BL-7A/2017G060

Strain-Induced Reversible Manipulation of Orbital Magnetic Moments in Ni/Cu Multilayers on Ferroelectric $BaTiO_3$

Jun Okabayashi[1*], Yoshio Miura[2], and Tomoyasu Taniyama[3]

[1]*Research Center for Spectrochemistry, The University of Tokyo, Bunkyo-ku, Tokyo 113-0033*

[2]*Research Center for Magnetic and Spintronic Materials, National Institute for Materials Science (NIMS), Tsukuba 305-0047*

[3]*Department of Physics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8602*

The coupling between ferromagnetic and ferroelectric properties has recently attracted considerable attention toward the creation of novel devices using multiferroic controlling of their properties. In particular, the hetero-interfaces in thin films comprising both ferromagnets and electrically polarized materials produce a rich variety of possibilities for creating multifunctional properties. Modulation of interfacial lattice constants by an electric field (***E***) induces interfacial changes in magnetism. The interfacial lattice distortion produces variations in magnetic properties, which are recognized as inverse magneto-striction effects. Moreover, magnetic anisotropy is also tuned by lattice distortions. Recent attempts have been focused on the modulation of the number of charge carriers at the interface between an ultrathin ferromagnetic layer and an oxide-barrier insulator in magnetic tunnel junctions. Other approaches, which are our focus in this study, are based on the interfacial mechanical strain coupling between ferromagnetic and ferroelectric layers using multiferroic hybrid structures. In this study, we focus on thin Ni layers sandwiched by Cu layers exhibit perpendicular magnetic anisotropy (PMA) because of the interfacial tensile strain in the Ni layers.

Recently, ***E***-control of the magnetic properties of Ni/Cu multilayers on $BaTiO_3$ was achieved; the magnetization was switched from the perpendicular axis to the in-plane easy axis by tuning the lattice distortion through the application of ***E*** [1]. To understand this relationship and the elastic phenomena from the view point of m_{orb}, we developed a technique by applying an electric field in XMCD measurements (EXMCD) to clarify the mechanism of the electric-field-induced changes in the magnetic anisotropy of Ni/Cu multilayers on $BaTiO_3$ hetero-structures through lattice distortions.

The samples were grown by using ultra-high vacuum molecular beam epitaxy on [100]-oriented 0.5-mm-thick $BaTiO_3$ single crystal substrates. Therefore, the bias voltage of 400 V applied between top and bottom electrodes means the electric field of 8 kV/cm. The stacked structures are shown in Fig. 1a. The XAS and XMCD measurements for the Ni and Cu *L*-edges were performed at the KEK-PF BL-7A beamline, at room temperature. The EXMCD measurements were performed using the partial fluorescence yield (PFY) mode.

Figure 1b shows the Ni *L*-edge XAS and XMCD spectra obtained in the PFY mode by applying an electric field, ***E***, of positive bias of 8 kV/cm. Sample surfaces are connected to ground and ***E*** is applied to the back side of the $BaTiO_3$ substrates. The spectral line shapes of the XAS and XMCD are modulated by ***E*** in normal incident (NI) case in spite of fixed sample measurement position. By comparing the results with and without ***E***, we observed a slight variation in the peak asymmetries between the L_3 and L_2 edges. These results reveal that the orbital moments are modulated by applying ***E***, thereby resulting in changes of magnetic anisotropy. The values of spin and orbital moments are estimated to be 0.56 and 0.055 μ_B, respectively, for an electric field of 0 kV/cm, and 0.56 and 0.045 μ_B, respectively, for an electric field of 8 kV/cm. The modulation of the orbital magnetic moments by 0.01 μ_B upon applying ***E*** is related to the induced lattice distortion of 2% from the $BaTiO_3$ substrates. Moreover, after releasing ***E*** to zero, spectral line shapes also revert to the pristine state [2]. Therefore, we conclude the reversible changes of m_{orb} is induced by lattice distortion, which is the demonstration of novel orbital-elastic effect.

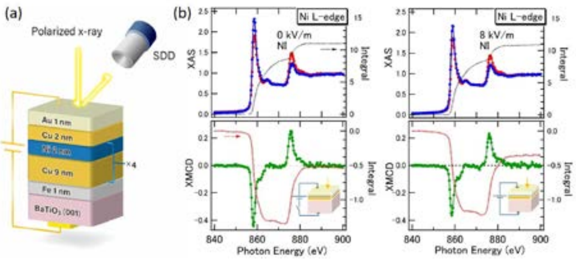

Fig. 1, (a) Schematic structure of the sample. The electrodes for applying the electric field are mounted at the top (Ni/Cu layer) and the bottom ($BaTiO_3$ substrate) of the films. (b) XAS and XMCD spectra obtained at Ni *L*-edges in partial-fluorescence-yield mode with and without an applied electric field.

References

[1] Y. Shirahata *et al. NPG Asia Materials* **7**, e198 (2015).

[2] J. Okabayashi *et al.*, *NPJ Quantum Mater.* **4**, 21 (2019). *Press release in Japanese*

*jun@chem.s.u-tokyo.ac.jp