Electric field control of magnetization in FeGa microstructures on PMN-PT

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In current generation memory devices, the significant usage of electric currents to control large number of magnetic bits inevitably results in large power consumption and also power losses due to Joule heating. In this regard, a new paradigm has been formed where the possibility of manipulating the magnetization using electric fields (rather than electric currents) are currently being explored. In this report, the magnetoelectric effect in soft FeGa microstructures fabricated on PMN-PT(011) (multiferroic heterostructures) is studied in the presence of electric fields via the strain-mediated effects.

Keywords: Magnetoelectric effect; Strain; Magnetic domains; Magneto-Optic Kerr effect

1. Introduction

The recent era of information technology and devices largely focusses on energy saving and cost efficiency. Manipulation of magnetic state of a micro element solely with the use of electric fields has attracted new attention in recent years due to its potential ability to be used in low-power magneto-electronics [1,2]. In the context, artificial magnetoelectric (ME) materials are suitable candidates to be used in these technologies due to its coupling between magnetization and electric-field induced strain, which therefore consumes less power and significantly reduces heat losses [3]. The application of voltage across the piezoelectric layer generates strain at the interface and this strain transfer to a soft magnetic layer from the piezoelectric layer induces change in magnetic anisotropy and domain structures [4].

2. Results and discussion

In the framework of artificial multiferroic heterostructures and their interfacial magnetoelectric interplay, we have investigated the properties of FeGa microstructures fabricated on PMN-PT (Fig. 1(a)) using E-beam lithography. Prior to the fabrication process, the top and bottom surfaces of the PMN-PT substrate were coated with Au and Ag layers for application of electric field across the substrate. The in-plane strains (ε_x, ε_y) generated in the PMN-PT substrate were measured using a strain gauge (Fig. 1(b)). Due to the [011] crystal orientation, the in-plane strains are anisotropic resulting in significant difference in remnant strain values marked by the blue (−0 kV/cm) and red (+0 kV/cm) dots. The magnetic hysteresis of elliptical disks (long axis of 5 µm) were recorded at the remanent polarized states using Magneto-Optic Kerr effect (MOKE) as represented by the −0 and +0 kV/cm curves in fig. 1(c). A difference in the shape of the hysteresis is observed which marks the rotation of magnetic anisotropy of the system. A vortex domain state is observed in reversal at −0 kV/cm whereas a S-shaped multidomain is recorded at +0 kV/cm. This influence in domain patterns marks the presence of strain-induced anisotropy in the system.

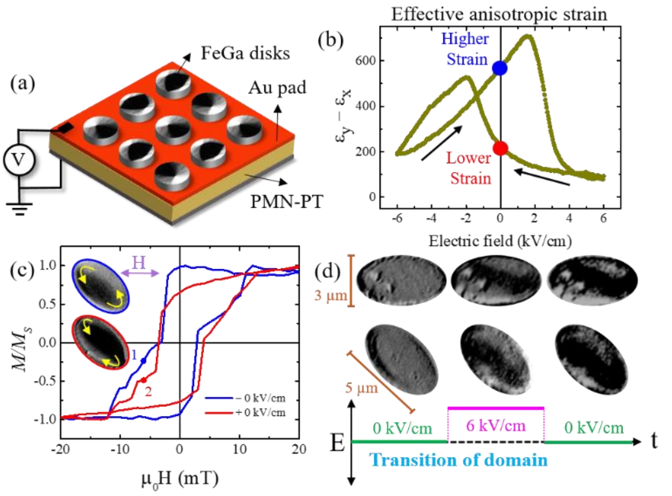

Figure 1: (a) Schematic of FeGa/PMN-PT heterostructure for voltage application. (b) Effective strain measured in PMN-PT. (c) Magnetic hysteresis and domains structures recorded at remanent strain states. (d) Magnetic state change under electric field pulse.

Further, an electric field pulse of +6 kV/cm was applied to the magnetic remanence state. A single domain state is observed before application of electric field (Fig. 1(d)). Under electric field application of +6 kV/cm, the magnetic state changes to a S-shaped multidomain state which remains stable even after the field is removed. This marks the manipulation of magnetic state with the sole use of electric field, thanks to the high magnetostriction and magnetic softness of FeGa.

References

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