Magnetic field dependence of threshold electric field for switching exchange bias polarity

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Electric field control of magnetization in magnetoelectric (ME) insulators plays an important role in spintronic applications owing to various advantages such as the high processing speed and the low power consumption. Antiferromagnetic (AFM) α-Cr_2O_3 is a typical ME material which showed a fascinating exchange bias as coupled with a ferromagnetic layer [1, 2]. The isothermal ME switching of the perpendicular exchange bias in an all-thin-film system was reversibly achieved with the change in polarity of exchange bias from negative-to-positive (N-to-P) and positive-to-negative (P-to-N) by tuning the applied electric field while maintaining the magnetic field [1]. At a temperature, the threshold electric field (E_{th}) at which the polarity of exchange bias is reversed depends on the applied magnetic field [1]. However the study on magnetic field dependence of E_{th} for switching exchange bias polarity, which is indispensable for future spintronic devices, is still insufficient.

In this study, we investigated the isothermal ME switching of perpendicular exchange bias in Cr_2O_3. Pt/Co/spacer/Cr_2O_3/Pt stacked films were prepared on an α-Al_2O_3 substrate using DC magnetron sputtering system. The isothermal switching of exchange bias was investigated by the anomalous Hall effect (AHE) measurement using a Hall-bar device with a 2-μm-width and a 40-μm-length. At 275 K, the exchange bias field was reversibly switched by reversing the electric field under a fixed magnetic field. Fig. 1 shows the hysteretic electric field dependence of the exchange bias field (left) and remanence ratio (right) under -60 kOe at 275 K. The rectangular hysteresis is in agreement with the isothermal switching of AFM domain state in Cr_2O_3. Fig. 2 shows the magnetic field dependence of E_{th} for switching exchange bias polarity, in which E_{th} was evaluated from the cross point of remanence ratio curve with the horizontal axis for both N-to-P and P-to-N processes. The switching condition, simply expressed by EH_{th} = constant, followed the coherent model [1, 2] in which the ME effect leads to the energy gain for switching exchange bias polarity. The asymmetry of EH_{th} between N-to-P and P-to-N was attributed to the uniaxial nature of magnetic anisotropy of AFM layer and the unidirectional nature of exchange coupling of the FM layer. The detail of the dependence of E_{th} on magnetic field (magnetic field and direction) will be discussed in the presentation.

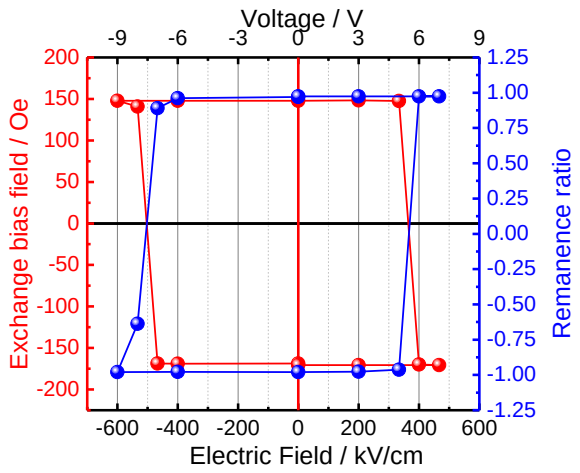

Fig. 1: Hysteretic electric field dependence of the exchange bias field (left) and remanence ratio (right) under -60 kOe at 275 K.

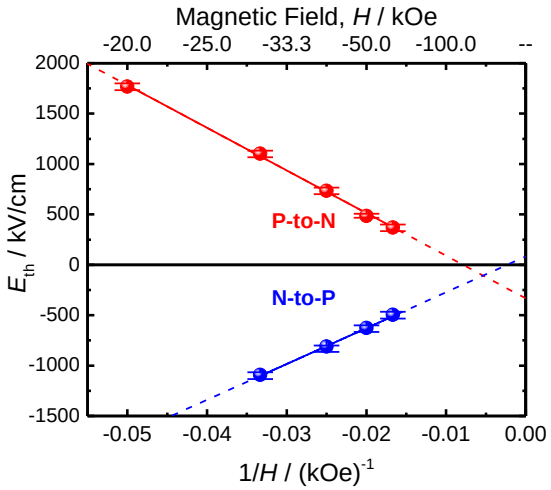

Fig. 2: Magnetic field dependence of threshold electric field E_{th} for switching exchange bias polarity measured at 275 K.

References

1) X. He et al., Nature Mat. **9**, 579, (2010).
2) K. Toyoki et al., Appl. Phys. Lett. **106**, 162402, (2015).