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Interfacial Exchange Coupling of Mn_3Ga/Co_2FeZ (Z=Al, Si) Heusler Bilayers

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Anti-ferromagnetic (AFM) exchange coupling is one of the important keys for fabrication of synthetic ferrimagnet film with perpendicular magnetic anisotropy (PMA). These synthetic ferrimagnet layers are practically important for memory applications based on magnetic tunnel junctions (MTJs). We reported recently strong interfacial anti-ferromagnetic coupling in Mn-Ga/Co bilayers with a large PMA [1, 2]. Here, we used Heusler alloys such as Co_2FeAl (CFA) and Co_2FeSi (CFS) to clarify origin of exchange coupling in Mn_3Ga/CFA and Mn_3Ga/CFS bilayers.

Two series of bilayers with the stacking structure of (100) MgO substrate / Cr(10) / $D0_{22}$-$Mn_{70}Ga_{30}$ (30) / CFA or CFS (20) / Cr(5) (thickness is in nanometers) were prepared. For epitaxy of these films, we used an ultrahigh vacuum magnetron sputtering system with base pressure of less than 1×10^{-7} Pa. All the layers were deposited at room temperature. The in-situ annealing was employed at 400°C after the MnGa deposition. Annealing temperature dependence has been investigated using ex-situ annealing at 200, 250, 300, 350, 400, and 450°C. For characterization of structural and magnetic properties, the X-ray diffractometer (XRD), polar magneto optical Kerr effect (MOKE), and a vibrating sample magnetometer (VSM) were used.

Fig. 1(a) shows typical MOKE curve and the magnetization configurations for the MnGa/CFA bilayer annealed at 450°C. The certain points were marked with 1, 2, 3, 4, 5 and 6 numbers for magneto-optical hysteresis loop which shows the steps corresponding to magnetization reversal. We also marked two magnetic field with H_{s1} and H_{s2} corresponding to saturation field in the parallel state ($H^{\uparrow\uparrow}$) and anti-parallel state ($H^{\uparrow\downarrow}$), respectively. If ferromagnetic (FM) and AFM exchange coupling exist, these fields are different. H_{s1} is larger than H_{s2} in the case of FM exchange coupling, whereas in the case of AFM exchange coupling H_{s1} is smaller than H_{s2}. Fig. 1(b) shows annealing temperature dependence of exchange coupling constant. For estimation of exchange coupling constant the following formula was used.

$$H_{s1(2)} = 4\pi M_{eff}^{CFA(S)} \mp \frac{J_{ex}}{M_s^{CFA(S)} d_{CFA(S)}}$$

By using the saturation magnetization $M_s^{CFA(S)}$ that was estimated from in-plane curve of VSM, we estimated the J_{ex} for different annealing temperature. Interfacial exchange coupling is FM and AFM, depending on annealing temperature, in the MnGa/CFA bilayer, whereas only AFM exchange coupling was observed in the MnGa/CFS bilayers.

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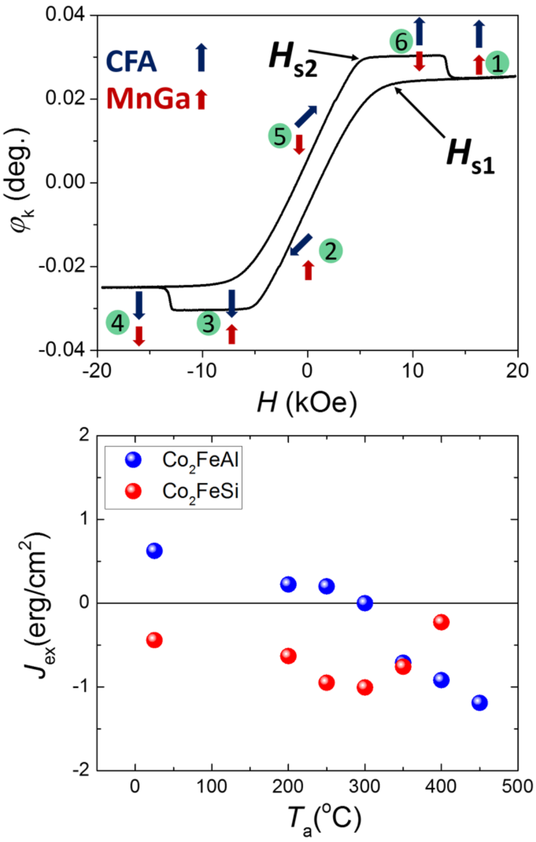

Fig. 1(a) Polar MOKE curve and magnetization configurations for the Mn_3Ga/Co_2FeAl bilayer annealed at 450°C (b) annealing temperature dependence of interfacial exchange coupling constant for the bilayers of Mn_3Ga/Co_2FeAl and Mn_3Ga/Co_2FeSi.

References

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