Magnetic and magneto-optical properties of two metallic phase magnet Co/Co_2TiSn films

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Abstract

The magneto-optical properties of Co/Co_2TiSn two-phase magnet films were studied. These films show the relatively large Kerr rotations which are -0.4 deg. at the wavelength of 400 nm, compared to that of pure Co. It is conceivable that the magneto-optical effects may be due to both contributions of ferromagnetic Co matrix and ferromagnetic Co_2TiSn Heusler alloy precipitate. The perpendicular magnetization curve demonstrates a typical bubble domain hysteresis loop. The saturation magnetization change of the annealed film is less sensitive to temperature in the low temperature region and the Curie temperature of Co2TiSn Heusler alloy precipitate is a little higher in the annealed film. These can be explained by the increase of the number of Co-Co exchange interaction in Heusler alloy structure resulting from the change of chemical ordering by annealing.

Key words : Two phase magnet. Bubble domain, Chemical ordering.

1. Introduction

In two-phase magnets when the two phases are in intimate contact it is possible to have exchange coupling at the phase boundary. The two-metallic phase magnets are materials consisting of two metallic magnetic phases with a negative or positive exchange at the phase boundary.

The Co/Co_2MnSn and Co/Co_2TiSn two-phase magnets have been studied in an effort to form a macroscopic ferrimagnet consisting of two metallic ferromagnetic phases which are antiparallel exchange coupled at the phase boundary. In the Co/Co_2MnSn system, the two metallic phases are a low Tc and low magnetization phase, hexagonal Co solid solution, and a high Tc and high magnetization phase, Co_2MnSn. The Co solid solution precipitates in the Co_2MnSn Heusler alloy matrix. In this system it has been shown that the Co solid solution precipitates are crystallographically coherent with the matrix and there is exchange coupling at the phase boundary[1]. The Co/Co_2TiSn system has a low Tc and high magnetization phase, Co_2TiSn , and a high Tc and low magnetization phase, hexagonal Co. On the contrary in the Co/Co_2MnSn system, the Co_2TiSn Heusler alloy precipitates out of the hexagonal Co matrix. This system showed an unusual coercivity change with temperature which was modeled on the basis of the wall formation caused by exchange coupling at the phase

boundary[2].

For measurements of magneto-optical properties, Co-Co_2TiSn thin films with two-phase magnet were deposited using facing target magnetron sputtering with composite target. These films have a perpendicular easy axis for magnetization and an unusual coercivity change with temperature. The perpendicular easy axis is probably induced by the columnar structure and the antiparallel exchange coupling between Co_2TiSn precipitates and Co matrix. The magnetization process in the films can be explained by the model proposed in the bulk Co-Co_2TiSn two phase magnet.[2]

2. Experiments

The Co/Co_2TiSn thin films were deposited with the film thickness of 5000 Å under 515 mTorr Ar pressure using FTMS with composite target which has the Co_4TiSn target composition. The annealing was carried out for 4 hours in vacuum. The analysis of microstructures was made with secondary electron images on a SEM. The compositional analysis of the phases was carried out using energy dispersive x-ray (EDX) analysis. The samples with two phases were characterized by x-ray diffraction analysis. The magnetization loops and magnetization vs temperature were made in the temperature range -100 °C to 400 °C up to 13 kOe field using a vibrating sample magnetometer (VSM).

3. Results and Discussion

The magnetization curve with the applied field perpendicular to film plane demonstrates a typical bubble domain hysteresis loop (Fig. 1), which means the perpendicular easy axis for magnetization. This perpendicular easy axis is expected to be induced by the columar structure in the film[3] and the antiparallel exchange coupling between Co_2TiSn precipitates and Co matrix[4] where they have a direction normal to the film plane. Although there is no microstructural evidence for the formation of a columnar structure in the Co matrix, the formation of columnar structure in sputtered films is frequently observed. Both in-plane and out-of-plane magnetization curves show a little opening with some coercivity in low field which indicates that the magnetization is caused by two magnetic phases. Considering the volume and magnetization fraction of each phase in the Co_5TiSn composition with two phases, the 25 % magnetization is able to be generated by Co_2TiSn Heusler alloy precipicates. This value is close to the 23 % magnetization fraction of the open loop portion obtained from Fig. 1 (a), which indicates that the magnetization at low field is carried out by the Co_2TiSn Heusler alloy precipitates. The magnetization process in the films with two phase magnet can be explained on the basis of the model proposed in the . The in-plane magnetization curve of the film with two phase magnet has a different shape from those of other bubble domain materials which are usually S-shaped. When the field is applied, the soft Co_2TiSn Heusler alloy precipitates are magnetized in a low field and all spins line up along the field direction (Fig. 1 a, state1). After that, as the field increases, the spins in the columnar structure of Co matrix which are perpendicular to the plane are rotated and the antiparallel exchange coupled spins at the phase boundary are also rotated by the field, then it starts to form a ferromagnetic wall (F) and the magnetization linearly increases with the field. Under high saturation field (Hsat), theDHc, is smaller (about 20 Oe) than the change in arc-melted bulk samples (82 Oe). This difference is interpreted as the dependence of DHc on precipitate size and is due to the small size of precipitates in the thin film. Magneto-optical data shows that Co/Co_2TiSn two phase magnet has relatively large Kerr rotations in the range of wavelength from 400 nm to 700nm.

4.Conclusions

The Co/Co_2TiSn thin films with two phase magnet has an unusual coercivity change with temperature and the magnetization process can be explained by the model proposed in the bulk Co/Co_2TiSn two phase magnet. Both as-deposited and annealed films show higher Curie temperatures which may be caused by the increase of magnetic Co sites in the Co_2TiSn Heusler alloy precipitates. The annealed film has a little higher Curie temperature than that of the as-deposited film, which may indicate that the precipitates in the annealed film are highly ordered.

References

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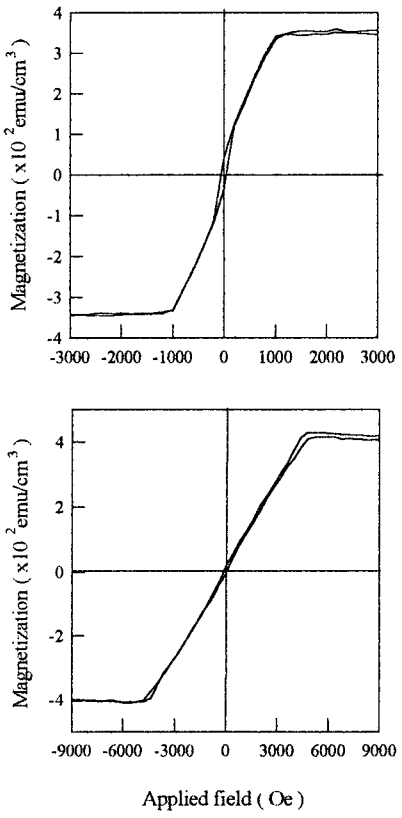

Fig. 1 The in-plane (a) and out of plane (b) magnetization hysteresis loops

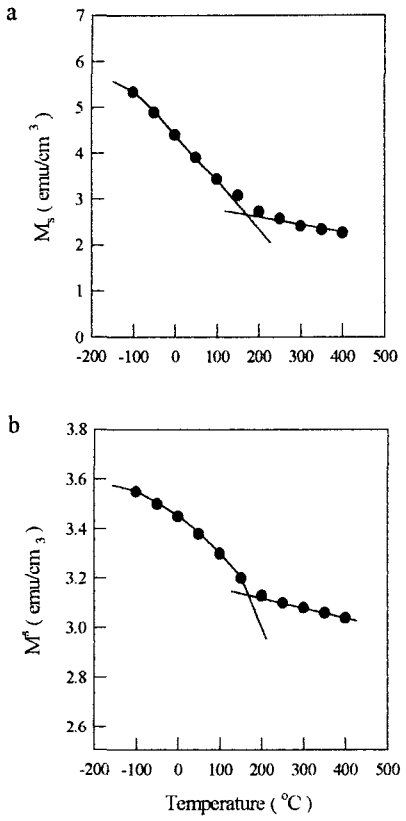

Fig. 2 The change of magnetization with temperature in as-deposited (a) and annealed (b) films.