Electric Field Effect on Exchange Bias in Perpendicularly-Magnetized Co/CoOx 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/CoOx structure, where the CoOx 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 HfO2 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 (Hc) and hysteresis loop shift can be observed, indicating that the EB effect is induced by the interfacial exchange coupling between Co and CoOx spins. The blocking temperature is about 200 K, which is lower than Néel temperature of bulk CoO. Figure 1 shows Hc and the magnitude of EB (HEB) at 50 K as a function of gate voltage (VG). Both of them are monotonically and reversibly changed by gating. There is no ME effect in the CoOx and the sign of HEB modulation cannot be explained by voltage-driven redox reaction. Thus, it can be concluded the modification of the interfacial electronic state at Co/CoOx interface is the possible mechanism of HEB modulation.

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