Exchange Bias and Multiferrocity on Co-$BiFeO_3$ Composite Films

Kim, Sang-Hyun, Kim, Ki-Yoen[1] and Shin,Sung-Chul
Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon, Korea, South.
[1]Neutron Science Division, Korea Atomic Energy Research Institute, Daejeon, Korea, South.

1. Introduction

$BiFeO_3$ (BFO) is of great current interest because of the possibility of manipulating the magnetic state by an electric field or vice versa and its great ferroelectricity. Microscopically, the antiferromagnetic spin order of BFO is not homogenous for BFO single crystal, but manifests itself as a cycloid with a long wavelength λ of ~ 600 Å. Consequently, the linear magnetoelectric effect averages to zero and only the quadratic effect exists, which precludes the magnetization manipulation induced by an electric field at room temperature.

To overcome such an inherent weakness of BFO in controlling the magnetization by an electric field, the exchange interaction between a traditional ferromagnet and antiferromagnet multiferroic BFO has been considered as a mechanism to control the magnetization by an electric field [1]:antiferromagnet multiferroic BFO, unlike conventional antiferromagnets such as CoO, NiO, and IrMn, exhibits the ability to be tuned by an electric field. In this report, we investigate exchange bias between Co and BFO and ferroelectricity in Co-BFO composite films.

2. Results and discussion

Co-BFO films with a Co concentration range of 0-5.6 atomic % were grown by co-sputtering Co and BFO. It was found that numerous bright and dark contrasts were observed in MFM images of the as-grown Cox-(BFO)1-x (x=0.038) film. We have confirmed that the bright and dark contrasts were changed in reversible manner in accordance to the polarity change of an applied magnetic field, as shown in Fig. 1. Therefore, it can be concluded that bright and dark spots are magnetic domains of two different magnetizations of Co inclusions dispersed in BFO film.

The M – H loop of the Cox-(BFO)1-x (x=0.004) film measured at room temperature is representatively presented in Fig. 2(a), together with the magnified center area in the inset. It is interesting to note that the loop is shifted to the negative direction, revealing an existence of the exchange bias with the exchange bias field (HEB) of -88 Oe in this particular sample. We believe that the exchange bias occurs at the interface between the antiferromagnetic BFO and the ferromagnetic Co embedded in BFO. In the dependance of HEB and coercivity on Co concentration, the exchange bias field was dominantly established in the Co-BFO films for small Co concentration, resulting from the strong coupling between the uncompensated BFO spins. However, the coercivity increase was mainly observed in the Co-BFO films for large Co concentration, because the coupling between the BFO and Co spins would be stronger than one between the spins within BFO.

It is essential for the exchange biased Co-BFO films to have the ferroelectric properties at room temperature for any possible manipulation of ferromagnetism by an electric field. A fully saturated P-E hyteresis loop with the remanent polarization of 59 μC/cm2 was observed in the Cox-(BFO)1-x (x=0.004) film at room temperature, as shown in fig. 2(b).

3. Conclusion

In summary, we observed exchange bias effects and ferroelectricity in Co-BFO composite films. This may encourage the recent efforts of the magnetization manipulation by an electric field through exchange bias effects between ferromagnet and multiferroic BFO.

4. References:

[1] Y.-H. Chu, L. W. Martin, M. B. Holcomb, M. Gajek, S.-J. Han, Q. He, N. Balke, C. ‐H. Yang, D. Lee, W. Hu, Q. Zhan, P.-L. Yang, A. Fraile-Rodriguez, A. Scholl, S. X. Wang, and R. Ramesh, Nat. Mater. 7, 478 (2008).

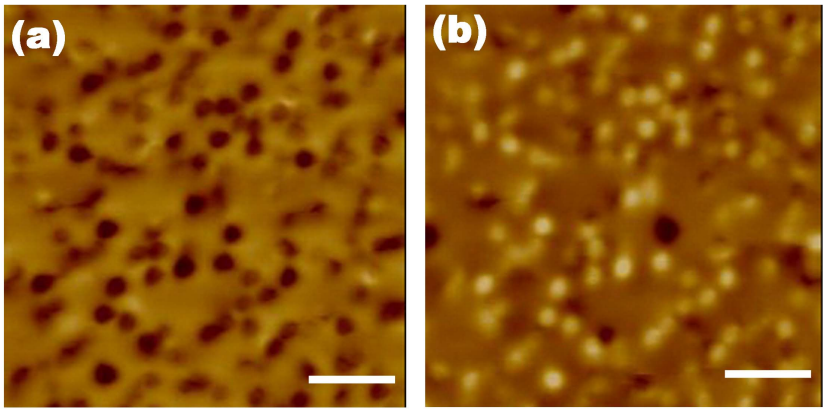

Figure 1. (a) and (b) are the MFM images of the same area in Cox-(BiFeO3)1-x (x=0.038) film with applying +15 kOe and -15 kOe, respectively.

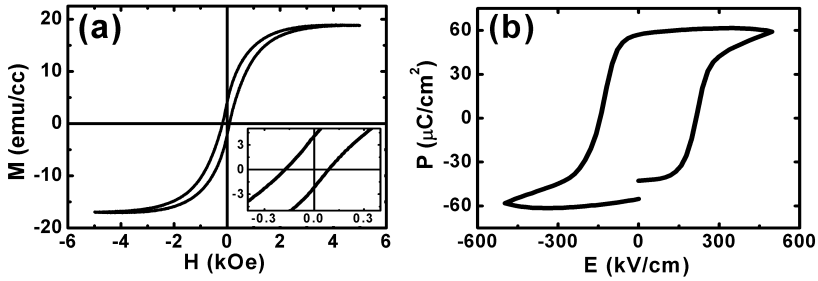

Figure 2. (a) M-H and (b) P-E hysteresis loops of Cox-(BiFeO3)1-x (x=0.004) film. The magnified center area of M-H loop is presented in the inset of Fig.2 (a). Both hysteresis loops were measured at room temperature.