Evaluation of the properties of ultrathin Mn_4N epitaxial films by growing tilted films with molecular beam epitaxy

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【Introduction】 Current induced domain wall motion (CIDWM) is key technology to enable non-volatile memory devices such as racetrack memory [1]. Our group focuses on ferrimagnetic Mn_4N and $Mn_{4-x}Ni_xN$ epitaxial films as candidates for fast and efficient CIDWM. We recently reported DW velocity of 900m/s with current density (j) of 1.3×10^{12}A/m^2 in Mn_4N [2] and 3,000m/s with same j in $Mn_{4-x}Ni_xN$ nanowires [3]. Notably, these values were recorded in purely spin-transfer torque (STT)-driven CIDWM. They largely exceeded previous records of STT-driven CIDWM, what's more, they're competitive with spin-orbit torque (SOT)-driven CIDWM.

This fact led us to new interest that SOT-driven CIDWM in Mn_4N and $Mn_{4-x}Ni_xN$ can show ultrafast velocity with lower threshold j thanks to its more efficient transfer of angular momentum [4]. In order to enable this, we're aiming at fabrication of HM/Mn_4N/STO heterostructure where HM refers to heavy metal such as Pt, W and STO is $SrTiO_3$(001) substrate. By applying current, HM generates spin current perpendicular to the plane and injects spin current to Mn_4N by spin Hall effect. In this case, however, Mn_4N must be thin as 1~2nm so that DWs in Mn_4N are stable at chiral Néel state, beneficial in SOT-driven CIDWM [4].

However, the growth of Mn_4N on STO is known to be disturbed due to anisotropic initial growth along the kinks on the surface. So far, the thinnest Mn_4N film with proper magneto-transport properties were 4-5 nm thick [2], which is still too thick for SOT-driven CIDWM. Therefore, in this work, we tried to evaluate the properties of ultrathin Mn_4N by growing tilted Mn_4N epitaxial films on STO and MgO(001) substrates.

【Experiment】 All samples grew by molecular beam epitaxy. Tilted layer was achieved by automatically controlling the shutter between solid metal source and a substrate. Figure 1 shows the schematic image of the growth. Samples were processed into Hall bars with the width of 100μm, and anomalous Hall effect (AHE) was evaluated at RT to investigate the magneto-transport property.

【Results】 Figure 2 shows the configuration of AHE hysteresis loop of Mn_4N(2~35nm)/MgO. Note that AHE measurements were performed at various thickness and Fig.2 shows the loop at 15nm. In this thickness region, the samples showed clear a hysteresis loop as previously reported in non-tilted layer [2], suggesting magneto-transport properties didn't change even in the tilted Mn_4N layer. However, such properties were not acquired in the thinner region. We attributed this to the improper ratio of Mn and N plasma, either of them partially disturbed by the shutter. In the talk, we'd like to talk about the result after optimizing the Mn and N plasma ratio.

【Reference】

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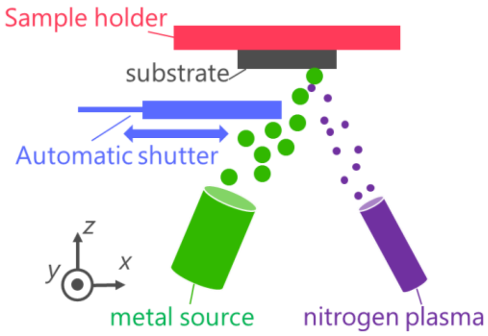

Fig.1 Schematic image of the molecular beam epitaxy growth of tilted layer.

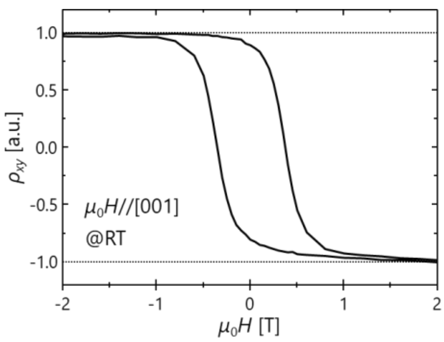

Fig.2 AHE of Mn_4N tilted layer at 15nm thick. Note that transverse resistivity (ρ_{xy}) was normalized.