MAGNETIC PROPERTIES OF Co-FERRITE FILMS BY SOLID REACTION AT LOW TEMPERATURE

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Abstract- Co-ferrite ($CoO\text{-}Fe_2O_3$) thin films have been prepared by two ways of low temperature solid reaction including oxidation process, being based on Co-layer/α-Fe_2O_3 films and Co-layer/Fe_3O_4 films. Magnetic properties of both Co-ferrite films have been measured and compared. The samples from Co-layer/Fe_3O_4 films have a large coercive force in the direction perpendicular and have a great poler kerr rotation angle at wavelength 700 nm than ones from Co-layer/α-Fe_2O_3 films. The typical magnetic properties are as follows; saturation magnetization $4\pi Ms$, 2.9 kG; remnant magnetization $4\pi Mr$, 2.0 kG; coercive force Hc, 4.0 kOe; kerr rotation angle ϕk, 0.39 deg ($\lambda = 700$ nm); and initial magnetization energy E, 3.3×10^6 erg/cm^3, respectively.

I. INTRODUCTION

The Co-ferrite ($CoO\text{-}Fe_2O_3$) is well-known to have a perpendicular magnetic anisotropy [1] and a strong chemical stability [2]~[4]. Co-ferrite thin films also exhibit an excellent magneto-optic property. Therefore those films are expected to be advantageous materials for magneto-optical memory and their recording applications.

Generally, magnetic oxide films as ferrites have been prepared by the sputtering techniques [5]~[6], the plasma assisted MO-CVD [7], the grown from an aqueous solution at low temperature [8], and the solid reaction at low temperature [9]~[10]. In these methods, the solid reaction method at low temperature is suitable for uniformed film formation, because of the less composition deviation due to fluctuation of process conditions. The solid reaction including oxidation at low temperature for metallic thin film has a series of following processes [11]~[14]; (a) absorbed oxygen molecules on a metallic thin film, (b) formed an oxide layer by generation and growth of oxide nucleus, and (c) formed a final oxide film through diffusion of ions in the oxide layer.

Authors have been presented some methods for preparation of Co-ferrite thin films all the while [15]~[17]. In this study, we have particularly taken note of diffusion process of Co ions in Fe oxide [18]~[19], and tried preparing Co-ferrite thin films by using the solid reaction method. As the result, Co-ferrite thin films have been successfully obtained by two ways of solid reaction techniques, and measured on magnetic properties of both films.

II. EXPERIMENTAL PROCEDURE

Figure 1 shows block diagram for the sample preparation on this study.

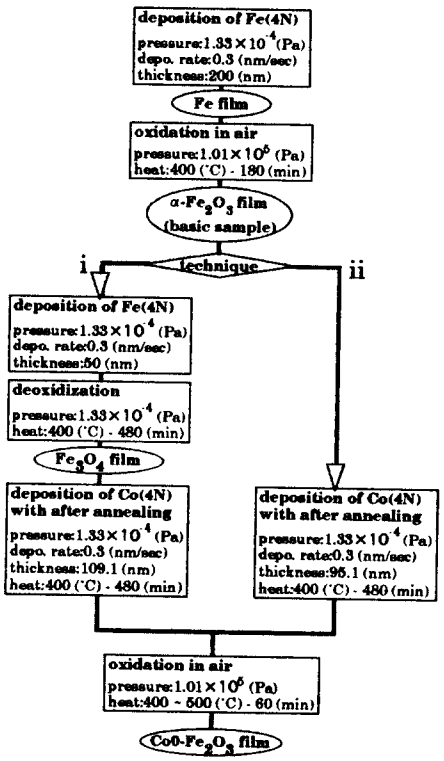

Fig. 1 Block diagram for the sample preparation.

Journal of Korean Magnetics Society, Volume 5, Number 5, October 1995

A. Basic Sample Preparation

Fe films were prepared by evaporation method with L-type electrobeam heater on heat-resisting glass substrates at room temperature. The sources were Fe ingots (99.99%). The pressure during carrying out the evaporation was keeping under 1.33×10^{-4} Pa and the rate of deposition was approximately 0.3 nm/sec. The thicknesses of samples were closely controlled by a quartz oscillating thickness monitor. These Fe film samples were put into an infrared oven and were annealed with 400 °C-180 min in an air. Through the processes mentioned above, α-Fe_2O_3 films were obtained, and we used them as basic samples in this study.

B. Preparation of Co-ferrite Films and Measurements

[Technique i] At first, Fe layer of 50 nm thick was evaporated on the basic samples. Then, the samples were deoxidized with heating (400 °C-480 min) in a vacuum (1.33×10^{-4} Pa). Through these processes, Fe_3O_4 films were obtained. Next, Co layer of 109.1 nm thick was evaporated on the Fe_3O_4 films with after annealing (400 °C-480 min) in a vacuum.

[Technique ii] Co layer of 95.1 nm thick was evaporated on the basic samples with after annealing (400 °C-480 min) in a vacuum.

Each Co layer thicknesses in the calculation of the plan at technique i and ii were designed with taking into the consideration the ratio of Co : Fe (=1 : 2) in the total composition. Finally, both films prepared by technique i and ii, according as mentioned above were oxidized and solid-reacted at low temperature (400 to 500 °C-60 min), Co-ferrite thin films were obtained.

The magnetization curve (M-H curve) of obtained Co-ferrite films were measured by vibrating sample magnetometer. Measurements of final film thicknesses were carried out by scanning a surface configuration.

III. RESULTS AND DISCUSSIONS

The final thicknesses of the oxidized films are 800 nm from the technique i and 750 nm from the technique ii, respectively.

A. Magnetization and Coercive Force

Figures 2 and 3 show dependence of the magnetic properties of the films from technique i and ii on annealing temperature. Where the symbols of open squares and open triangles are to represent the directions for the films in-plane and perpendicular

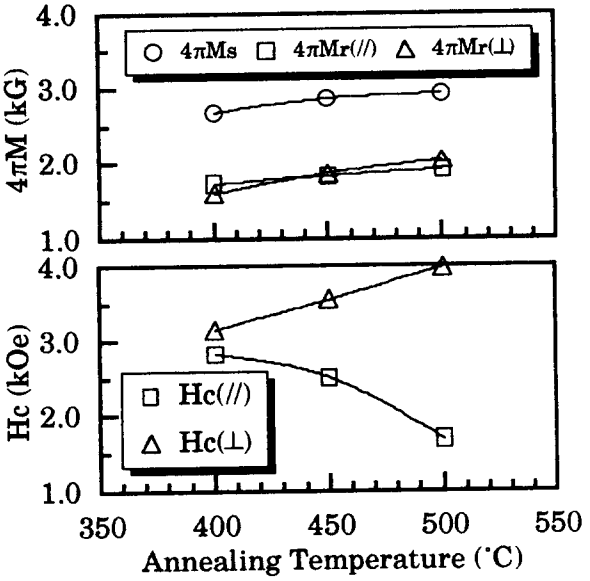

Fig. 2 Dependence of the magnetic properties of the films from technique i on annealing temperature.

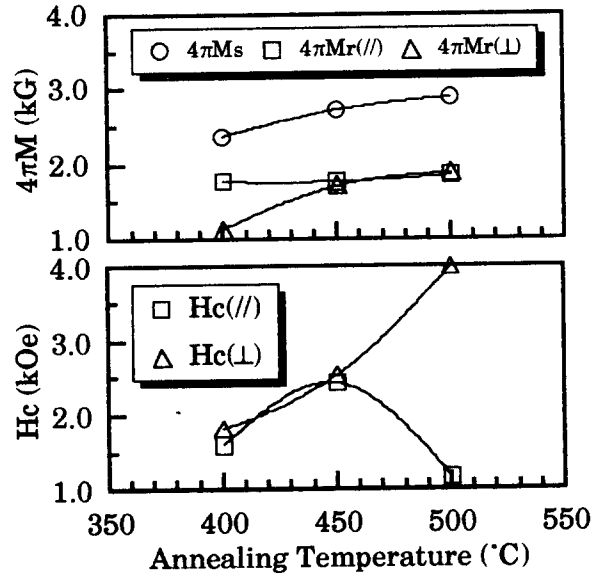

Fig. 3 Dependence of the magnetic properties of the films from technique ii on annealing temperature.

between the film surface and the applied magnetic field. Saturation magnetization $4\pi Ms$ is determined from in-plane M-H curves. Remnant magnetization $4\pi Mr$ and coercive force Hc are perceived both in-plane and perpendicular directions.

In the magnetization properties, magnetizations at annealing temperature 400 °C are slightly less than a whole. It is consider that there are locally deviations on Co ions from regularity due to various reason or are originating the nonmagnetic oxide particles in the films during the oxidation process.

In the coercive force properties, the coercive forces on perpendicular direction increase with annealing temperature and the ones on in-plane are conversely decreases. At the absolute quantity on the both techniques, coercive forces of the perpendicular are larger than ones of in-plane. This phenomenon is in proposition to be induced perpendicular anisotropy on these Co-ferrite films.

B. Magnetic Anisotropy

The Co-ferrite has a large magneto crystalline anisotropy with axis of easy magnetization <110> thereby leading to perpendicular magnetic anisotropy. The checking for the existence of an anisotropy is the purpose of this section. The energy required to initial magnetized for samples has close conjunction with a magnetic anisotropy. The energy is measured as a function of axis between a normal line to the film and an applied magnetic field.

Figure 4 shows dependence of the energy required to initial magnetized for films from technique i and ii prepared with 500 °C annealing on axis. Where the symbols of open circles and close circles are to represent the energy for the films from technique i and ii, respectively. At the both techniques, there is not very much change. Comparing the value of energy, their values of the sample from technique ii are larger than ones from technique i. It is assumed that the differences of the grain size in the films from each techniques affect values of energy. The samples on Fe_3O_4 films are easier to move on domain wall at initial magnetized process than ones on α-Fe_2O_3, in conformity with ones have a more closely packed structure of fine particles.

C. Polar Kerr Rotation Angles

Magneto-optic property is investigated with polar kerr rotation angle measurements. However, films of the Co-ferrite doesn't have a reflect layer on the surface.

Figure 5 shows the polar kerr rotation angle

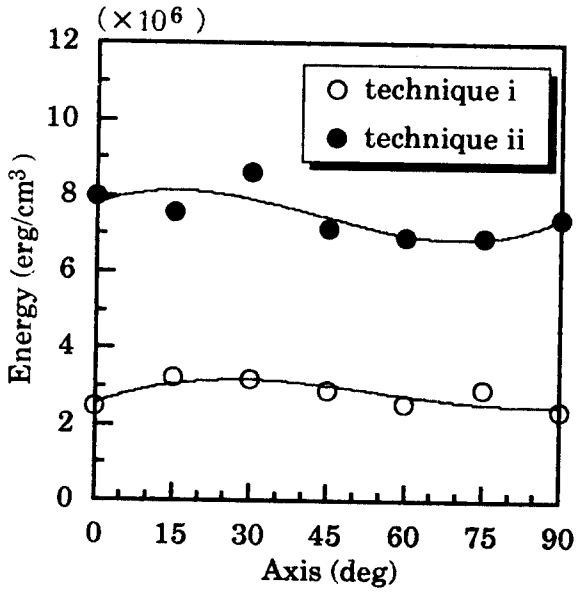

Fig. 4 Dependence of the energy required to initial magnetized for films from technique i and ii prepared with 500 °C annealing on axis.

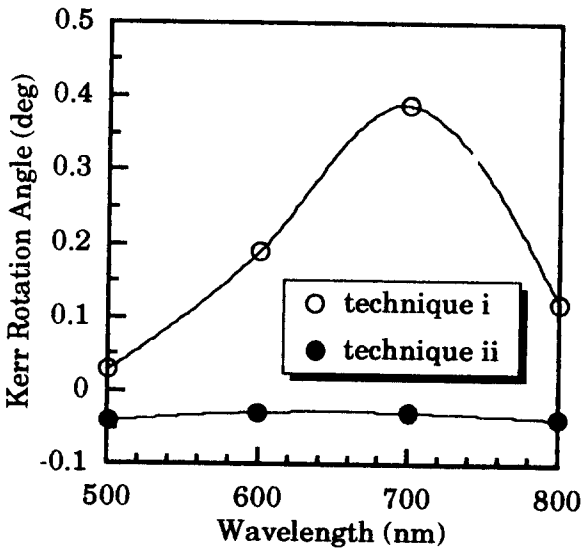

Fig. 5 The polar kerr rotation angle dependence on the wavelength irradiated for the films from technique i and ii prepared with 500 °C annealing.

dependence on the wavelength irradiated for the films from technique i and ii prepared with 500 °C annealing. Where the symbols of open circles and close circles are to represent the polar kerr rotation angles for the films from technique i and ii, respectively. It is seems that polar kerr rotation angle of the film from technique ii is very smaller than that from technique i. The reason for this result is not sure but might be due to the differences in optical constants as a reflectance or an index of refraction owing to the morphology of film surface and the grain shape of Co-ferrite formed in films. When the wavelength is 700 nm, the sample on Fe_3O_4 film has a maximum polar kerr rotation angle 0.39 deg.

IV. CONCLUSIONS

This study suggests that Co-ferrite thin films can be prepared from α-Fe_2O_3 or Fe_3O_4 films by solid reaction at low temperature. Here we may draw the following conclusions.

-Coercive forces of the perpendicular are larger than ones of in-plane. This phenomenon is in proposition to be induced perpendicular anisotropy on both Co-ferrite films.

-Comparing the value of energy, their values of Co-ferrite films on α-Fe_2O_3 are larger than ones on Fe_3O_4. It is assumed that the differences of the grain size in the films from each techniques affect the value of energies.

-In the magneto-optic properties, the polar kerr rotation angles of the Co-ferrite films on α-Fe_2O_3 are very smaller than that on Fe_3O_4 as supposed the difference in the morphology of film surface or the grain shape of Co-ferrite formed in films.

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