Epitaxial growth of $Mn_{4-x}Ni_xN$ thin films by MBE and their characterizations

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[Introduction]

Antiperovskite type ferromagnetic nitrides have attracted much attention as a new spintronics material. Among them, Mn_4N ferrimagnetic thin film has potential for the application to current-driven domain wall (DW) motion devices due to its high perpendicular magnetic anisotropy (PMA) of about 10^6 erg/cm^3 and small saturation magnetization (M_S) of 110 emu/cm^3. We have previously succeeded to grow $Co_xMn_{4-x}N$ and $Fe_xMn_{4-x}N$ mixed crystal thin films, where Mn atoms are partially substituted for Co and Fe atoms, and revealed their magnetic properties[1, 2]. In this study, we focused on $Mn_{4-x}Ni_xN$ mixed crystal thin films, where Mn atoms are substituted for Ni atoms, because there is a possibility that they have smaller M_S than that of Mn_4N with PMA, which can promote higher efficiency of DW motion at low current density. However, there are quite limited information of $Mn_{4-x}Ni_xN$ thin films and their magnetic properties haven't been revealed. Therefore, we grew $Mn_{4-x}Ni_xN$ epitaxial thin films by molecular beam epitaxy (MBE) and evaluated their structures and magnetic properties.

[Experiment]

$Mn_{4-x}Ni_xN$ (x = 0, 1, 2, 3, 4) (30 nm-thick) thin films were grown on MgO(001) substrates by MBE using solid Mn, Ni and radio frequency N_2 plasma. Substrate temperature (T_S) was fixed at 450 °C when $x \leq 1$ and was varied in the range between 150 and 250 °C to be optimized when $x \geq 2$. The crystalline qualities and structures of the grown layers were evaluated by reflection high-energy electron diffraction (RHEED) and x-ray diffraction (XRD). The magnetic properties were measured by vibrating sample magnetometer (VSM) at room temperature.

[Results and discussion]

Figure 1 shows ω-2θ XRD and RHEED patterns of $Mn_{4-x}Ni_xN$(x = 0, 1, 3, 4) thin films grown at optimized T_S. The (001)-oriented XRD peaks from $Mn_{4-x}Ni_xN$ and streaky RHEED patterns were observed for all x, indicating epitaxial growth of $Mn_{4-x}Ni_xN$ thin film. However, other phases such as MnNi became pronounced for samples grown at elevated T_S for $x \geq 2$, which attributed to the release of N atoms. Figure 2 shows composition dependence of M_S and magnetic anisotropy constants (K_u). M_S and K_u drastically decreased even by small substitution of Ni, and they were likely to decrease as the Ni content increased at $x \leq 1.0$. Distinct PMA was realized for $x \leq 0.25$. At higher Ni content, magnetization almost disappeared when x = 2 and 4, whereas magnetization clearly appeared when x = 3. We plan to evaluate the temperature dependence of magnetization and grow samples on another substrate.

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1) K. Ito *et al.*, AIP Advances **6**, 056201 (2016).
2) A. Anzai *et al.*, the 64th JSAP spring meeting, 14p-P10-67 (2017).

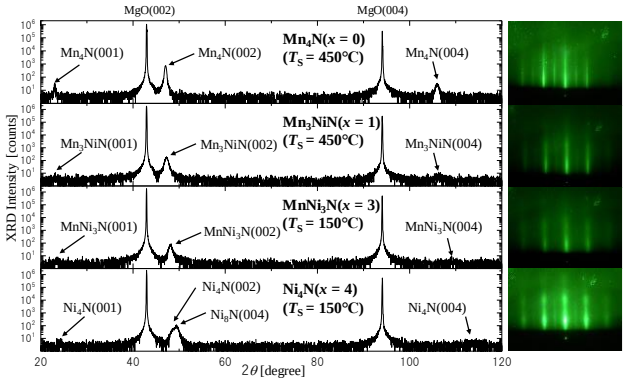

Fig. 1 ω-2θ XRD profiles and RHEED patterns observed along MgO[100] azimuth.

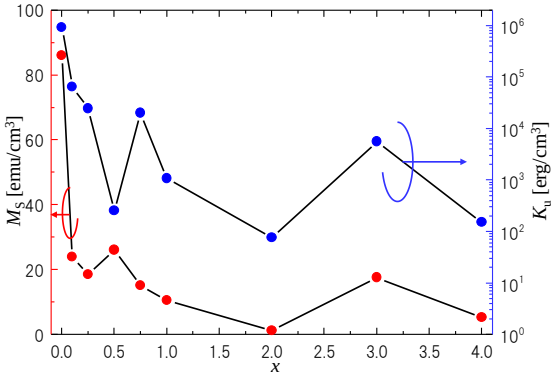

Fig. 2 Composition dependence of M_S and K_u.