top Ru layer (P_{Rut}), oxygen partial pressure ratio (R_O) and total pressure for the magnetic layer (P_m) on the magnetic properties and the recording performance of CoCrPt–SiO_2-based granular media. The aim of this investigation is to get an understanding on the effect of these parameters, which will help to get an optimized preparation condition for the best recording performance.

2. Experimental details

The samples used in this study were prepared on 95 mm polished NiP-plated AlMg substrates by DC magnetron sputtering with a commercial BPS Circulus M12 tool at room temperature. The layer structure was $Ta/Ru_b/Ru_t/CoCrPt-SiO_2/C$ for the media. The working gas for Ru layers was pure argon. In this study, the pressure for Ru_b layer was 0.5 Pa for all samples, while the pressure for Ru_t layer was changed by adjusting the flow rate. The CoCrPt target contained 6 mol% of SiO_2. The working gas for this magnetic layer was a mixture of argon and oxygen. Two mass-flow controllers were used to carry out the sputtering of CoCrPt–SiO_2. Through one controller, a gas mixture of 95% Ar and 5% O_2 was flown into the sputtering chamber, and through another controller pure Ar (99.999%) gas was introduced. The flow rates of these two controllers were adjusted to control the

*Corresponding author.
E-mail address: Shi_Jianzhong@dsi.a-star.edu.sg (J.Z. Shi).

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oxygen concentration at minute levels, which could help to control the grain size and grain isolation of the magnetic layer. The oxygen partial pressure ratio R_O is calculated as, $5x/(x+y)$, where x is the flow rate of argon–oxygen (95–5%) gas mixture and y is the flow rate of pure Ar gas. The magnetic properties were characterized by a magneto-optical polar Kerr magnetometer (MOKE). The microstructure was investigated by X-ray diffraction (XRD), and transmission electron microscopy (TEM). The magnetic domains were observed by magnetic force microscopy (MFM). The recording performance was studied employing a Guzik spin-stand tester with a ring-head writer and a MR reader.

3. Results and discussion

Fig. 1(a) and (b) shows the TEM images of plane-view and cross-sectional view of Ta(3 nm)/Ru_b(9 nm)/Ru_t(9 nm)/CoCrPt−SiO_2(14 nm)/C(3.5 nm), respectively. Ru_b and Ru_t layers were deposited at 0.5 and 7 Pa, respectively. The plane-view exhibits a grain growth image with grain size of 6–15 nm in diameter. The white-contrast portion located in the grain boundaries was thought to be SiO_2 by many authors [7–9], which serves as the barrier to decouple the neighbor magnetic grains. As shown in Fig. 1(b), the carbon layer cannot be seen because of the poor contrast and the presence of glue used during TEM sample preparation. However, we can observe that the Ru_b layer has a continuous structure. This is because Ru_b was deposited under high-mobility deposition conditions. During the initial growth stage of the Ru_t layer, the columns are packed closely and in the late growth stage the columns are well-isolated one another. This can be explained by Thornton's film growth model: in sputtering deposition a low-mobility deposition condition (high Ar gas pressure) tends to create polycrystalline film, which corresponds to the "zone 1" structure in the well-known Thornton microstructure zone diagram, and leads to fine columnar grains with voided grain boundaries [10]. On the other hand, a high-mobility deposition condition (low Ar gas pressure) tends to promote a continuous structure of morphology. In CoCrPt–SiO_2 layer, the columns of Co-alloy stand on those of Ru_t layer, and the segregation between the columns in the magnetic layer remains.

In order to study the effect of P_{Rut} and R_O, samples with a layer structure of Ta(2.5 nm)/Ru_b(8 nm)/Ru_t(5 nm)/CoCrPt−SiO_2(14 nm)/C(3.5 nm) were used. Only P_{Rut} and R_O were changed independently with the rest deposition conditions for the media kept the same. For example, the total pressure for magnetic layer P_m was kept to be 8.5 Pa. Fig. 2(a) shows Hc as a function of P_{Rut} and R_O. Here, P_{Rut} was varied from 2.5 to 5.5 Pa, and R_O from 0.00% to 2.22%. With the increase of P_{Rut}, Hc increases rapidly at lower P_{Rut}(2.5–3.5 Pa) and slowly at higher P_{Rut} (3.5–5.5 Pa). When R_O increases from 0.00–1.67%, Hc increases monotonously. However, when R_O further increases from 1.67% to 2.22%, Hc reduces. The phenomenon of Hc increase with both P_{Rut} and R_O increasing could be attributed to the improved segregation between the magnetic grains. The reduction in Hc with R_O increasing from 1.67% to 2.22% could arise from two factors: (i) part of oxygen was incorporated into the magnetic grains and reduced the magnetic anisotropy and accordingly reduced the Hc [5]; (ii) the addition of oxygen has reduced the grain size, which led to a reduction in the $K_u V/K_b T$. Recently, Inaba et al. observed that the grain size decreased significantly from 8.8 to 5.4 nm and K_u decreased from 9.5×10^6 to 4.0×10^6 erg/cm^3 as the SiO_2 content increases from 0 to 14.4 at % [7]. This indicates that a suitable combination of P_{Rut} and R_O is critical to achieve a high Hc. It is interesting to note that the full width at half-maximum (FWHM, or $\Delta\theta_{50}$) of Co(0 0 0 2) and Ru(0 0 0 2) was almost kept unchanged, i.e. around 4°. This implies that the perpendicular orientation of the magnetic grain is mainly determined by the deposition conditions of Ru_b layer of the dual-Ru media.

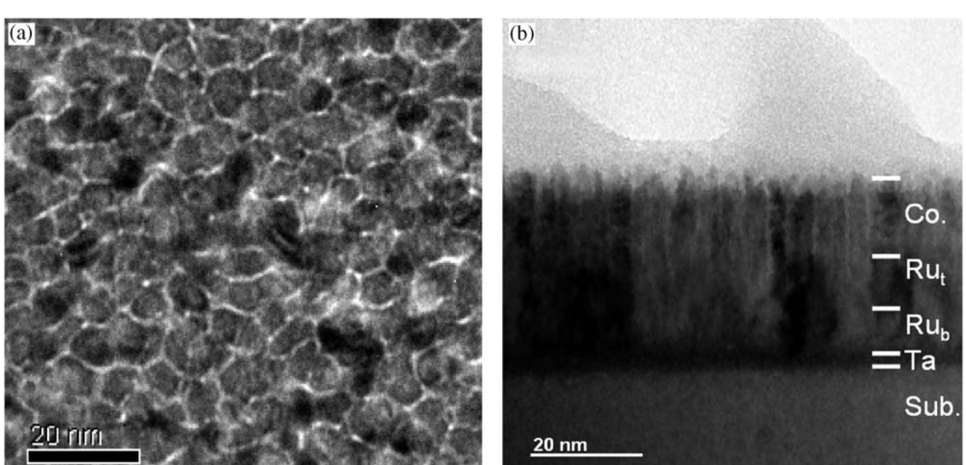

Fig. 1. TEM images of (a) plane-view and (b) cross-sectional view of Ta(3 nm)/Ru_b(9 nm)/Ru_t(9 nm)/CoCrPt−SiO_2(14 nm)/C(3.5 nm).