Electric Field Induced Magnetization Reversal Using Multiferroic BiFeO$_3$ Epitaxial Thin Films Grown on (001)-SrTiO$_3$ Substrates

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Introduction

BiFeO$_3$ (BFO) is the multiferroic material with anti-ferromagnetism and ferroelectricity. Electric field induced magnetization reversal has been demonstrated in BFO films with stripe-domain grown on DyScO$_3$. [1] In principle, the magnetization reversal could be realized regardless of domain structures; however, there is no report using BFO with multi-domain. In this work, electric field induced magnetization reversal using BFO thin films with multi-domain grown on SrTiO$_3$ (STO) was observed.

Method

(001)-STO sub./La$_{0.6}$Sr$_{0.4}$MnO$_3$(70 nm)/BFO(120 nm) structures were prepared with r.f. magnetron sputtering technique. NiFeCuMo(10 nm)/Ru(5 nm)/Au(5 nm) top electrodes were deposited on the BFO layer. After deposition of top electrodes, field cooling (FC) from 100°C under magnetic field of 10 kOe was carried out to apply the exchange bias to the NiFeCuMo layer. Top electrodes were processed to square of 100×100 µm$^2$. $M$-$H$ curves of the NiFeCuMo layer were measured with magneto-optical Kerr effect.

Experimental Results

Fig. 1 shows the $M$-$H$ curves for NiFeCuMo electrodes measured with Kerr effect. After FC, clear shift of the $M$-$H$ curve for negative magnetic field direction was observed, (gray lines in Fig. 1) which implied the exchange bias due to the anti-ferromagnetism of BFO. Pinning direction was the same as the magnetic field direction in FC (BFO $[100]_\text{pc}$, where pseudo cubic notation was denoted as pc). After ferroelectric polarization switching in BFO, the shift direction in the $M$-$H$ curve of NiFeCuMo was changed as shown in fig. 1. $M$-$H$ curves with various applying magnetic field direction revealed that the pinning direction for the magnetization of NiFeCuMo was switched to BFO $[-110]_\text{pc}$ from $[100]_\text{pc}$ by ferroelectric polarization switching. Correlation between pinning direction and crystal orientation of BFO was indicated. It was demonstrated that electric field induced magnetization reversal using multiferroic BFO thin films with multi-domain could be realized in this work.


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