Growth of Fe$_4$N/Cu/Fe$_4$N tri-layer structure for current-perpendicular-to-plane giant magnetoresistance devices

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Anti-perovskite type 3$d$ transition metal ferromagnetic nitrides are promising candidates for a new spintronics material. Fe$_4$N, one of these compounds, is theoretically predicted to have a large negative spin-polarization of electrical conductivity ($P_\sigma = -1.0$) [1]. In addition, a large tunnel magnetoresistance effect is theoretically expected due to coherent tunneling in a Fe$_4$N/MgO/Fe$_4$N magnetic tunnel junction with perpendicular magnetic anisotropy [2], and voltage control of magnetocrystalline anisotropy in Fe$_4$N/MgO is predicted by theoretical calculations [3]. On the other hand, we consider that the large $|P_\sigma|$ and relatively high electrical resistivity of Fe$_4$N are suitable for application to a current-perpendicular-to-plane giant magnetoresistance (CPP-GMR) recording head of a next generation hard disk drive [4]. In this work, we grew Fe$_4$N/Cu/Fe$_4$N tri-layer structure by molecular beam epitaxy toward fabrication of Fe$_4$N-based CPP-GMR devices.

Fe$_4$N(20 nm)/Cu(5 nm)/Fe$_4$N(7 nm)/Au(7 nm) layered structure was grown on a SrTiO$_3$(STO)(001) single crystal substrate. The top and bottom Fe$_4$N layers were grown at 450 °C by supplying Fe and radio-frequency N$_2$ plasma, simultaneously. The Cu spacer and Au capping layers were formed at room temperature. The grown layered sample was characterized by reflection high-energy electron diffraction (RHEED) and out-of-plane ($\omega$-2$\theta$) x-ray diffraction (XRD).

Figure 1 shows the RHEED patterns during the growth of the sample. Streaky patterns are observed in each layer. Figure 2 shows the $\omega$-2$\theta$ XRD pattern of the sample, and the diffraction peaks of Fe$_4$N 001, 002, and Cu 002 are clearly observed. From these results, the epitaxial growth of Fe$_4$N/Cu/Fe$_4$N structure on STO(001) is confirmed. As a next step, we are trying to grow the Fe$_4$N/Cu/Fe$_4$N tri-layer structure on a thick Cu$_3$Au metallic buffer layer, and fabricate CPP-GMR devices, the results of which will be shown in the presentation.


![Fig. 1 RHEED patterns of the sample.](image1)

![Fig. 2 The $\omega$-2$\theta$ XRD pattern of the sample.](image2)