Fast spin-transfer-torque switching in a spin-valve nanopillar having a conically magnetized free layer

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Fast switching is required in spin-transfer-torque (STT) magnetoresistive random access memory (MRAM) when spin valve (SV) nanopillar is developed for the usage in CPU cache memory. In the conventional SV with perpendicularly magnetized free layer (p-FL) and reference layer (RL), the magnetizations of FL and RL take parallel or anti-parallel configuration, the so-called "collinear configuration". Since the magnitude of STT is proportional to the sine function of the relative angle between the magnetization directions of the FL and RL, the SV with the collinear configuration suffers from long switching time.

In this study [1], we theoretically analyze the STT switching properties of an SV having a conically magnetized FL (c-FL) where the angle of the magnetization is determined by the competition between the first-order ($K_{u1,eff}$) and the second-order (K_{u2}) magnetic anisotropies. An SV with a c-FL does not take the collinear configuration in the initial configuration. The conically magnetized state has been experimentally demonstrated in double-layer or multilayer systems composed of Co/Pt [2,3] and Co/Pd [3] and has been theoretically proposed in applying to STT-MRAM [4].

Our results show that the switching current density (J_{sw}) of a c-FL can be expressed by $J_{sw} \cong (8/3\sqrt{6})(\alpha d|e|/\hbar P)[(K_{u1,eff} + 2K_{u2})^3/ K_{u2}]^{1/2}$, and J_{sw} of a c-FL with a thermal stability (Δ_0) of 60 is 22% smaller than that of a p-FL with the same Δ_0. In the expression, α, d, and P represent the Gilbert damping constant, thickness of c-FL, and the spin polarization. Fig. 1 shows the typical STT-switching behavior of the c-FL and p-FL with $\Delta_0 = 60$ at the current density of 12 MA/cm^2. Here, m_x and m_z are the in-plane and out-of-plane components of the magnetization unit vector, respectively. Our results also show that the c-FL exhibits shorter switching time (T_{sw}) than that of the p-FL. For example, in Fig. 1, T_{sw} is 60% shorter in the c-FL than in the p-FL. This work was partially supported by NEDO normally off computing project.

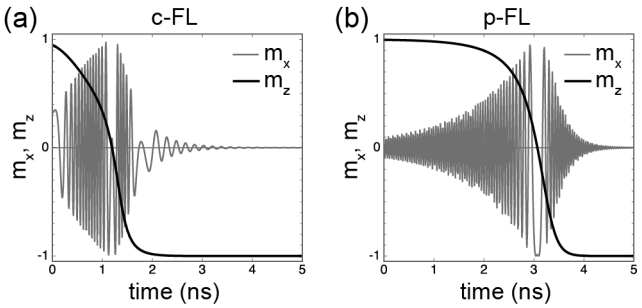

Fig. 1 STT-switching behavior of (a) the c-FL and (b) the p-FL.

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