Growth temperature dependence of magnetic properties for monolayer-controlled Co/Ni multilayers

Junpei Shimada[1*], Akihiro Shioda[1], Takeshi Seki[1], and Koki Takanashi[1]

1. IMR, Tohoku Univ.,

*E-mail: j.shimada0803@imr.tohoku.ac.jp

Introduction: A perpendicularly magnetized thin film having high magnetic anisotropy is essential for the development of high-density magnetic storage devices. In order to increase the recording density, it is necessary to reduce the size of magnetic element. However, the magnetic moments are greatly agitated by the thermal energy at the reduced size. $L1_0$-ordered alloys such as FePt, FePd, and CoPt with large uniaxial magnetic anisotropy energy (K_u) can increase the thermal stability of magnetization, which are promising hard magnets for the ultrahigh-density magnetic storage. However, the rare earths and the noble metals contained in typical hard magnets are unfavorable in term of the production cost and the sustainability of the resources. Thus, it is necessary to develop an alternative material having high K_u without rare earths and noble metals. We focus on CoNi artificial ordered alloys. Our previous paper reported that the epitaxial Co/Ni superlattice had perpendicular magnetic anisotropy even for the monolayer-controlled Co/Ni stacking [1], implying the formation of ordered structure. In this study, we fabricated monolayer-controlled Co/Ni multilayers by molecular beam epitaxy (MBE) with changing the growth temperature, and systematically investigated the influence of the growth temperature on their magnetic property.

Experiments: Figure 1 schematically illustrates the stacking structure. The Co/Ni multilayers were grown on an Al_2O_3 (11–20) single crystal substrate with a V/Au buffer layer by using a MBE system equipped with two independent e-guns under the base pressure below 10^{-7} Pa. First, the Al_2O_3 substrate was heated at 600 °C for 1 hour in the UHV chamber to obtain clean surface, and a 10 nm-thick V buffer layer was grown at 600 °C. Then, a 10 nm-thick Au layer was grown at 100 °C and was subsequently annealed at 300 °C for 30 minutes. The Co/Ni multilayers were grown on the buffer layer at various temperatures. In this study, the growth temperature (T_g) was set at room temperature (RT), 100 °C, 200 °C, and 300 °C. Finally, a 4 nm-thick Au layer was deposited as a capping layer. The structural characterization for the prepared Co/Ni multilayers was carried out using X-ray diffraction (XRD) with a Cu-*K*α radiation. The surface morphology was evaluated by using an atomic force microscopy (AFM). The magnetic properties were measured by a vibrating sample magnetometer (VSM) and a superconducting quantum interference device (SQUID) magnetometer. The effective magnetic anisotropy energy (K_{eff}) of the Co/Ni multilayer, which was evaluated from the area enclosed between the perpendicular and in-plane magnetization curves, was increased with increasing T_g, and K_{eff} showed a maximum value at T_g = 200 °C. The maximum value of K_u, in which the shape anisotropy energy was corrected, was obtained to be and 7.3 × 10^6 erg/cm^3, respectively. However, further increment of T_g up to 300 °C give rise to the large reduction of K_{eff}. These results suggest that the atomic diffusion on growth surface was promoted and the crystallinity of Co/Ni superlattice was improved due to the high growth temperature at T_g = 200 ºC, implying the possibility of the formation of ordered structure. However, we consider that T_g = 300 ºC led to the significant interdiffusion between the Co and Ni monolayers and collapsed the superlattice structure.

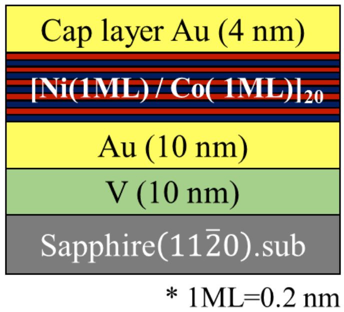

Fig. 1. Schematically illustration of the structure of Co/Ni multilayer.

[1] A. Shioda, T. Seki, J. Shimada, and K. Takanashi, *Journal of Applied Physics*, **117**, 17C726 (2015).