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$L1_0$-MnGa/Co Bilayer Films with Anti-ferromagnetic Exchange Coupling

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The MnGa films and their alloys have attracted considerable attention in theoretical and applied physics. These films can be used in many applications such as Gbit-class spin-transfer torque magnetic random access memory (STT-MRAM) and magnetic tunnel junctions (MTJs) due to high perpendicular magnetic anisotropy (PMA), high spin polarization, low saturation magnetization, and small Gilbert damping constant [1]. One of the problems related to the MnGa film was small tunnel magnetoresistance (TMR) ratio of MTJs with MnGa electrode. TMR ratio increases with insertion of an ultra-thin 3d ferromagnetic metal/alloy interlayer between the perpendicular magnetized ferromagnetic electrodes and barrier layer in perpendicular magnetic tunnel junctions (p-MTJs) as reported in previous studies [2, 3]. Ma *et al*. indicated presence of the antiferromagnetic (AF) exchange interaction between the MnGa/Co bilayers in which TMR ratio were increased 40% at room temperature. Therefore, to investigation of AF exchange interaction, the Co layer was inserted between the MnGa as the PMA electrode and barrier layer in this work.

Two films with the same stacking structure of MgO(100)/ Cr(40)/ $L1_0$-$Mn_{57}Ga_{43}$(30)/ Co(20)/ Mg(0.4)/ MgO(2)/ Al(2) (thickness is in nanometers) without and with annealing at 350°C after Co deposition were prepared. For epitaxy of these films, we used an ultrahigh vacuum magnetron sputtering system with base pressure $< 1\times10^{-7}$ Pa. All the layers were deposited at room temperature. The Cr and MnGa layers were annealed at 700 and 500°C, respectively after deposition. In addition, we fabricated a MnGa film without Co layer based on above stacking structure and also a single Co layer buffered and capped by Ta layer on MgO substrate as reference samples. For characterization of structural and magnetic properties, the X-ray diffractometer (XRD), polar magneto optical Kerr effect (MOKE), a vibrating sample magnetometer (VSM), superconducting quantum interference device (SQUID) were used. In addition, theoretical calculation based on one dimensional Landau-Lifshitz-Gilbert equation was carried.

Fig. 1 shows the polar magneto-optical Kerr effect curves. Sample without annealing (Fig. 1(a)) shows the Kerr rotation angle hysteresis curve is summation of hysteresis curves of the MnGa with PMA and Co with in-plane magnetic anisotropy (IMA). Sample annealed at 350°C (Fig. 1(b)) shows the hysteresis curve similar to pure Co that shown in Fig. 1(c), whereas annealed sample did not saturate even at 20 kOe. In addition, the inverted hysteresis loop (Fig. 1(d)) was observed in annealed sample. These kind of inverted loops have been reported in antiferromagnetically coupled bilayer [5]. We also confirmed these kinds of behaviors with theoretical calculation.

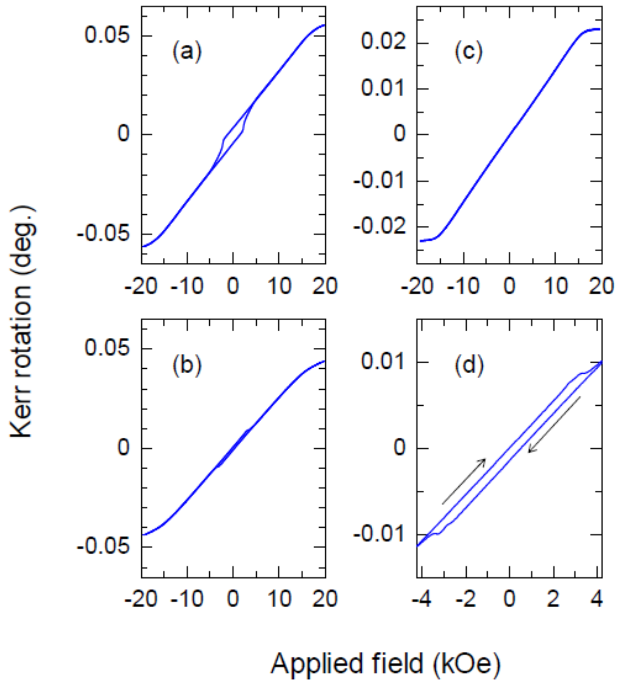

Fig. 1 Polar magneto-optical Kerr effect curves for (a) unannealed bilayer, (b) annealed bilayer, and (c) the Co reference film. (d) Expanded figure for (b) around zero field.

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