

Crystal growth of $L1_0$ -MnAl film on Mn_4N underlayer and effect of crystallinity on magnetic properties

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[Introduction] $L1_0$ -MnAl film has excellent magnetic properties, such as large perpendicular magnetic anisotropy (PMA) of $K_u > 10^7$ erg/cm³ and small damping constant ($\alpha \sim 0.006$),^{1,2)} which are suitable for STT-MRAM with perpendicular magnetic tunneling junctions. Since the $L1_0$ -MnAl alloys are in a metastable phase, the fabrication conditions are crucial to obtain high-quality films. In this regard, it is necessary to choose a suitable underlayer, such as one with a small in-plane lattice mismatch. In this study, we used ferrimagnetic Mn_4N as an underlayer, which is perfect lattice matching with respect to $L1_0$ -MnAl, and investigated crystalline qualities and magnetic properties of MnAl film on Mn_4N underlayer.

[Experiment] All films were prepared by molecular beam epitaxy system equipped with radio-frequency N_2 plasma. The film structure was MgO(001) or SrTiO₃(STO)(001) sub./ Mn_4N (5 nm)/MnAl(15 nm)/Cap. The MnAl films were grown at substrate temperature of 150 °C. The crystalline qualities were characterized by reflection high energy electron diffraction and X-ray diffraction (XRD). The magnetic properties were measured by superconducting quantum interference devices at 300 K.

[Results and discussion] Figure 1 shows XRD patterns of MnAl film on Mn_4N /MgO and Mn_4N /STO. The c -axis oriented XRD peaks from MnAl and Mn_4N layer were confirmed, which indicates the epitaxial growth of MnAl film on Mn_4N underlayer. The peak intensity from MnAl and Mn_4N layer was drastically increased by using STO, and MnAl(002) ω -rocking curve full width half maximum marked very small value of 0.08°. Figure 2 shows hysteresis curves of samples. Distinct PMA was realized in those films. The K_u was estimated to be 5.0 ± 0.7 , and 6.0 ± 0.2 Merg/cm³ for MnAl/ Mn_4N film on MgO and STO, respectively. The larger magnetic anisotropy, better squareness, and smooth magnetization switching were realized for MnAl/ Mn_4N film on STO. These notable magnetic properties were mainly ascribed to the better crystallinity of ferromagnetic layer.

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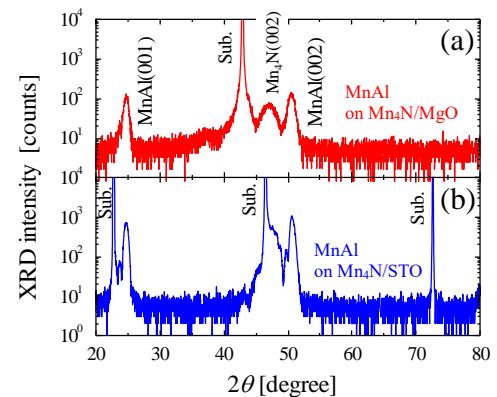


Fig. 1 XRD patterns of MnAl films grown on (a) Mn_4N /MgO(001) and (b) Mn_4N /STO(001).

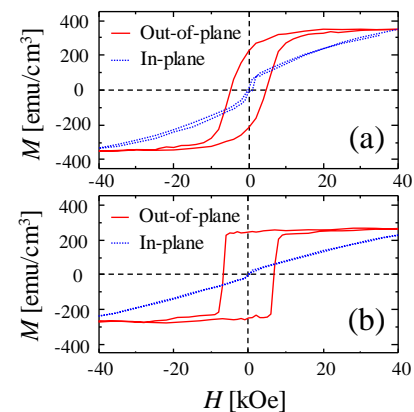


Fig. 2 Hysteresis curves of MnAl/ Mn_4N film grown on (a) MgO(001) and (b) STO(001).