Non-linear behavior of electric-field effect on domain period in Ta/CoFeB/MgO

Laboratory for Nanoelectronics and Spintronics, RIEC, Tohoku Univ.[1], CSIS, Tohoku Univ.[2], CSRN, Tohoku Univ.[3], CIES, Tohoku Univ.[4], WPI-AIMR, Tohoku Univ.[5]

○Naoki Ichikawa[1], Takaaki Dohi[1], Atsushi Okada[1], Hideo Sato[1-4]

Shunsuke Fukami[1-4], and Hideo Ohno[1-5]

E-mail: ichikawa@riec.tohoku.ac.jp

Electric-field effect on exchange stiffness constant A_S was recently demonstrated by measurements of magnetic domain structure [1,2] and spin-wave resonance. [3] In this study, we investigate a variation in domain structure under an application of wide-range electric field and discuss the electric-field effect on A_S.

Stacks, from substrate side, Ta/ CoFeB (t_{CoFeB} = 1.18 – 1.25 nm)/ MgO (2 nm)/ Al_2O_3 (5 nm), are deposited by sputtering on Si/SiO_2 substrate and are annealed at 350ºC for 1 h under a perpendicular magnetic field 0.4T in vacuum. After the fabrication of bottom electrode, Al_2O_3 (28 – 32 nm) is deposited by atomic layer deposition, and then indium-tin-oxide (30 nm) is formed as a top electrode by sputtering. The applied gate voltage of +1 V to top electrode with respect to bottom electrode corresponds to an electric field of +0.02 V/nm. Spontaneous magnetization M_S and effective perpendicular magnetic anisotropy field H_K^{eff} are measured by vibrating sample magnetometer (VSM) and ferromagnetic resonance (FMR), respectively. The domain structure is observed by magneto-optical polar-Kerr-effect (MOKE) microscope. All measurements are conducted at room temperature.

To obtain domain images, the samples are first demagnetized by applying an ac-perpendicular magnetic field with exponentially decaying amplitude. The maze domain patterns are observed in all the samples. Domain period D_P is determined by two-dimensional fast Fourier transformation of the obtained domain images. We confirm a modulation of D_P with the applied electric field for all the samples. Interestingly, D_P shows non-linear response to the field. Further detailed analysis with the obtained M_S and electric-field dependence of H_K^{eff} reveals that this peculiar behavior originates from a non-linear variation in A_S with the electric field. The obtained results provide a useful clue to understand the underlying mechanism of exchange stiffness in heterointerfaces.

We thank M. Tsujikawa and M. Shirai for fruitful discussion. This work was supported in part by a R&D Project for ICT Key Technology of MEXT, JST-OPERA, GP-Spin of Tohoku Univ., Grant-in-Aid for JSPS Research Fellows (No. 16J05455), and the Cooperative Research Project of RIEC.

[1] T. Dohi *et al*., 2016 JSAP Spring Meeting 22a-W241-1 (2016); T. Dohi *et al*., AIP Advances **6**, 075017 (2016).

[2] F. Ando *et al*., Appl. Phys. Lett. **109**, 022401 (2016).

[3] T. Dohi *et al*., Appl. Phys. Lett. **111**, 027403 (2017).