Dependence of switching current on out-of-plane field in CoFeB/MgO magnetic tunnel junctions with perpendicular easy axis at low temperature

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Switching magnetization by spin-transfer torque (STT) is of importance for applications such as STT-Magnetoresistive random access memory. Although it was reported that domain wall propagation is involved in switching by STT of magnetic tunnel junctions (MTJs) for larger device sizes, in smaller devices, coherent magnetization reversal is expected to occur [1]. Magnetization reversal by STT could be affected by an inhomogeneous stray field from the reference layer and damage possibly introduced during device processing. In this study, we investigate switching properties of the MTJs by STT with two different structures in which we anticipate different stray fields from the reference layer and different degrees of process-induced damage.

The stack structure is, substrate/Ta(5)/Pt(5)/synthetic ferrimagnetic reference layer/MgO/CoFeB(1.5)/Ta(5)/Ru(5) deposited by dc/rf magnetron sputtering. The numbers in parentheses are nominal thicknesses in nm. We fabricated two types of MTJ with recording layer diameter of ~20 nm to investigate the influence of both edge damage and stray field on the switching properties by STT: one is the step structure where the size of the reference layer is much larger than that of the recording layer, and the other is the standard structure in which the reference layer has almost the same diameter as the recording layer [2]. The edge damage could be also different because of differences in the ion milling angle in the two types of MTJ. We measure the dependence of the switching current density J_C on the out-of-plane applied field H_{out} at 5 K to minimize the effect of thermal fluctuations on J_C. In the step structure, J_C is proportional to H_{out}, which is consistent to that expected in coherent reversal mode. On the other hand, in the standard structure, larger J_C is observed at zero H_{out} and J_C decreases with increasing H_{out} more significantly. Micromagnetic simulations reveal that the difference can be explained by considering the reduction of magnetic anisotropy, increase of damping constant, and reduction of STT efficiency in the vicinity of the device edge.

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