Large voltage-controlled magnetic anisotropy change in epitaxial Cr/ultrathin Fe/MgO/Fe magnetic tunnel junctions

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Technological development in electric-field control of magnetic properties is strongly demanded to realize novel spintronic devices with ultralow operating power. Voltage-controlled magnetic anisotropy (VCMA) effect in an ultrathin ferromagnetic metal layer[1), 2)] is the most promising approach, because it can be applied in MgO based magnetic tunnel junction (MTJ). We have demonstrated fast speed response of VCMA effect through the voltage-induced ferromagnetic resonance[3)] and pulse-voltage induced dynamic magnetization switching[4)] so far. One of the outstanding technical issues in the VCMA effect is the demonstration of scalability. For example, for the development of G-bit class memory applications, high VCMA coefficient of more than 1000 fJ/Vm is required with sufficiently high thermal stability. However, the VCMA effect with high speed response is limited to be about 100 fJ/Vm at present. [5)]

In this study, we investigated the VCMA effect in an ultrathin Fe layer sandwiched between epitaxial Cr(001) buffer and MgO(001) barrier layers.[6)] High interface anisotropy energy, $K_{i,0}$ of about 2 mJ/m^2 was recently demonstrated in Cr/ultrathin Fe/MgO structure,[7)] probably due to the atomically flat interfaces and suppression of surface segregation from the buffer material. We applied this structure in the voltage-driven MTJ and performed systematic investigations on perpendicular magnetic anisotropy (PMA) and VCMA effect through the tunnel magnetoresistance (TMR) properties. Fully epitaxial MTJ of MgO seed (3 nm)/Cr buffer (30 nm)/ultrathin Fe (t_{Fe})/MgO (t_{MgO})/Fe (10 nm)/Ta/Ru were deposited on MgO (001) substrates by molecular beam epitaxy. Here, the ultrathin Fe layer is the voltage-controlled free layer with perpendicular magnetic easy axis and top thick Fe layer is the reference layer with in-plane magnetic easy axis. The PMA energy, K_{PMA} and VCMA properties were evaluated from the normalized TMR curves measured under in-plane magnetic fields with various bias voltage applications. Saturation magnetization value was obtained by SQUID measurement.

High interface anisotropy energy, $K_{i,0}$ of 2.1 mJ/m^2 was confirmed in our sample. Figure 1 shows an example of applied electric field dependene of surface anisotropy energy, $K_{PMA}t_{Fe}$ for the MTJ with t_{Fe} = 0.45 nm and t_{MgO} = 2.8 nm. We observed large VCMA coefficient of about 400 fJ/Vm under the negative electric field application, while non-linear behavior appeared under the positive direction. In the presentation, we'll discuss the possible origin of the enhanced VCMA effect and non-linearity including the evaluation results of structural analysis at the Cr/ultrathin Fe/MgO interfaces.

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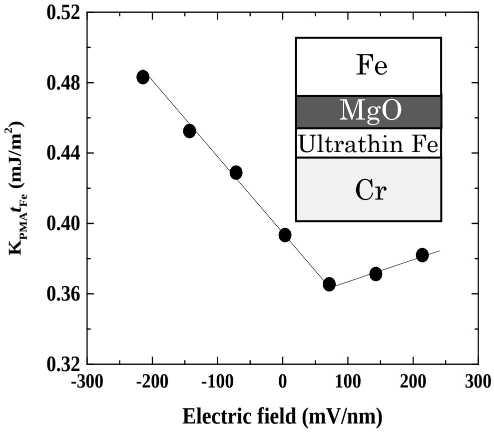

Figure 1 Example of VCMA effect observed in epitaxial Cr/ultrathin Fe/MgO/Fe MTJ with t_{Fe}=0.45 nm and t_{MgO} = 2.8 nm. Perpendicular magnetic anisotropy, K_{PMA} was evaluated from normalized TMR curves and saturation magnetization value measured by SQUID.

Reference

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