Crystal orientation dependence of converse magnetoelectric effect in $Co_2FeSi/Fe/Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ multiferroic heterostructures

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Magnetism of ferromagnetic (FM)/ferroelectric (FE) interfacial multiferroic heterostructures can be controlled by applying an electric field (*E*) because of the converse magnetoelectric (ME) coupling mediated by piezostrains from FE to FM layers [1]. Recently, we found that one of the Co-based Heusler alloys, Co_2FeSi (CFS), grown on (001)-oriented $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) shows a giant ME coupling coefficient (α) of 6.0 - 6.3 $\times$ 10^{-6} s/m at room temperature [2]. Here, we explore the crystal-orientation dependence of the converse ME effect in CFS/PMN-PT multiferroic systems.

30-nm-thick CFS films were grown at 350 ºC on PMN-PT substrates with various crystal orientations of (001), (110), and (111) by molecular beam epitaxy. X-ray diffraction measurements revealed that (001)-, (211)-, and (220)-oriented CFS films were formed on PMN-PT(001), PMN-PT(011), and PMN-PT(111), respectively. From in-plane XRD measurements, diffraction peaks of {111} plane are observed in the CFS films on PMN-PT(001) and PMN-PT(011), indicating the formation of an $L2_1$-ordered structure in the films.

To investigate the converse ME effect, we measure an in-plane magneto-optical Kerr effect at room temperature with applying *E*. Figure 1 shows normalized Kerr loops with applying *E* for the heterostructures. Kerr hysteresis loops of CFS/PMN-PT(001) and CFS/PMN-PT(011) are modulated by varying *E*, while that of CFS/PMN-PT(111) is almost insensitive to the variation in *E*. Notably, for CFS/PMN-PT(011), we observe relatively large change in the hysteresis loops compared to CFS/PMN-PT(001). We attribute the crystal-orientation dependence to the unique FE polarization switching depending on the crystal-orientation of PMN-PT, as shown in the inset of Fig. 1.

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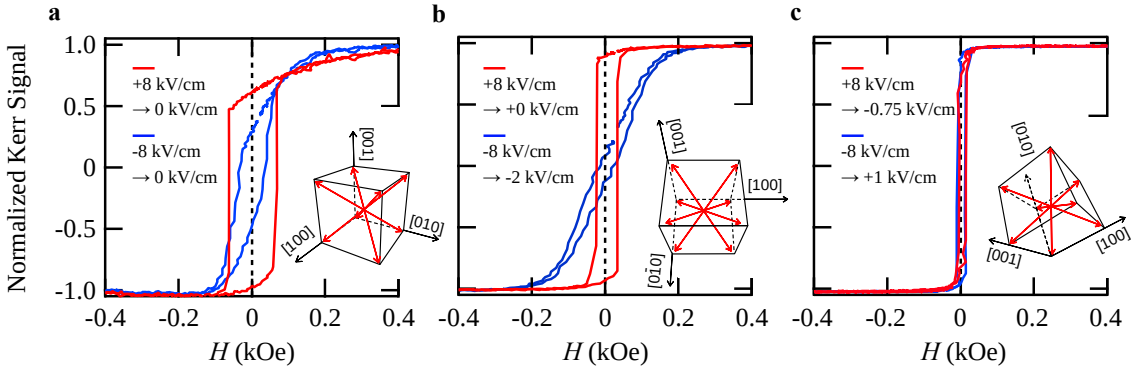

Fig. 1. Normalized magneto-optical Kerr loops for (a) CFS/PMN-PT(001), (b) CFS/PMN-PT(011), and (c) and CFS/PMN-PT(111) at room temperature at different *E* fields. Insets show schematic of the polarization vectors for each PMN-PT crystal orientation.