Higher order magnetic anisotropy in Fe/MgO under electric field: a first-principles calculations

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Voltage control of magnetic anisotropy (VCMA) in ferromagnetic thin films has attracted much attention as a writing technology for magnetoresistive random access memory (MRAM), which is capable of spin manipulation with low-power consumption. The magnetic anisotropy (MA) energy consists of K_1 and K_2 of a first- and second-order MA coefficients. Recent experimental and theoretical studies revealed that zero-field switching in voltage-torque MRAM is available if a conically magnetized state is stabilized by K_2 in MgO-based magnetic tunnel junction [1].

Here, we study the first- and the second-order MA coefficients, K_1 and K_2, in Fe thin films on MgO substrates under electric fields by using first-principles calculations [2]. The dependence of the Fe layer thickness on K_1 and K_2 by applied the external electric field is studied by varying the number of Fe MLs from one to four in the Fe /MgO systems. For all the systems, the VCMA coefficients of K_1 and K_2 have the opposite sign to each other as observed in recent experiments [3], and the VCMA coefficients of K_1 and K_2 are maximized at the thickness of 1 ML of Fe. The effect of the Cr-capping layer on VCMA coefficients of K_1 and K_2 is also studied. Although the VCMA coefficient of K_1 is suppressed down to 57% by adding the Cr-capping layer, that of K_2 is almost unchanged.

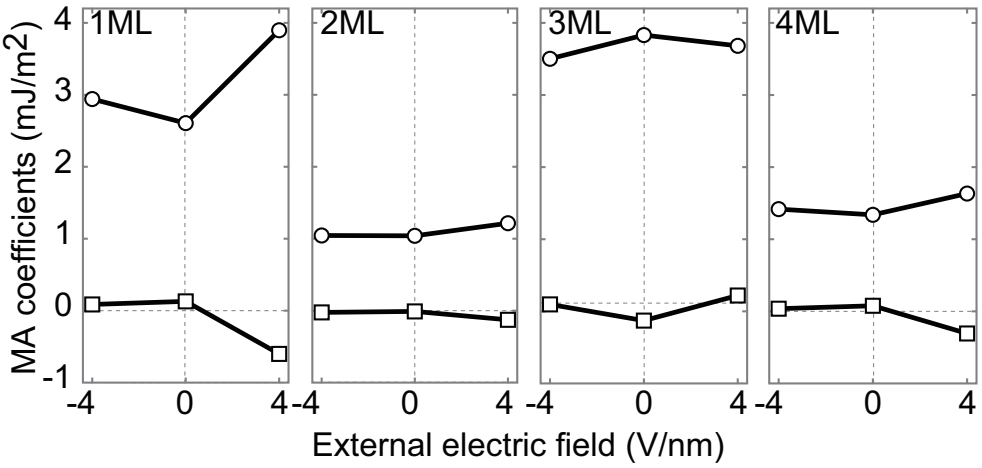

Fig. The first- and the second-order magnetic anisotropy coefficients, K_1 (○) and K_2 (□), of the Fe layer thickness on a MgO(001) substrate is plotted as a function of an external electric field.

[1] R. Matsumoto et al., Phys. Rev. Appl. 9, 14026 (2018)., [2] Y. Kitaoka et al., Jpn. J. Appl. Phys. 60, 018003 (2021)., [3] A. Sugihara et al., Jpn. J. Appl. Phys. 58, 90905 (2019).