Local structure analysis of MnGa and MnGe thin films by HAADF-STEM observation

Samsung R&D Institute Japan, Shigeki Takahashi

E-mail: stakahashi@samsung.com

High-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) is valuable for observation technology of crystal and interface structures with atomic resolution, and it can be applied for detailed local analysis in conjunction with microscopy-related analytical techniques [1]. These physical analyses were applied for ordered ferromagnetic alloy thin films, MnGa and MnGe, which were studied for STT-MRAM application.

$L1_0$-MnGa sample structures were MgO(001)-substrate / Cr(40 nm) / $Mn_{57}Ga_{43}(t_{MnGa})$ /Ta(5 nm), and $D0_{22}$-Mn_3Ge sample structures were MgO(001)-substrate / Cr(40 nm) / $Mn_{82}Ge_{18}(t_{MnGe})$ / MgO(2.5 nm) / Ta(5 nm), and that were deposited with a ultra-high vacuum sputtering tool. MnGa samples were post-annealed at 500 °C after depositing MnGa at room temperature. Meanwhile, MnGe samples were deposited at substrate temperature at 400 °C since good magnetic properties could not obtained by post-annealing only.

For the epitaxially grown MnGa sample with t_{MnGa} = 30 nm, some misfit dislocations are observed at the Cr/MnGa interface in the HAADF-STEM image. By fast Fourier transform (FFT) analysis of the HAADF-STEM image for the 30 nm-thick MnGa sample, the lattice spacing with perpendicular to the Cr/MnGa interface (a-axis) relaxes to 0.194 nm (bulk lattice spacing: 0.195 nm [2]), and the lattice spacing with parallel to the Cr/MnGa interface (c-axis) shrinks to 0.174 nm (bulk lattice spacing: 0.181 nm [2]). Meanwhile, for the MnGa sample with t_{MnGa} = 5 nm, no misfit dislocation is observed at Cr/MnGa interface within the HAADF-STEM image, and the MnGa film is lattice-matched to the Cr buffer. Then, the a-axis lattice spacing 0.198 nm is close to the bulk lattice spacing of Cr 0.204 nm. Since the MnGa film with t_{MnGa} = 5 nm is lattice-matched to the Cr buffer, the MnGa film suffers tensile strain to the a-axis. Thus, the thin MnGa film receives strong compressive strain to the c-axis, which is shown by the FFT image with the MnGa lattice spacing 0.159 nm, which is much lower than the bulk lattice spacing 0.181 nm. On the other hand, the MnGe samples show lattice relaxation in both t_{MnGe} = 50 nm and 5 nm, with a lot of misfit dislocations at the Cr/MnGe interfaces. The correlation between the HAADF-STEM analyses and the magnetic properties of the MnGa and MnGe samples will also be discussed at the presentation.

References

[1] Y. L. Tang *et al.*, *Ultramicroscopy* **160** (2016) 57.

[2] H. Niida *et al.*, *J. Appl. Phys.* **79** (1996) 5946.