Thermal fluctuation in electric-field induced magnetization switching in CoFeB/MgO magnetic tunnel junctions observed by transmitted voltage

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Magnetization precession and switching through the precession can be induced in a CoFeB/MgO magnetic tunnel junction (MTJ) through the modulation of the magnetic anisotropy by applying an electric field [1,2]. In this work, from time-resolved measurements of the precession [3], we elucidate the factors determining the electric-field induced switching probability, and demonstrate the way to achieve low switching error rate.

MTJs with diameter of 80 nm are fabricated from a stack with $Co_{20}Fe_{60}B_{20}$(0.9 nm or 1.0 nm)/MgO(1.3 nm)/$Co_{20}Fe_{60}B_{20}$(1.8 nm) with perpendicular magnetic easy axis. When the magnetic easy direction is changed to in-plane by applying positive voltage to thicker CoFeB free layer with respect to the thinner CoFeB reference layer, the magnetization in the free layer processes about an in-plane effective field composed of anisotropy field and in-plane external magnetic field H_{in}. The magnetization dynamics during voltage application is detected by transmitted voltage thanks to the tunnel magnetoresistance effect.

We observe oscillatory transmitted voltage with ~0.5 GHz, reflecting the electric-field induced magnetization precession in the free layer. The oscillatory amplitude does not show significant decay up to 16 ns, indicating the damping constant is less than 0.02. We observe that the phase of the oscillation is randomized with time evolution. The randomization is explained by stochastic change in precessional frequency through the change in precessional angle due to the thermal fluctuation field, and determines the error rate for electric-field induced magnetization switching. Because the effect of the thermal fluctuation increases with time, faster precession is preferable for switching with lower error rate. We achieve the error rate less than 10^{-2} at pulse duration of 0.25 ns by increasing H_{in} and thus precessional frequency to 2 GHz.

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