Physics and stack engineering of ultra-small magnetic tunnel junctions using shape anisotropy

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Shape-anisotropy magnetic tunnel junction (MTJ) [1] is attracting much attention for future-generation spin-transfer torque magnetoresistive random access memory (STT-MRAM) because of its scalability into the X/1X nm regime. Making a cylindrical nanomagnet with its thickness (t) larger than its diameter (D) allows one to positively combine shape anisotropy and interfacial anisotropy, resulting in a high thermal stability factor Δ ($\equiv E/k_BT$, where E is the energy barrier between the two magnetization states, k_B is the Boltzmann constant, and T is a temperature) even at the X/1X nm regime [1,2]. STT switching has also been demonstrated in such small and stable MTJs [1]. Understanding the change in E at high temperatures is of significant interest from both fundamental and applications points of view. In this study, we investigate the temperature dependence of E in the X/1X nm shape-anisotropy MTJs and show designs compatible with applications at high temperatures.

We evaluate Δ at various temperatures up to 191 °C for MTJs with D ranging from 5.0 to 11.9 nm by measuring the switching probability using a pulsed magnetic field. We find that the scaling relationship between the temperature dependence of spontaneous magnetization and E ($= \Delta k_BT$) for the shape-anisotropy MTJs is well described by a model assuming a dominant contribution of shape anisotropy. Based on the obtained scaling relationship, we also discuss a window of shape-anisotropy MTJ for high-temperature applications below 20 nm [3].

In the presentation, we also present our latest results on shape-anistropy MTJs employing a multilayered ferromagnetic structure (Fig. 1), showing notable performance in X-nm regime: (1) stable switching and high Δ at high temperatures, (2) switching efficiency improvement, and (3) high speed STT switching with a 10-ns pulse below 1 V [4].

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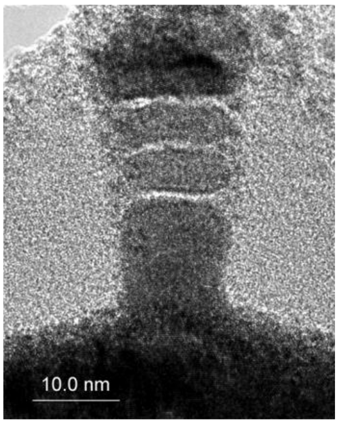

Fig. 1 Cross-sectional TEM image for the shape-anisotropy MTJ employing multilayered ferromagnetic structure.