Magnetization reversal by electric field in Co substituted $BiFeO_3$

Masaki Azuma[1,2], Kei Shigematsu[1,2], Hajime Hojo[3], Keisuke Shimizu[1], Takuma Itoh[1], Ko Mibu[4]

[1] *Laboratory for Materials and Structures, Tokyo Institute of Technology, Japan*

[2] *Kanagawa Institute of Industrial Science and Technology, Japan*

[3] *Department of Energy and Material Science, Kyushu University, Japan*

[4] *Nagoya Institute of Technology, Japan*

Electric field manipulation of magnetization is intensively investigated because of potential application in low-power-consumption non-volatile magnetic memory devises. Ferroelectric $BiFeO_3$ has a cycloidal space-modulated spin structure with a periodicity of 62 nm superimposed on the G-type antiferromagnetic structure which prohibits the appearance of net ferromagnetic magnetization due to spin canting. We have observed a spin structure transition from low-temperature cycloidal one to high-temperature collinear one with at ~200 K using Mössbauer spectroscopy in rhombohedral $BiFe_{0.1}Co_{0.9}O_3$ thin films fabricated by PLD on $SrTiO_3$ (STO) (111) substrate [1, 2]. Spontaneous magnetization of 0.03 u_B/f.u. confined in a magnetic easy plane perpendicular to the electric polarization is generated by Dzyaloshinskii-Moriya interaction. Films fabricated on $GdScO_3$ (110) substrate has out-of-plane component of magnetization which can be observed by magnetic force microscopy (MFM). It is demonstrated that the out-of-plane magnetization can be reversed by electric polarization reversal using piezoresponse force microscopy (PFM) at room temperature [3, 4] while the magnetization reversal is absent when the polarization reversal is in-plane [5].

[1] H. Hojo, R. Kawabe, K. Shimizu, H. Yamamoto, K. Mibu, K. Samanta, T. Saha-Dasgupta, M. Azuma, *Adv. Mater*., **29**, 160313 (2017).

[2] H. Hojo, K. Oka, K. Shimizu, H. Yamamoto, R. Kawabe, M. Azuma. *Adv. Mater*., 1705665 (2018).

[3] K. Shimizu, R. Kawabe, H. Hojo, H. Shimizu, H. Yamamoto, M. Katsumata, K. Shigematsu, K. Mibu, Y. Kumagai, F. Oba, M. Azuma, *Nano Lett*., **19**, 1767-177 (2019).

[4] M. Katsumata, K. Shigematsu, T. Itoh, M. Azuma, *Appl. Phys. Lett*., **119**, 132901 (2021).

[5] K. Shigematsu, M. Katsumata, Y. Itoh, K. Ozawa, H. Shimizu, K. Shimizu, M. Azuma, *Adv. Phys. Res*., 2200099 (2023).