Energy barrier of X/1X-nm shape-anisotropy magnetic tunnel junctions at high temperature

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Shape-anisotropy magnetic tunnel junction (MTJ)[1] is attracting much attention for high-performance nonvolatile spintronics device beyond 20 nm regime due to its potential to achieve high thermal stability factor Δ ($\equiv E/k_BT$) at the MTJ size down to X/1X nm, where E is the energy barrier between the two magnetization states, k_B is the Boltzmann constant, and T is the temperature[1,2]. Evaluating E at high temperature is of crucial interest for fundamental and application points of view. So far, while temperature dependence of E is studied for conventional interfacial-anisotropy MTJs[3], that of the shape-anisotropy MTJ has not been studied. In this study, we measure Δ of CoFeB-based shape-anisotropy MTJs at various temperatures to understand the physics governing the temperature dependence of E.

Figure 1(a) shows the switching probability as a function of the pulse magnetic field H_{pulse} at various temperatures for an MTJ with a diameter D = 5.8 nm. Solid lines are fitted curves. We note that MTJs studied here are designed not to have too high Δ so that the properties are clearly changed within the temperature range we can access in our setup. Temperature dependence of Δ obtained from the fitting is shown in Fig. 1(b) for MTJs with D = 5.8, 8.4, and 11.9 nm. We then evaluated the scaling relationship between the temperature dependence of E (= Δ/k_BT) and spontaneous magnetization M_S. The relationship enables one to design the MTJ dimensions (D and free-layer thickness t) to achieve high Δ at arbitrary temperatures. From this analysis, we discuss a window of shape-anisotropy MTJ to design devices beyond 20 nm for high-temperature applications.

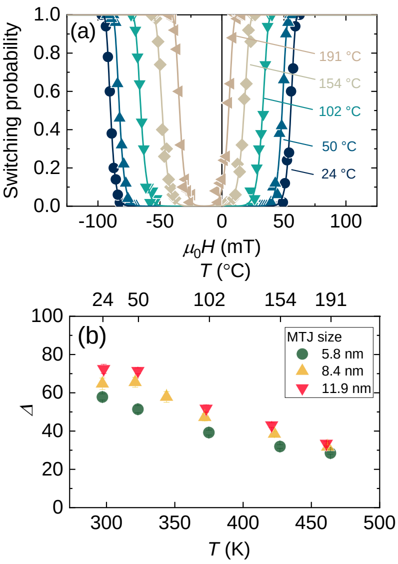

Fig. 1 (a) Switching probability measured under application of H_{pulse} with pulse duration of 1 s for D = 5.8 nm at various temperatures. (b) Temperature dependence of Δ for D = 5.8, 8.4, and 11.9 nm.

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