Optimization of substrate temperature of Mn_4N thin films on STO(001) by molecular beam epitaxy

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[Introduction] Mn_4N thin film is expected to be a candidate material for current induced domain wall motion (CIDWM) devices. It has perpendicular magnetic anisotropy with K_u ~10^2 kJ/m^3 [1] and small M_S with 100 kA/m [1]. It consists of light and abundant elements. $SrTiO_3$ (STO) is a substrate suitable to grow Mn_4N thin films thanks to extremely a small lattice mismatch with Mn_4N (-0.1 %). Recently, we achieved a domain motion velocity of 900 m/s at a current density of approximately 10^{12} A/m^2 for Mn_4N nanowire grown on STO(001) without applying an external magnetic field [2]. Moreover, heavy metal/ferromagnet/oxide structure makes the threshold of current density of CIDWM lower with spin orbit torque [3]. However, there have been no reports on effect of substrate temperature (T_{sub})for the growth condition of Mn_4N thin films on STO.

[Experiment] 25-nm-thick Mn_4N films were grown on STO(001) substrates by molecular beam epitaxy using a solid source of Mn and radio-frequency N_2 plasma. T_{sub} was set at 350, 400, 450, 500 and 550 °C. After the growth, the films were sputtered *in situ* with Ta to prevent oxidation. The crystalline quality of grown films was evaluated by reflection high-energy electron diffraction (RHEED) and X-ray diffraction (XRD) ω-2θ, ϕ-$2\theta\chi$. Surface structure was observed by atomic force microscope. Magnetic property was measured by vibrating sample magnetometer (VSM) at room temperature (RT). Anomalous Hall effect was measured by physical properties measurement system at RT.

[Result & Discussion] Streaky RHEED patterns along STO[100] azimuth were obtained except the 550 °C sample in the left side of Fig.1. Instead, the RHEED image of the 550 °C sample showed ring pattern. The right side of Fig.1 shows ω-2θ XRD profiles. Epitaxial growth of Mn_4N films were confirmed for samples grown at T_{sub} = 350-500 °C. For the 500 °C sample, a peak from Mn oxide appeared. We attributed such phenomena to oxygen atoms diffusion from STO. Besides, the Mn_4N 004 peak of 350 °C sample was unclear. Fig.2 shows M-H curves of all samples with magnetic field applied perpendicular to the plane. Remarkably, only the 350 °C sample showed significantly smaller M_S. On the basis of results, we conclude that 400-450 °C is desirable to grow pure, and c-axis oriented Mn_4N thin films. In addition, we are going to report the growth of Mn_4N thin films on (La, Sr)(Al, Ta)O_3 (LSAT)(001).

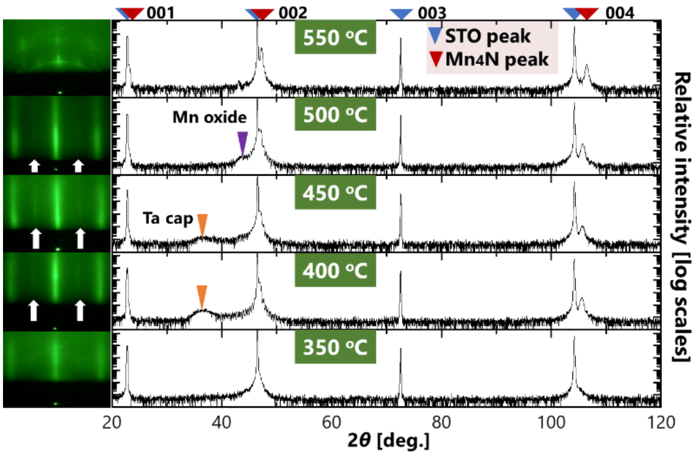

Fig. 1 T_{sub} dependence of RHEED images along STO[100] azimuth (left) and XRD ω–2θ profiles (right). The white arrows in the inset indicate the positions of superlattice diffraction lines.

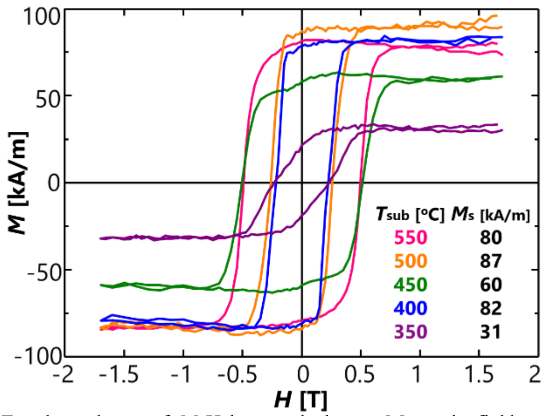

Fig. 2 T_{sub} dependence of M-H hysteresis loops. Magnetic field was applied perpendicular to plane (H // [001]).

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[References]

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