Structure and Magnetic Properties of Sm-Co(x nm)/Co(6 nm) Multi-layered Nanocomposite Films

Electromagnetic Materials Laboratory, Research Institute of Industrial Science and Technology (RIST), P.O. Box 135, 790-330 Pohang, South Korea

Choong Jin Yang

Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Science, Shenyang 110016, People's Republic of China and International Centre for Materials Physics, Chinese Academy of Sciences, Shenyang, 110016, People's Republic of China

Cai Yin You
Zhi Dong Zhang

1. Introduction

Tthe structure and magnetic properties of Sm-Co/Co films treated at various annealing temperatures and times are reported. The effects of an externally applied magnetic field during annealing were also investigated. These result is discussed in terms of magnetization reversal of nano grains which seems to compete with the exchange interaction occurring between the nano grains.

2. Experimental

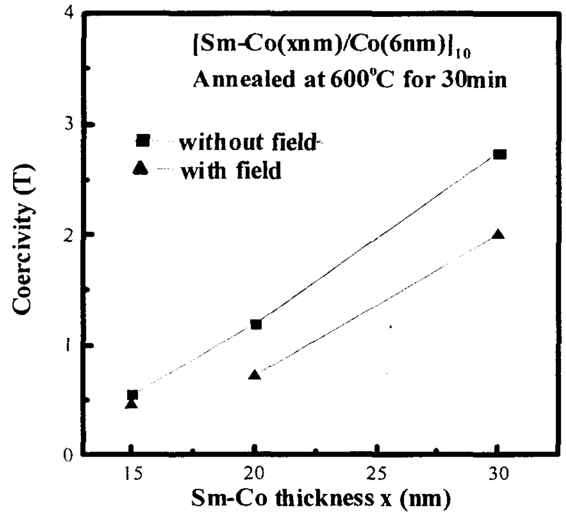
Ten-layered films of nanocomposite [Sm-Co(x nm)/Co(6 nm)] with Ta underlayer and toplayer were prepared with a multiple-gun rf-sputtering system by sputtering the target onto silicon substrates. The target of $SmCo_5$ composition was made by compressing the powders of $SmCo_5$ alloys, and then sintered at 1000°C. Ta and Co t targets were made by melting the pure elements (> 99.9 %). Magnetization behaviors were measured by a vibrating sample magnetometer (VSM), a physical property measurement system (PPMS) and an alternating gradient magnetometer (AGM) along the plane of films. Phase ingredients were identified by X-ray diffraction (XRD). The thickness of the films was measured by using α-step (Tencor Instrument, Inc.) and calculated at the same time by Auger electron spectra.

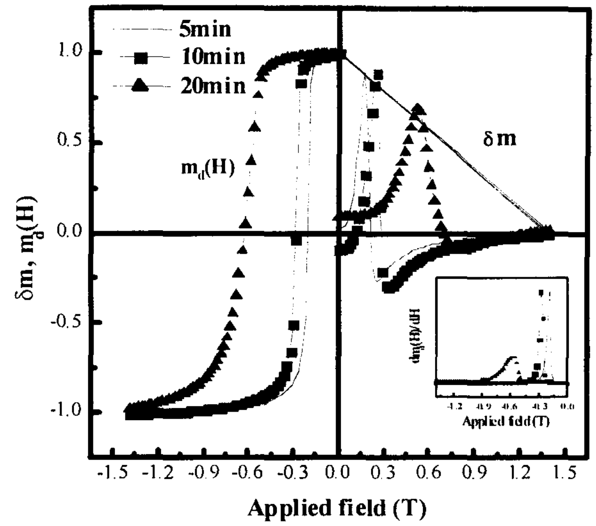
3. Results and Discussion

Fig. 1 shows the variations of coercivity of the samples annealed at 600 °C for 30 min under a field of 4.5 kG or not. Applying the magnetic field during annealing was observed to decrease the coercivity With decreasing the thickness of Sm-Co layer, the deterioration of the coercivity caused by the magnetic field annealing becomes smaller. It is resumed that the amount $SmCo_5$ phase decreases with reducing the thickness of the magnetically hard Sm-Co layer. From the dependence on the annealing temperature the coercivity can be seen to increase quickly and reaches its maximum at 570 °C. Namely the crystallization temperature of the films (x = 20nm) is supposed to be around 570 °C, and annealing for 20 min is observed to be optimal.

we examine the detailed δm curves in Fig. 2 obtained by using AGM. Positive values of δm are due to the exchange coupling promoting the magnetized state, whereas negative values are due to the magnetostatic interactions tending to assist the magnetization reversal of the nanoscale grains. It can be seen that exchange coupling (positive values of δm) is the main interaction and has rare enhancement with annealing time, to some extent a little decrement. But the coercivity increases significantly with annealing time corresponding to the shift of δm peak to the higher applied field. It suggests that exchange coupling is not the reason for the enhancement of coercivity with increasing the annealing time.

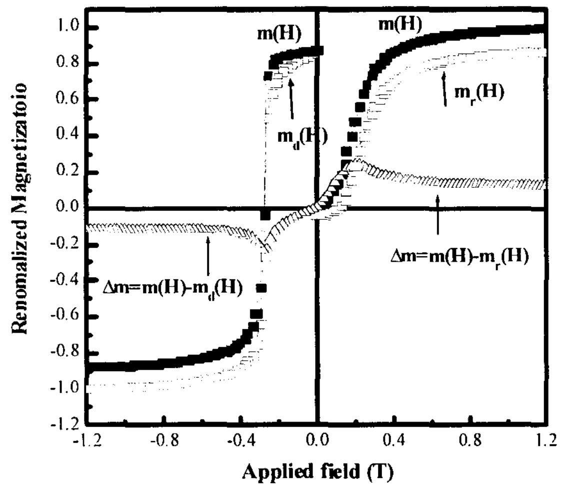
In order to discuss more informative of the magnetization and demagnetization, a comparison of remanence magnetization and direct magnetization was studied by measuring the value of isothermal remanence, $m_r(H)$, demagnetization remanence, $m_d(H)$, and direct magnetization, m(H), at the same time for samples (x = 15 nm) annealed at 600 °C for 10 min as shown in Fig. 3.





(Fig. 1) (Fig. 2)

The Δm was obtained by subtracting the remanence magnetization ($m_d(H)$, $m_r(H)$) from the direct magnetization (m(H)): $\Delta m = m(H) - m_r(H)$ or $\Delta m = m(H) - m_d(H)$, which represent reversible magnetization and demagnetization, respectively. It can be seen that the reversible magnetization or demagnetization is dominant under a critical field (H_{cr}), which shows two peaks in the Δm curve. When the applied field is under the critical field, the reversible magnetization and demagnetization becomes predominant. With further increasing the applied field, Δm decreases slowly and becomes stable finally, meaning that irreversible magnetization and demagnetization become dominant.



(Fig. 3)

4. Conclusion

Magnetic viscosity measurements indicated that a higher coercivity corresponds to a smaller switching volume. δm and switching volume measurements implied a pinning-type mechanism of coercivity for the present films studied.