CoFeB thickness dependence of electric-field effects on magnetic anisotropy and damping constant in Ta/CoFeB/MgO structures

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Magnetic anisotropy and damping constant $\alpha$ are important parameters characterizing spintronics materials and devices. They are expected to be related to each other through the spin-orbit interaction, and thus the correlation between them has been studied in various materials [1-3]. We investigated the correlation in Ta/CoFeB/MgO structures by modulating the anisotropy through the application of the electric field $E$ [4,5], where clear modulation of $\alpha$ was observed for one device with the largest perpendicular magnetic anisotropy among studied devices [5]. In order to clarify the trend experimentally, we investigate here the electric-field effect on $\alpha$ in devices with thinner CoFeB and thus larger magnetic anisotropy than that in the previous study [5].

Stack structures, Ta/Ru/Ta/Co$_{0.6}$Fe$_{0.4}$B$_{0.2}$ ($t = 1.30, 1.36$ nm)/MgO (2 nm)/Al$_2$O$_3$ (5 nm), are deposited on a Si (001)/SiO$_2$ substrate by rf magnetron sputtering, and are annealed at 300°C for 1 h in vacuum under perpendicular magnetic field of 0.4 T. The stacks are processed into a 1-mm diameter circular mesa, and a 57-nm-thick Al$_2$O$_3$ insulator and a Cr (3)/Au (50) counter electrode were deposited to complete electric-field-effect devices. Positive voltage is defined as the Cr/Au layer positive with respect to the CoFeB layer.

The magnetic field angle $\theta_H$ dependence of ferromagnetic resonance spectra are measured as a function of $E$ at room temperature. The magnetic anisotropy and $\alpha$ are determined from the analysis of the angle dependence of resonant field and linewidth, respectively. The effective perpendicular magnetic anisotropy energy constant $K_1^{\text{eff}}$ and $\alpha$ decrease by the application of positive $E$ for the two devices, and their modulation ratios increase with decreasing $t$. The present result along with the previous result indicates that the modulation of $K_1^{\text{eff}}$ is observed for all the devices, whereas that of $\alpha$ is observed only in devices with a perpendicular easy axis ($K_1^{\text{eff}} > 0$). The modulation ratio of $\alpha$ increases with increasing $K_1^{\text{eff}}$ and thus decreasing $t$. These results suggest that the modulation of $\alpha$ is related to the interfacial effect and the direction of easy axis plays a role in the emergence of the electric field effect.

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