Fabrication of $L1_0$-$Mn_{1-x}Co_xAl$ Thin Films for Magnetic Tunnel Junctions

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Magnetic tunnel junctions (MTJs) show a tunnel magneto-resistance effect (TMR) and are applied widely for spintronic devices such as magnetic random access memory (MRAM), HDD read heads and magnetic sensors etc. MRAM using spin transfer torque effect (STT-MRAM) attracts much attention because it can decrease power consumption in comparison with conventional MRAM. Magnetic materials using the ferromagnetic layer in STT-MRAM are required a high magneto-crystalline anisotropy (K_u), a low gilbert damping constant (α) and a low saturation magnetization (M_s). We focus $L1_0$-MnAl alloy with a high K_u (1.5×10^7 erg/cc), a low α (0.006) and a small M_s (550 emu/cc) [1]. According to previous reports, (Mn-Co)-Al alloys with a few % Co atoms were easily crystalized to $L1_0$ structure in comparison with Mn-Al binary alloys [2]. In this study, we have investigated the structural and magnetic properties in $Mn_{1-x}Co_xAl$ thin films with various Co content (x) to apply them to ferromagnetic electrodes of MTJs.

All thin films were prepared by UHV-DC/RF magnetron sputtering system. The film structure was MgO (100) sub. / CrRu (40 nm) / $Mn_{1-x}Co_xAl$ (t nm) / Ta (5 nm). $Mn_{1-x}Co_xAl$ layer thickness was varied from 5 to 50 nm. Substrate temperature (T_s) during deposition and post annealing temperature (T_a) after deposition of $Mn_{1-x}Co_xAl$ layer were varied as T_s = 200 ~ 400°C and T_a = 300 ~ 500°C to investigate the temperature dependences of structural and magnetic properties. We measured structural and magnetic properties by XRD and SQUID.

From the XRD measurements, we found that $Mn_{1-x}Co_xAl$ films (50 nm) with x = 0.05 annealed below T_a = 350°C had $L1_0$-ordered structure. On the other hand, the films annealed above T_a = 400°C showed a disordered crystal structure. Fig. 1 shows the post annealing temperature dependences of saturation magnetization (M_s) and M_r/M_s ratio in $Mn_{1-x}Co_xAl$ (50 nm) thin films with x = 0.05. Both high M_s and M_r/M_s ratio were observed at T_a = 350°C and both M_s and M_r/M_s ratio decreased with increasing T_a due to the disordering of $L1_0$ structure. We will also present substrate temperature and Co content dependences of structural and magnetic properties in $Mn_{1-x}Co_xAl$ thin films.

This work was supported by Research and Development Project for ICT key technology to realize future societies by MEXT and grand-in-aid for scientific research S (No.24226001).

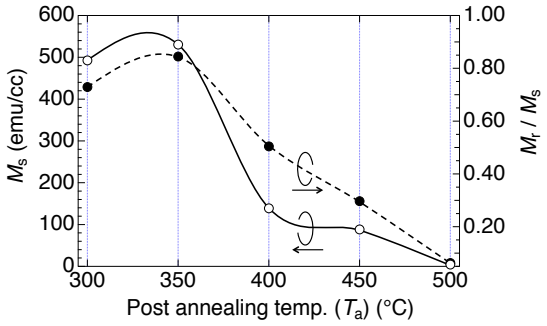

Fig. 1 M_s and M_r / M_s ratio as function of post annealing temperature (T_a) for $Mn_{1-x}Co_xAl$ thin films.

Reference: [1] M. Hosoda, M. Oogane, M. Kubota et al., J. Appl. Phys., 111, 07A324 (2012)

[2] Y. Kurimoto, Tohoku Univ. Master Thesis (2015)