Converse magnetoelectric effect in bcc Co_3Mn/PMN-PT(001) multiferroic heterostructures

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As a highly efficient method for controlling magnetization vectors by applying an electric field (E), ferromagnetic (FM)/ferroelectric (FE) multiferroic heterostructures are promising [1]. To apply this structure to spintronic devices such as MRAM, it is essential to use FM materials that exhibit a high TMR ratio as FM electrodes in magnetic tunneling junctions (MTJs). Recently, metastable body-centered-cubic (bcc) Co_3Mn alloys have been focused on as the electrodes in MTJs [2]. However, there is no study of the Co_3Mn-based multiferroic heterostructures. In addition, since a bulk Co_3Mn alloy, in general, has thermodynamically stable face-centered-cubic (fcc) and/or hexagonal-close-packed (hcp) phases [3], exploring of the detailed growth condition of Co_3Mn on a FE material is also required. In this study, we demonstrate bcc Co_3Mn-based multiferroic heterostructure and giant converse magnetoelectric (CME) effect at room temperature.

A 30-nm-thick Co_3Mn film was grown on a FE $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$(001) [PMN-PT(001)] substrate by molecular beam epitaxy. Here, PMN-PT was chosen due to its large piezoelectric effect, and the mismatch between the lattice constant of the bcc Co_3Mn and the diagonal length of the lattice constant of the PMN-PT is less than 1%. Prior to the growth of Co_3Mn layer, a 2-nm-thick Fe layer was terminated on the PMN-PT(001) surface. Subsequently, the Co_3Mn layer was grown at 200°C. Figure 1(a) shows the X-ray diffraction (XRD) profile of the Co_3Mn/Fe/PMN-PT(001) heterostructure. A diffraction peak from the bcc Co_3Mn(002) is observed at 2θ of ~ 66 degrees, indicating the presence of (001)-oriented and metastable bcc Co_3Mn on PMN-PT(001). To investigate the CME effect, we measured an in-plane magneto-optical Kerr effect at room temperature with applying an E. Figure 1(b) shows representative magneto-optical Kerr loops for the bcc Co_3Mn/Fe/PMN-PT(001). When the E value is varied, the Kerr hysteresis loops are largely modulated. The CME coupling coefficient is estimated to be 8×10^{-6} s/m, which is comparable to that for $L2_1$-ordered Co_2FeSi/PMN-PT(001) (6.0 – 6.3×10^{-6} s/m) in our previous work [4]. This study will open a path for achieving the large CME effect for bcc Co_3Mn alloys that show a high TMR ratio.

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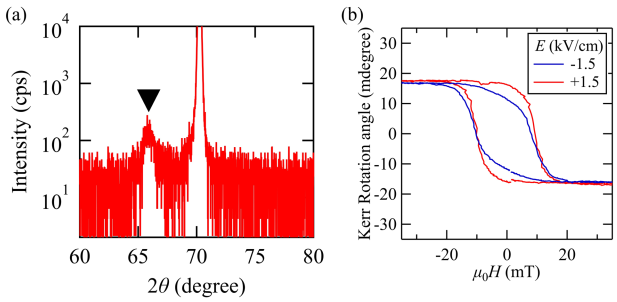

Fig. 1 (a) XRD profile of the Co_3Mn/Fe/PMN-PT(001) heterostructure. The triangle shows the diffraction peak of the bcc Co_3Mn(002). (b) Magneto-optical Kerr loops for the bcc Co_3Mn/PMN-PT(001) heterostructure at E = ±1.5 kV/cm at room temperature. The external magnetic field is applied along the PMN-PT[100] direction.