Voltage-controlled, strain-mediated magnetic domains in a multiferroic heterostructure having interfacial perpendicular magnetic anisotropy

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Significant research activities on voltage control of magnetism are progressing because of its profound physics and enormous potential for application. Recently demonstrated memory and logic devices use an interfacial multiferroic (iMF) heterostructure in order to achieve ultra-low power dissipation in the device [1,2]. To achieve high magnetoelectric coefficient (α) for higher efficiency of the device, artificial iMF heterostructures are favorable rather than single phase multiferroics. There are several ways to demonstrate iMF materials i.e. mediated by strain, exchange bias, charge, and redox etc. Strain mediated iMF comprising a ferromagnet (FM) and a ferroelectric (FE) material are proved to be promising candidates. In this work, we demonstrate the effect of voltage induced polarization switching of a FE PMN-PT substrate on the magnetic domain switching of coupled perpendicularly magnetized Ni/Cu multilayers.
We fabricated a multilayer heterostructure of PMN-PT (001) (sub.)/Fe(1)/Cu(9)/$[Ni(2)/Cu(9)]_8$/Au(5) by using ultra-high vacuum molecular beam epitaxy (MBE). 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 magnetic domain structure was captured by magneto-optical Kerr effect (MOKE), where voltage was applied across the thickness of the heterostructure. Fig. 1 (a) and (b) demonstrates the Kerr microscopy results measured at 0 V and +50V respectively with a magnetic field of -45 Oe. A clear change of contrast was demonstrated attributing the voltage induced domain switching. A gradual evolution of magnetic domains was realized by varying the applied voltage. This result was supported by voltage dependent Kerr spectroscopic signal, which exhibits mostly a hysteresis like curve due to non-volatile switching of PMN-PT polarization (109^{o} switching). In general, when FE domains of PMN-PT undergo 109^{o} switching, it leads to a change in the elongated diagonal direction from the [110] axis to the [-110] axis due to the rhombic distortion. Strain mediated magnetization switching occurs with the application of electric field ≈ ± 60 V (≈1.2 kV/cm). Moreover, gradual increase in the initial value of Kerr signal was also detected while measuring minor loops of different cyclic electric fields (Fig.2). Distinct voltage induced lattice strain in the PMN-PT substrate should play an important role in the switching process of the perpendicular magnetization of the Ni layers, giving rise to the ME effect in the heterostructure.
This work was supported in part by by JST CREST Grant No. JPMJCR18J1, JSPS Bilateral Joint Research Projects Grant No. JPJSBP120197716, and the Asahi Glass Foundation.

Reference

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2) J.-M Hu *et al.* Nat. Commun. **2**, 553 (2011)

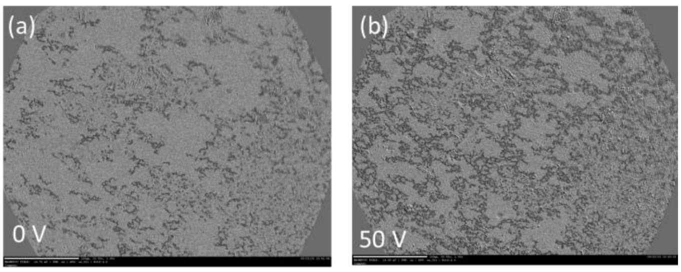

Fig. 1 Voltage dependent magnetic domain structure in FE/FM heterostructure with application of a gate voltage of (a) 0 V and (b) 50 V

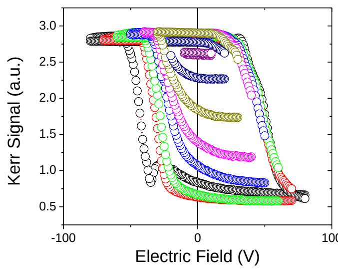

Fig. 2. Electric field dependent Kerr signal demonstrating the multilevel switching of magnetization.