Analysis of the magneto-transport properties in $Mn_{4-x}Ni_xN$ films with large current induced domain wall mobility and anomalous Hall effect

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【Introduction】 Mn_4N film is a notable candidate for the fast magnetization switching thanks to its PMA and small M_S (≃ 80 kA/m)[1]. Our group has recently achieved domain wall motion velocity of 900 m/s at $j = 1.3\times10^{12}$ A/m^2[1], the fastest and most efficient among the ones driven by spin-transfer torque. We also found the magnetic compensation in $Mn_{4-x}Ni_xN$ between x = 0.1–0.25 [2], around which we expect more efficient magnetization switching. Large anomalous Hall angle ($\theta_{AHE} = \rho_{AH}/\rho_{xx} \cong 2$ %) is the unique feature of this material as well although it doesn't content any element with strong spin orbit coupling. In this work, anisotropic magnetoresistance (AMR) measurements were performed to study the interaction between conduction *s* electrons and localized *d* electrons. The temperature dependence of ρ_{xx} and ρ_{AH} was also investigated to find the origin of large AHE in $Mn_{4-x}Ni_xN$ films.

【Experiment】 $Mn_{4-x}Ni_xN$ epitaxial films (30 nm) were fabricated onto $SrTiO_3$(001) substrates by molecular beam epitaxy. AHE and AMR measurements were performed by physical properties measurement system (PPMS). Before measurements, film samples were processed into Hall bars with a width of 200 μm and a length of 3500 μm. We set the DC current flow in the [100] azimuth during the measurement. The magnetic field of 9 T was applied parallel to the plane.

【Results and Discussion】 Figure 1 shows the Fourier coefficients in AMR curves in $Mn_{4-x}Ni_xN$ (x = 0, 0.05, and 0.15). As we observe in Fig. 1, $\cos2\theta(C_2)$ and $\cos4\theta(C_4)$ components are recognized in $Mn_{4-x}Ni_xN$ systems. It was reported that C_4 components derive from the split in $d\varepsilon$ states (d_{xy}, d_{yz}, d_{xz}) under the tetragonal crystal field below 100 K in antiperovskite nitrides[3]. In $Mn_{4-x}Ni_xN$, however, the magnitude of C_4 components became smaller at larger Ni composition x although there was no significant change in their lattice constants. Therefore, we expect such crystal field was weakened by Ni replacement. Since the orbitals of $d\varepsilon$ states have significant influence on AHE, this discovery can lead to the understanding of the magneto-transport properties of $Mn_{4-x}Ni_xN$.

Figure 2 shows the relationship between ρ_{xx} and ρ_{AH} in Mn_4N film measured under T = 2–300 K. Although ρ_{AH} is proportional to ρ_{xx}^2 at T = 2–100 K, it's rather proportional to ρ_{xx} at T = 100–300 K. This change is attributed to the different origin of AHE, intrinsic and extrinsic, respectively. However, this trend is opposite to other metals,[4] wherein ρ_{AH} is proportional to ρ_{xx}^2 at high temperatures. This trend may be related with the change in the $d\varepsilon$ states orbitals as stated above.

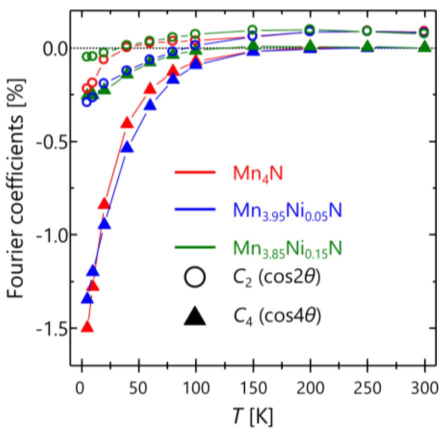

Fig.1 Fourier coefficients C_2 and C_4 of AMR curves of $Mn_{4-x}Ni_xN$.

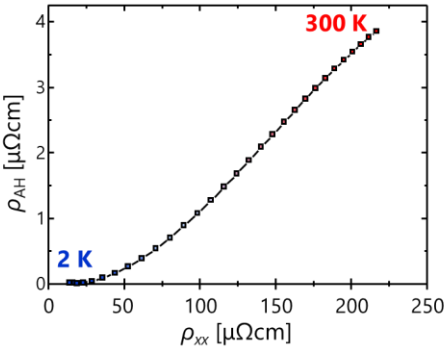

Fig.2 ρ_{xx} dependence of ρ_{AH} in Mn_4N in the temperature range 2–300 K.

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【References】

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