Converse magnetoelectric effect in perpendicularly magnetized $[Co/Pd]_5/Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$(011) multiferroic heterostructures

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Magnetism of ferromagnetic/ferroelectric interfacial multiferroic heterostructures can be controlled by applying an electric field (E) [1]. Electric-field control of perpendicular magnetic anisotropy (PMA) is essential for the high-density nonvolatile magnetic memory with low energy consumption. In this study, we demonstrate electric-field modulation of PMA in $[Co/Pd]_5/Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) multiferroic heterostructures.

Pd(8 nm)/[Pd(2 nm)/Co(t_{Co} nm)]$_5$/Pd(3 nm) multilayers were grown on PMN-PT(011) substrates at room temperature by molecular beam epitaxy, where the thickness of the Co layer (t_{Co}) was varied from 0.5 to 1.5 nm. From polar Kerr measurements, the t_{Co} dependence of the PMA was evaluated. The magnetic easy axis changes from perpendicular to in-plane direction as t_{Co} increases (Fig. 1), which is consistent with the previous report on $[Co/Pd]_n$ on MgO [2].

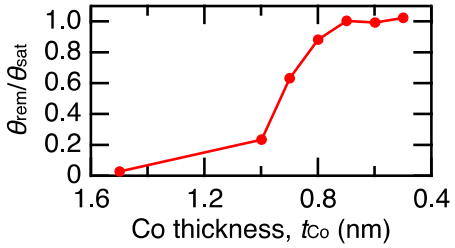

Fig. 1 Co-layer-thickness dependence of the remanent magnetization in various [Co/Pd]/PMN-PT heterostructures.

To investigate a converse magnetoelectric effect (CME), anomalous Hall effect (AHE) for samples with t_{Co} = 0.7, 0.8 and 0.9 nm was measured in the Van der Pauw method with applying E. Figure 2 shows normalized AHE curves for t_{Co} = 0.7 (a), 0.8 (b) and 0.9 (c) nm with E of 0 and -8 kV/cm or 2 and -8 kV/cm. For all the samples, the CME effect is observed clearly. We attributed the modulation of the PMA to transferring of the piezoelectric strain from the PMN-PT(011) substrate. We will discuss the value of the CME coupling coefficient for these [Co/Pd]/PMN-PT multiferroic heterostructures.

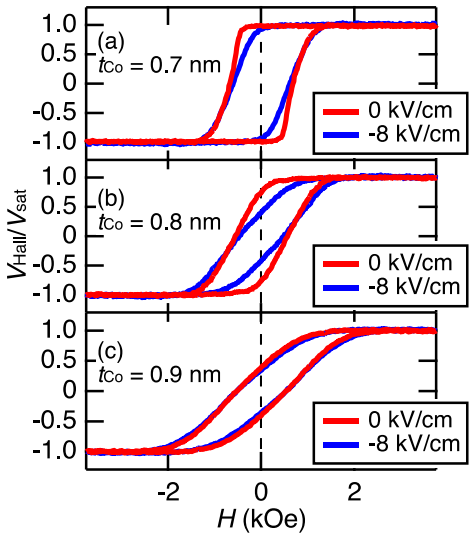

Fig. 2 AHE curves for [Co/Pd]/PMN-PT heterostructures with t_{Co} = 0.7 (a), 0.8 (b) and 0.9 (c) nm with E of 0 and -8 kV/cm.

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