Improvement of crystalline quality and magnetic properties of Mn_4N thin films on LSAT substrate by post-annealing process

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[Introduction]

Ferrimagnetic Mn_4N is promising for current-induced domain wall (DW) motion due to its perpendicular magnetic anisotropy (PMA), small saturation magnetization (M_S~80 kA/m) and low pinning[1]. Besides, a very high DW motion velocity in Mn_4N nanowire has already been recorded at 900 m/s driven by pure spin transfer torques without an external magnetic field [1]. We anticipated the origin of PMA to be in-plane tensile distortion from the first-principle calculation[2]. However, this hypothesis has yet to be proved experimentally. Therefore, we tried to grow Mn_4N epitaxial films on $(LaAlO_3)_{0.3}(Sr_2TaAlO_3)_{0.7}$ [LSAT](001) substrates by molecular beam epitaxy (MBE), which would induce in-plane compressive strain. But at T_{sub} < 650℃, polycrystalline Mn-N compounds were grown. In contrast, at T_{sub} > 700℃, *c*-axis oriented Mn_4N films were grown, but we did not succeed in the epitaxial growth of Mn_4N due to the appearance of a magnetic dead layer [3]. In this work, we performed post-annealing (PA) of Mn_4N films on LSAT after the growth at 550℃ and characterized their crystalline quality and magnetic properties.

[Method]

We attempted to form 10-30 nm Mn_4N on LSAT(001) at T_{sub} = 750 ℃ or 550 ℃. For 550 ℃ samples, we carried out PA at 550 ℃ for 30 min in the growth chamber. Sample preparation details are summarized in Table 1. We observed lattice images and reciprocal lattice diffraction images by X-TEM and performed element analysis by energy dispersive x-ray spectrometry (EDS). Crystalline quality of grown films were characterized by reflection high-energy electron diffraction and X-ray diffraction. Their magnetic properties were measured by vibrating sample magnetometer.

Table 1. Sample preparation details.

Sample	T_{sub} (℃)	Thickness (nm)	PA (600 ℃)
1	750	10	---
2	750	20	---
3	550	30	30 min
4	550	30	---

[Result & Discussion]

Figure 1 shows the X-TEM image of sample 1. We confirmed the presence of both epitaxial grains of Mn_4N and polycrystalline grains. From the analysis of EDS, we confirmed non-stoichiometric Mn-N compounds such as an Mn/N atomic ratio of 9 also form at T_{sub} = 750℃. Epitaxial growth of Mn_4N films was confirmed in sample 3 by XRD.

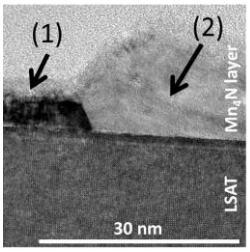

Fig. 1. Cross-section TEM image of sample1; both (1) epitaxial and (2) polycrystalline Mn_4N grains exist.

Figure 2 shows the *M-H* curves of samples 3 and 4. The M_S of sample is much larger than of sample 4. Sample 3 also showed PMA. These results demonstrate that post-annealing will be a pathway to grow Mn_4N thin films epitaxially on LSAT, and modulate the magnetic properties of grown films.

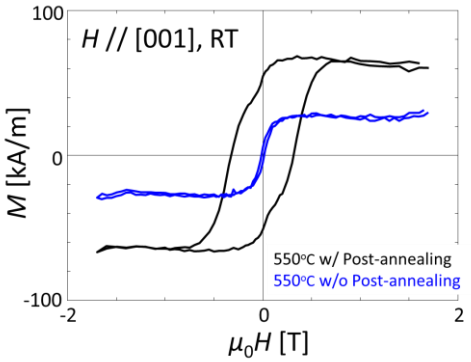

Fig. 2. *M-H* curves of sample 3(W/PA) and sample 4 (W/O PA) under *H* normal to sample surface.

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[References]

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