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Research articles

Magnetic anisotropies and its optical manipulation in epitaxial bismuth ferrite/ferromagnet heterostructure

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A B S T R A C T

Exchange-coupled $BiFeO_3$/ferromagnet thin film heterostructures are promising for a fast and power efficient control of magnetization of the ferromagnetic layer. In the paper, the results of the study of magnetic properties of the epitaxial $Fe_2B/BiFeO_3$ heterostructure on (001)-$SrTiO_3$ substrate with ferromagnetic resonance (FMR) spectroscopy are presented. The hierarchy of magnetic anisotropies that determine the angular variation of the resonance field in-plane and in-/out-of the plane of the system include the tetragonal four-fold and uniaxial terms for the Fe_2B layer, uniaxial term for antiferromagnetic $BiFeO_3$ layer and the exchange coupling at the interface. We find out that the exchange bias direction can be switched by a strong enough applied magnetic field. Both the exchange bias and an in-plane FMR resonance field of the heterostructure are strongly affected by the illumination with $\lambda = 405$ nm light. An optical tunability of the exchange bias and ferromagnetic resonance fields of the heterostructure has been demonstrated.

1. Introduction

Nowadays due to applications in information storage, sensor, spintronic and tunable microwave magnetic devices, fast, compact and low-power approaches for tuning of magnetic properties of materials are of great technological and scientific importance. Much of the recent research has been devoted to the use of multiferroic heterostructures for a control of the magnetic properties by electric field instead of the electric current [1–8]. Among different kinds of these heterostructures, exchange-coupled $BiFeO_3$ (BFO)/ferromagnet (FM) bilayers attracted a lot of the attention in the last decade [9–15]. These studies have already provided the community with the means for a magnetization reversal by electric field which obviously is of great significance for information storage [11,14,16]. With the trends towards further device miniaturization, requirement to use electrical contacts however makes these approaches too complex. Therefore, the search for alternative non-contact methods is of great interest.

Recently, optical control of magnetic properties has been studied based on photostriction of BFO in the strain-coupled BFO/Ni structure [17]. BFO is an amazing multiferroic material that in addition to ferroelectricity, antiferromagnetism and weak canted magnetic moment [18–20] demonstrates an advanced susceptibility to illumination with light [21,22]. Namely, a combination of the photovoltaic effect and ferroelectricity results in a photostriction effect in BFO [23]. Ultrafast and large-magnitude photo-induced strain has been observed recently in BFO films grown on (001)-$SrTiO_3$ substrate [24–27]. The crystal structure of bulk BFO is a rhombohedrally distorted perovskite (pseudo-cubic), with the lattice constant 3.965 Å and rhombohedral angle of 89.3–89.4 degrees at room temperature [28]. It has been found that in epitaxial BFO film grown on the (001) oriented $SrTiO_3$ (STO) the monoclinic (pseudo-tetragonal) phase of BFO was stabilized due to the substrate-induced strain related to a significant lattice mismatch [19,29]. In addition to the crystal structure modification, epitaxial constraint results in the destruction of a spatially modulated spin structure in BFO film. The transition between cycloidal and homogeneous antiferromagnetic spin states releases a latent canted antiferromagnetic component locked within the cycloid [30]. Also it was reported that canted antiferromagnetic magnetization in BFO film is modified under different strain conditions [19]. These properties of BFO may be used in exchange-coupled BFO/FM thin film heterostructures to establish a contactless and fast approach to control magnetic properties of a FM film.

Here we will first describe the synthesis of the Fe_2B/BFO heterostructure and its characterization. Then ferromagnetic reso-

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