Growth of the Mn_4N epitaxial film with the gradient and the cap and substrate dependence of the properties in the ultrathin region

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【Introduction】 Current-induced domain wall motion (CIDWM) is one of the most attractive spintronics technologies because it can be applied to the non-volatile memory represented by racetrack memory[1]. Our group focus on Mn_4N and $Mn_{4-x}Ni_xN$ epitaxial films as the candidates. Especially, we recorded DW velocity approaching 3,000 m/s only by spin-transfer torques (STTs), one of the fastest records among all reports on CIDWM experiments[2]. Seeking further progress, we're currently attempting to utilize both STTs and spin-orbit torques (SOTs) in CIDWM of $Mn_{4-x}Ni_xN$. In this case, $Mn_{4-x}Ni_xN$ films are supposed to be ultrathin, generally thinner than 5 nm, so that the spin current or accumulation to induce SOTs can effectively work on localized electrons in $Mn_{4-x}Ni_xN$.

However, we have been facing the obstacle for the growth of ultrathin $Mn_{4-x}Ni_xN$ films due to anisotropic growth along the substrate interface induced by the morphology of the substrates. In order to overtake this obstacle, in this work, we attempted to fabricate Mn_4N films with the gradient and acquire properties in their ultrathin regions. We succeeded in their growth by installing a linearly moving shutter.

【Experiment】 Samples were fabricated by molecular beam epitaxy. Films with a wedge-shaped thickness distribution were grown by moving the automatic shutter at the constant velocity, and the thickness was set to be 0-32 nm. MgO(001) or $SrTiO_3$(STO)(001) was used as the substrate and SiO_2 or Pt was sputtered after the epitaxial growth. Figure 1 shows the schematic image of the growth of tilted Mn_4N film. Crystalline qualities were evaluated by reflection high-energy electron diffraction (RHEED) and X-ray diffraction (XRD). Electric properties were investigated by anomalous Hall effect (AHE) and longitudinal resistivity (ρ_{xx}).

【Results & Discussion】 Figure 2 shows the RHEED images taken along substrate [100] azimuth and ω-2θ XRD profiles of $SiO_2/Mn_4N/MgO$ and $SiO_2/Mn_4N/STO$. Both XRD profiles and RHEED images are expected to have included the information of all entire sample because the size of the beam is as large as that of our samples (1cm×1cm). However, we concluded Mn_4N epitaxially grew on both types of substrates because we didn't observe any features of polycrystalline or amorphous like growth. According to the investigation on the thickness dependence of longitudinal and Hall resistivity, we concluded that we succeeded in the epitaxial growth of Mn_4N with the thickness of approximately 2 nm. The details will follow in the talk.

【Reference】

[1]S. Parkin, S.-H. Yang, Nat. Nanotechnol. **10**, 195 (2015).
[2]S. Ghosh *et al.*, Nano Lett. **21**, 2580 (2021).

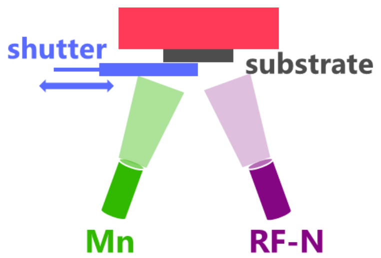

Fig.1: Schematic image of the growth of Mn_4N film with the gradient

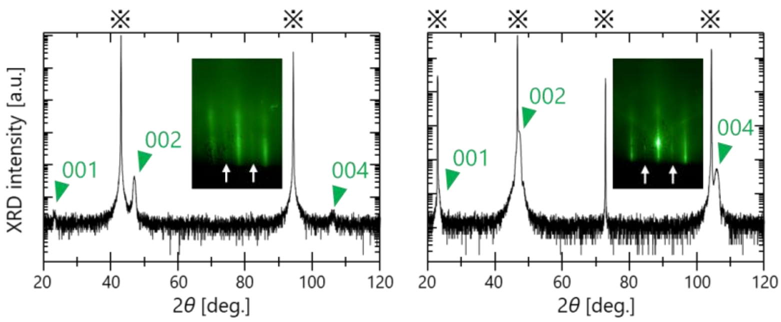

Fig.2: ω-2θ XRD profiles of $SiO_2/Mn_4N/MgO$ (left) and $SiO_2/Mn_4N/STO$ (right). Insets are RHEED images taken along substrate [100] azimuth. Asterisks indicate the diffraction from substrates and arrows suggest superlattice diffraction