MAR14-2013-020027

Abstract for an Invited Paper
for the MAR14 Meeting of
the American Physical Society

Full Electric Field Control of Exchange Bias

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Exchange bias is the shift of a magnetic hysteresis curve due to interfacial magnetic coupling between a ferromagnet (FM) and an antiferromagnet (AFM). This ubiquitous effect has long been used in the electronics industry to bias the magnetization of FM layers in magnetic devices. Its continued understanding is of critical importance to advance the development of future high-density magnetic storage media and other novel magnetic devices. However, due to the technological limitations of manipulating and observing an atomically thin interface, exchange bias is not well understood. In this talk we present a multiferroic field effect device with $BiFeO_3$ (BFO) (antiferromagnetic-ferroelectric) as the gate dielectric and $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) (ferromagnetic) as the conducting channel, which exhibits the direct, bipolar electric control of exchange bias. Here the magnetic states at the AFM/FM interface can be directly manipulated with electric fields and the results can be observed as a change in exchange bias polarity and magnitude. Control of exchange bias at this level has significant implications because it represents a form of electric field control of magnetism and may potentially offer a route toward the eventual full electric field control of magnetization. In this device, exchange bias is reversibly switched between two stable states with opposite exchange bias polarities upon ferroelectric poling of the BFO. No field cooling, temperature cycling, or additional applied magnetic or electric field beyond BFO poling is needed for this bipolar modulation effect. Detailed temperature dependent measurements and a model will be presented which will attribute this effect to the coupled antiferromagnetic-ferroelectric order in BFO along with the modulation of interfacial exchange interactions due to ionic displacement of Fe^{3+} in BFO relative to $Mn^{3+/4+}$ in LSMO.