垂直磁化した Co/CoO_x 系における交換バイアスの電界効果

Electric Field Effect on Exchange Bias in Perpendicularly-Magnetized Co/CoO_x System

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Electric field (EF) control of exchange bias (EB) has been proposed for a fast and ultralow magnetization manipulation method in spin-valve type of spintronic devices. Previous reports show the modulation of EB by EF application using ferromagnet (FM)/multiferroic antiferromagnet (AFM) heterostructure. In this multiferroic system, AFM spin is directly manipulated by EF due to magnetoelectric (ME) coupling between ferroelectricity and antiferromagnetism, resulting in the modulation EB [1]. In this work, we investigate the EF effect on EB in solid state capacitor structure with Co/CoO_x structure, where the CoO_x is insulator and non-multiferroic AFM below its Néel temperature.

Ta(3.3 nm)/Pt(3.0 nm)/Co(1.0 nm) bottom electrode was deposited on a thermally oxidized Si substrate by rf-sputtering. The sample was exposed to the air for 10 min to oxidize the surface of Co. As a gate insulator, a 45-nm-thick HfO_2 was deposited at 150°C by an atomic layer deposition method. Finally, Cr/Au counter gate electrode were formed by lift-off process. Anomalous Hall measurement by sweeping out-of-plane magnetic field was conducted for evaluating magnetic properties. At 300 K, clear perpendicular easy axis was observed. After the field cooling was performed, the increase in coercivity (H_c) and hysteresis loop shift can be observed, indicating that the EB effect is induced by the interfacial exchange coupling between Co and CoO_x spins. The blocking temperature is about 200 K, which is lower than Néel temperature of bulk CoO. Figure 1 shows H_c and the magnitude of EB (H_{EB}) at 50 K as a function of gate voltage (V_G). Both of them are monotonically and reversibly changed by gating. There is no ME effect in the CoO_x and the sign of H_{EB} modulation cannot be explained by voltage-driven redox reaction. Thus, it can be concluded the modification of the interfacial electronic state at Co/CoO_x interface is the possible mechanism of H_{EB} modulation.

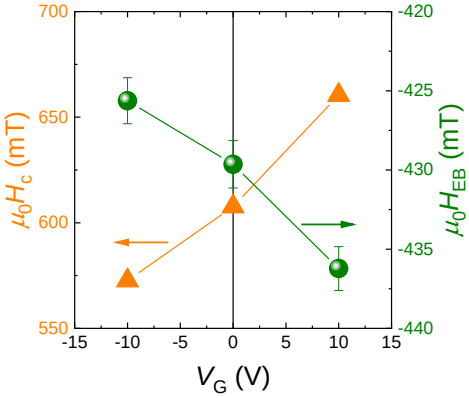

Figure 1. H_c and H_{EB} as a function of V_G.

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[1] Y. Chu *et al.*, *Nat. Mater.* **7**, 478 (2008). [2] D. Gilbert *et al.*, *Nat. Commun.* **7**, 11050 (2016).