# Voltage-controlled magnetic anisotropy of Fe/Co/Pd/MgO epitaxial multilayer

**Osaka Univ. [1], CSRN. [2]**

**○Joko Suwardy[1], Kohei Nawaoka[1], Minori Goto[1,2], Yoshishige Suzuki[1,2] and Shinji Miwa[1,2]**

**E-mail: suwardy@spin.mp.es.osaka-u.ac.jp**

Voltage-controlled magnetic anisotropy (VCMA) magnitude need to be increased for practical use. By inserting a heavy-metal layer such as Pt, at Fe/MgO interface, significant enhancement had been obtained [1]. Previously, we had reported the VCMA of Fe/Pd/MgO system. Although a declining observed due to Pd insertion, post-annealing treatment increased the VCMA which may be attributed to alloying of Fe and Pd [2]. In this present study, we inserted 3*d*-material (Co) and 4*d*-material (Pd) at Fe/MgO interface because high VCMA was reported in Co/Pd/MgO system [3]. Moreover, post-annealing treatment has been done to form alloying interface.

Multilayer film structure was grown onto MgO(001) substrate as depicted in Fig. Insertion layer thickness of Co ($t_{Co}$) and Pd ($t_{Pd}$) were varied to 0–0.52 nm and 0–0.38 nm, respectively, on the same wafer. By this configuration, we can investigate several interfaces conditions: Fe/MgO, Fe/Co/MgO, Fe/Pd/MgO and Fe/Co/Pd/MgO. The characterization of VCMA effect was performed through spin-wave spectroscopy, by measuring frequency shift without and with voltage applications. Figure 2 shows the VCMA value as a function of Pd-thickness ($t_{Pd}$). Black square indicating Fe/Pd/MgO. It can be seen that by inserting Pd, VCMA increase slightly before declining as Pd-thickness increase. This trend reproduced our previous result [2]. Interestingly when the Co layer inserted, higher VCMA value was obtained. The configuration of $t_{Co}$ = 0.52 nm (~4 ML) and $t_{Pd}$ = 0.19 nm (~1 ML) gave the highest VCMA about -180 fJ/Vm. In the presentation, the influence of post-annealing treatment will be discussed. This work was partially supported by ImPACT program and JSPS KAKENHI (No. 26103002).

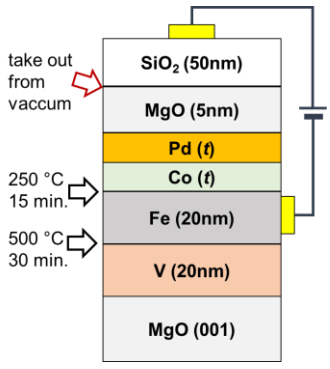


Fig. 1 Schematic of the sample structure

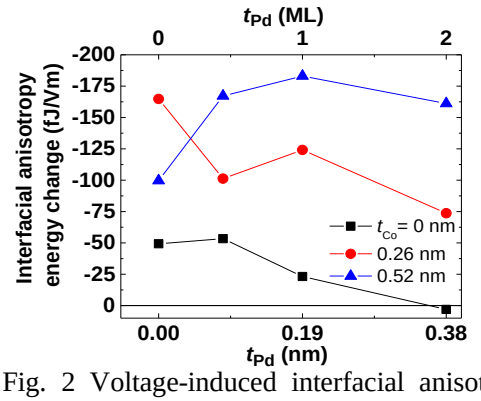


Fig. 2 Voltage-induced interfacial anisotropy energy changes as a function of Pd-thickness

[1] S. Miwa *et al.*, Nat. Commun. **8**, 15848 (2017). [2] J. Suwardy *et al.*, JSAP Autumn Meeting 2017.
[3] Y. Hibino *et al.*, Appl. Phys. Lett. 109, 082403 (2016).