Enhanced interfacial perpendicular magnetic anisotropy and voltage-controlled magnetic anisotropy in iridium-doped Fe/MgO structures

AIST [1], AGH Univ. [2], Tohoku Univ.[3], NIMS[4], Osaka Univ.[5], JASRI[6],

°Takayuki Nozaki[1], Anna Koziol-Rachwal[1,2], Masahito Tsujikawa[3], Yoichi Shiota[1], Xiandong Xu[4], Tatsuya Yamamoto[1], Tadakatsu Ohkubo[4], Takuya Tsukahara[5], Shinji Miwa[5], Motohiro Suzuki[6], Shingo Tamaru[1], Hitoshi Kubota[1], Akio Fukushima[1], Kazuhiro Hono[4], Masafumi Shirai[3], Yoshishige Suzuki[1,5], Shinji Yuasa[1]

E-mail: nozaki-t@aist.go.jp

The voltage-controlled magnetic anisotropy (VCMA) effect in a 3*d*-transition ultrathin ferromagnetic layer is attracting much attention as a promising approach of ultra-low spin manipulation for future spintronic devices, such as voltage-torque MRAM [1]. However, to show the scalability of voltage-torque MRAM, we need a sufficiently high VCMA coefficient, for example, 200-500 fJ/Vm for cache memory and 500-2000 fJ/Vm for main memory applications. However, the demonstrations of high-speed VCMA effect in magnetic tunnel junction (MTJ) devices are limited to be about 100 fJ/Vm at present. In this work, following the prediction by first-principles calculation [2], we tried the interface engineering using 5*d* heavy metal iridium (Ir) to enhance the VCMA effect and found that low concentration of Ir doping in an ultrathin Fe layer is effective to achieve the enhanced interfacial PMA with large VCMA coefficient over 300 fJ/Vm [3].

Fully epitaxial MTJs consisting of Cr/ultrathin Fe (t_{Fe})/ Ir doping layer (t_{Ir})/MgO(2.5 nm)/Fe(10 nm)/Ta/Ru were deposited on MgO(001) substrates. We found that the ultrathin Ir doping layer ($0 \leq t_{Ir} \leq 0.15$ nm) intermixed with the Fe layer and form a relatively uniform Ir-doped Fe layer as shown in Fig. 1(a). Optimum concentration of Ir doping resulted in the enhancement of intrinsic interfacial PMA, $K_{i,0}$ of up to 3.7 mJ/m^2. In addition, large VCMA coefficient of 320 fJ/Vm was achieved with the demonstration of high speed response using voltage-induced ferromagnetic resonance excitation [3].

This work was supported by the ImPACT Program of the Council for Science, Technology and Innovation.

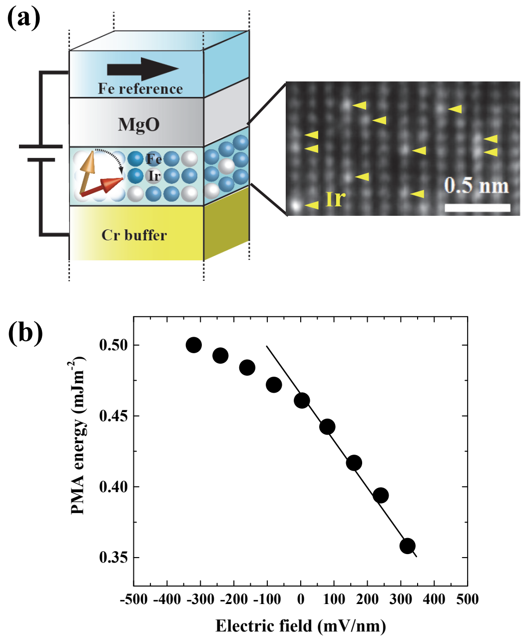

Fig. 1(a) Schematic illustration of the prepared MTJ and HAADF-STEM image of the Ir-doped ultrathin Fe free layer. (b) Applied electric-field dependence of the PMA energy observed in the Ir-doped Fe.

References

[1] T. Maruyama *et al. Nat. Nanotechnol.* **4**, 158 (2009).
[2] K. Nakamura *et al. J. Magn. Magn. Mater.* **429**, 214 (2017).
[3] T. Nozaki *et al. NPG Asia Mater.* **9**, e451 (2017).