Diameter and thickness dependence of magnetization reversal in shape-anisotropy magnetic tunnel junctions

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Shape-anisotropy magnetic tunnel junction (MTJ), where a cylindrical ferromagnetic layer is used as a free layer to induce a perpendicular easy axis, has shown high data retention even at an ultra-small scale beyond 10 nm in diameter [1] and superiority at high-temperature applications over conventional interfacial-anisotropy MTJ [2]. Understanding magnetization reversal in such cylindrical ferromagnets is crucial to achieving highly reliable STT-MRAM. We confirmed that magnetization coherently switches in cylindrical ferromagnets of 15 nm in thickness and X/1X nm in diameter [3]. However, magnetization reversal has not been experimentally revealed in larger cylindrical ferromagnets. Micromagnetic simulation indicated incoherent reversal in cylindrical ferromagnets thicker than 15 nm [4,5]. Here, we study magnetization reversal mode in shape-anisotropy MTJs with various free-layer thicknesses and diameters by measuring magnetic field angle dependence of switching field H_{SW}, i.e., an astroid curve.

Fig. 1 shows astroid curves for (thickness t, diameter D) = (15 nm, 11.5 nm) and (50 nm, 22.4 nm). The solid curve is the best fit based on the coherent reversal model as used in [6]. For t = 15 nm, the experimental result is well explained by the fit, indicating a coherent reversal. On the other hand, for the t = 50 nm, the result is not well fitted; the switching field along the easy-axis, where in-plane $\mu_0 H_{\mathrm{SW}}$, or $\mu_0 H_{\mathrm{SW,in}}$, is equal to 0 mT, is smaller compared with the other angles. Here μ_0 is the permeability in a vacuum. Such a distortion indicates incoherent reversal and is also seen for t = 30 nm with D > ~15 nm. This study provides a key understanding of the magnetization reversal in the shape-anisotropy MTJs.

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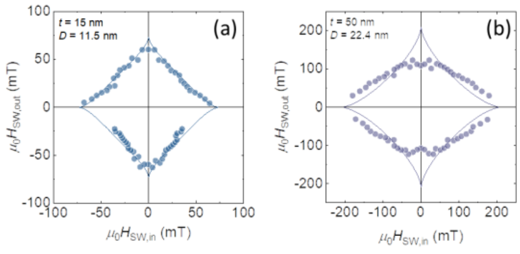

Fig. 1. Astroid curves for (t, D) = (a) (15 nm, 11.5 nm) and (b) (50 nm, 22.4 nm).