Voltage induced multilevel nonvolatile switching of perpendicular magnetization in an interfacial multiferroic heterostructure

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The use of converse magnetoelectric (ME) effect, i.e., voltage control of magnetization is one of the solutions towards reduction of power consumption in spintronic devices [1]. Interfacial multiferroics (iMF) comprising a ferromagnet (FM) and a ferroelectric (FE) material are proved to be promising candidates rather than single phase multiferroics [2, 3]. A quantitative understanding is still required to offer a clear description of the mechanisms of the iMF coupling in a wide range of FM/FE heterostructures. In this work, we investigate the voltage induced ME response at the interface of Cu/Ni multilayer and (001) oriented $[Pb(Mg_{1/2}Nb_{2/3})O_3]_{0.7}$-$[PbTiO3]_{0.3}$ (PMN-PT) substrate.

Ultra-high vacuum molecular beam epitaxy (MBE) has been used to fabricate a multilayer structure as PMN-PT (001) (sub.)/Fe(1)/Cu(9)/$[Ni(2)/Cu(9)]_8$/Au(5). X-ray diffraction measurement confirmed the epitaxial growth of the multilayers. Room temperature magnetic hysteresis measurements in the in-plane and out-of-plane magnetic fields by a vibrating sample magnetometer (VSM) reveals the interfacial perpendicular magnetic anisotropy (iPMA) due to tensile strain in the Ni layers sandwiched between the Cu layers. One of the main challenges in realizing mutiferroic based magnetoelectric memories is to switch perpendicular magnetic anisotropy with a control voltage. Electric field dependent Kerr signal was measured by magneto-optical Kerr effect (MOKE), where voltage was applied across the thickness of the heterostructure. The result exhibits mostly a hysteresis like curve, which is known as a non-volatile behavior. The magnetization can be switched from the out-of-plane direction to the in-plane direction with the application of ≈ ± 60 V, corresponding to an electric field of ≈1.2 kV/cm. Voltage induced lattice strain in the PMN-PT substrate plays an important role in the switching process of the perpendicular magnetization of the Ni layers, giving rise to the ME effect in the heterostructure. Figure 1 shows the multilevel switching in a Cu/Ni multilayer system, which is demonstrated by measuring the minor loops of cyclic electric fields. When an electric field comes back to zero from various negative electric fields, distinct magnetization states are observed. These results based on multilevel nonvolatile switching of magnetization in the Ni/Cu heterostructure will enrich the fundamental and applied research in the area of multiferroics based magnetoelectric memories.

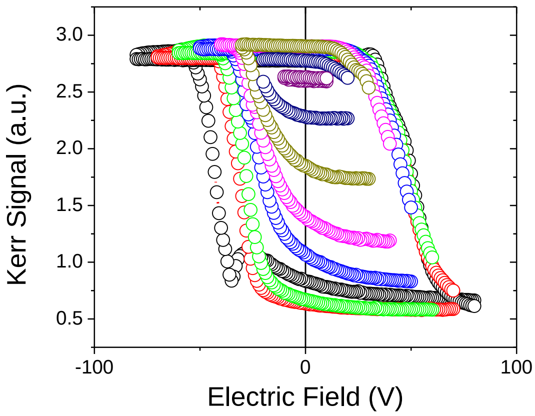

Fig. 1. Electric field dependent Kerr signal demonstrating the multilevel switching of magnetization.

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