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Effect of oxygen on magnetic properties of Co–Pt–Cr–SiO_2 thin films for perpendicular recording media

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Abstract

The effect of oxygen on magnetic properties of Co–Pt–Cr–SiO_2 films deposited with various sputtering conditions of Ar gas pressure and deposition speed was investigated. It was suggested that optimum oxygen composition in the film for obtaining large H_c was to have the oxygen/silicon ratio of 2 in Co–Pt–Cr–Si–O films. No X-ray photoelectron spectroscopy spectrum of Co–O or Cr–O was observed in this film, while the Si spectrum shifted to higher energy indicating Si–O bonding. The film exhibited a well-isolated fine grain structure, and the oxygen/silicon ratio was almost constant throughout the depth. It is suggested that the granular structure with SiO_2 grain boundaries is formed from the initial deposition stage.

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Keywords: Co–Pt–Cr–SiO_2; Perpendicular recording media; Magnetic property; Oxygen effect; X-ray photoelectron spectroscopy

1. Introduction

Perpendicular magnetic recording [1] media are actively studied for the next-generation high-density magnetic recording. Especially, Co–Pt–Cr-oxide composite media with a well-isolated fine magnetic grain structure are expected to realize a high recording density [2,3]. It was reported that the grain boundaries of RF sputter-deposited Co–Pt–Cr–Si–O media with a granular structure consisted of a silicon oxide with little Co and Pt [4]. On the other hand, Zheng et al. [5] indicated the importance of Cr–O formation at the grain boundaries in the oxide composite media deposited by DC magnetron sputtering. It is considered that the grain structure, the crystallographic property of the magnetic grain, and the chemical condition of atoms are important factors for magnetic properties of Co–Pt–Cr-oxide media. In this work, the effect of oxygen on magnetic

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properties of DC magnetron sputter-deposited Co–Pt–Cr–SiO_2 film was investigated.

2. Experiment

Co–Pt–Cr–SiO_2 films were deposited on glass disks using a DC magnetron sputtering system with a composite-type target at base pressure below 10^{-5} Pa. The target composition was $[Co_{76}Pt_{19}Cr_5$ at%](70)–SiO_2(30) vol%, and the film thickness was 20 nm. No substrate heating was carried out during the deposition process, and a Ru film was used as an underlayer. No oxygen gas was introduced to the sputtering Ar gas. Magnetic properties were measured using vibrating sample magnetometer (VSM). Magnetic domain size was measured using a magnetic force microscope (MFM). The microstructure was investigated using transmission electron microscopy (TEM), and the film composition and chemical bonds were analyzed using X-ray photoelectron spectroscopy (XPS).

3. Results and discussion

3.1. Influence of sputtering pressure

Figs. 1(a) and (b) show the magnetic properties and composition of the Co–Pt–Cr–SiO_2 composite film as a function of the sputtering Ar pressure. The Co–Pt–Cr–SiO_2 films shown in Fig. 1 were deposited at relatively low speeds of 0.13–0.21 nm/s. The slope parameter, $\alpha(dM/dH$ at $H_c)$, decreased with increasing Ar pressure from about 2.6 to 0.7. Fig. 1(b) indicates that the oxygen concentration in the film is changed by the sputtering Ar pressure. The oxygen concentration markedly increased with increasing Ar pressure; however, the silicon concentration was almost the same for the sputtering pressure. Therefore, the concentration ratio of oxygen to silicon increased with increase in the Ar pressure. Maximum H_c of about 3.8 kOe was obtained at an Ar pressure of 1.5 Pa, and the saturation magnetization M_s of this film was about 550 emu/cm^3. This deposition condition provides stoichiometric ratio of oxygen/silicon of about 2. Fig. 2 shows the XPS spectra for Co, Cr and Si in this film. The XPS spectra for Co–O and Cr–O were not observed, while the Si spectrum shifted to a higher energy corresponding to the energy of Si–O bond. The appearance of the Co–O spectrum in XPS was observed for the film deposited at a high Ar pressure of 5.0 Pa, and the M_s decreased to about 300 emu/cm^3. Magnetic domain structures were observed using MFM at the AC-demagnetized state for these samples. Fig. 3 shows the MFM images for the Co–Pt–Cr–SiO_2 films deposited at 0.2, 1.5 and 5.0 Pa. The film deposited at 1.5 Pa exhibited the minimum magnetic domain size of approximately 55 nm. On the other hand, a maze-like magnetic domain with a width of approximately 65 nm was observed in the

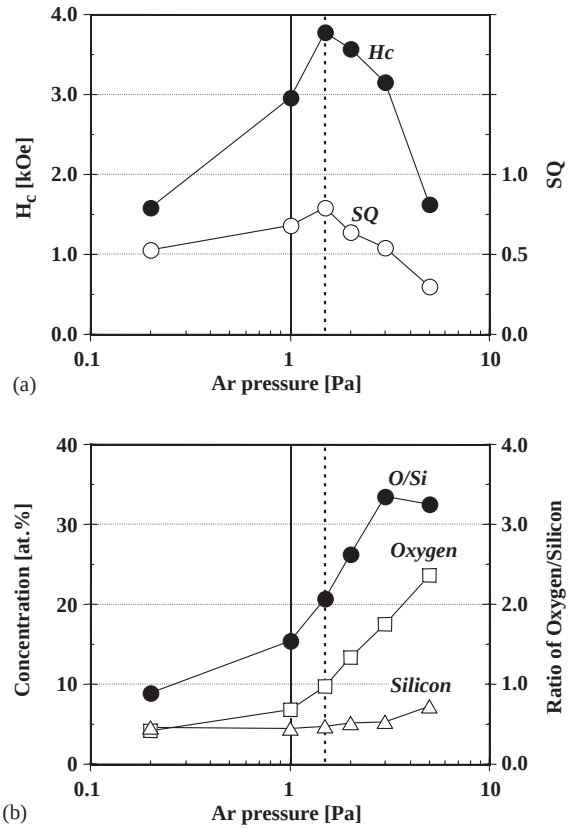

Fig. 1. Magnetic properties (a) and film composition (b) of 20-nm-thick Co–Pt–Cr–SiO_2 film as a function of sputtering Ar pressure (Speed = 0.13–0.21 nm/s).