Spin-orbit torque magnetization switching in a perpendicularly magnetized ferromagnetic-semiconductor single layer: Damping like torque and field like torque

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Spin-orbit torque (SOT) magnetization switching, which is induced by a spin current generated by a charge current, is a promising phenomenon that can be used to improve the performance of magnetoresistive random access memory. In our previous study, we achieved a highly efficient full SOT magnetization reversal in a GaMnAs single layer by applying a very low current density (J_c) of 3.4×10^5 A cm^{-2} [1], which is two orders of magnitude smaller than that required in the conventional SOT systems [2]. According to the Landau–Lifshitz–Gilbert (LLG) equation, the SOT is contributed by two parts; damping like torque (DLT) and field like torque (FLT). By fitting simulated results using the LLG equation to the experimental results, we clarified that the DLT is dominant during the magnetization switching in the 7-nm-thick GaMnAs single layer.

Here, we explore the contributions of DLT and FLT by inducing the SOT switching in perpendicularly magnetized GaMnAs single layers with different thicknesses; d = 5 nm, 7 nm, 10 nm, and 15 nm as shown in Fig. 1. In the GaMnAs single layer with d = 5nm, SOT magnetization switching (dominated by DLT) is observed with J_c = 1.6×10^5 A cm^{-2}, which is even smaller than that of our previous paper [1]. With the increase of d, the FLT starts to act on the magnetization switching and competes with the DLT. When d < 15 nm, J_c increases as d increases, which is caused by the enhancement of the contribution of FLT. At d = 15 nm, the switching polarity is totally reversed, indicating that the FLT becomes dominant. This result is understandable, considering that the acting direction of FLT is opposite to that of DLT. Our finding will advance the understanding on the contributions of DLT and FLT during the SOT switching in GaMnAs single layer, which will promote the development of SOT devices in the practical application.

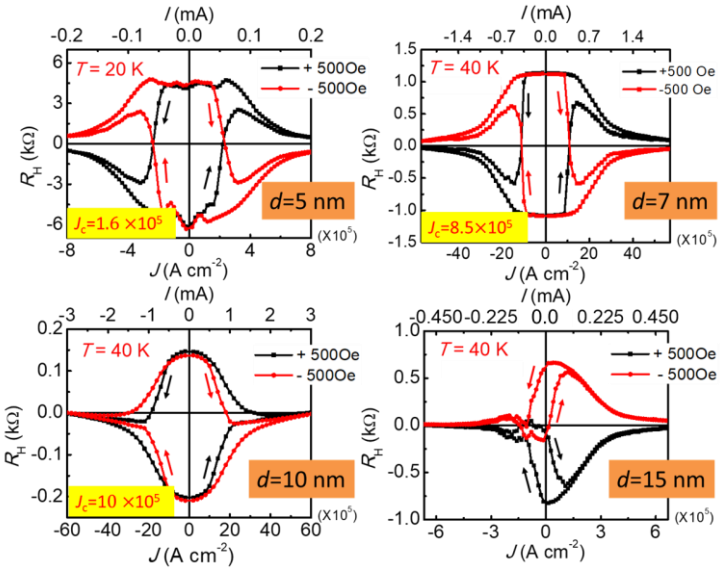

Fig. 1 Thickness dependent spin-orbit torque magnetization switching in a GaMnAs single layer. (The values in the yellow rectangles are J_c of the corresponding samples with a unit of A cm^{-2}.)

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