Effective magnetic field by orbital torque in Pd/Co_2MnGa perpendicular magnetization films

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Three terminal spintronics devices based on nonmagnetic metal/ferromagnet heterostructures are promising for next-generation electronics. Orbital torque (OT) has recently attracted much attention for writing information to such spintronics devices. Heterostructures composed of Weyl ferromagnets are expected for reducing current density required for the writing operation because orbital current can be efficiently converted to spin current through strong spin orbit interaction (SOI) in Weyl ferromagnets. However, OT induced in Weyl ferromagnets has not been clarified yet. In this work, we investigated it by comparing the current-induced torque in a perpendicularly magnetized Pd/Weyl ferromagnet Co_2MnGa (CMG) with that in Pd/weak-SOI ferromagnet Co_2MnSi (CMS).

Two stacking structures composed of, from the surface side, Pd (3.0 nm)/CMG (1.8 nm), and Pd (3.0 nm)/CMS (0.8 nm) were deposited on an MgO (001) substrate. Both stacking structures were processed into Hall-bar-shaped devices with a 2 μm-wide channel and a pair of Hall probes. Out-of-plane hysteresis loops were measured by applying a constant current I under an in-plane magnetic field H_x. along the channel direction while sweeping the perpendicular magnetic field H_z. The center of the hysteresis loop was shifted along the H_z-axis depending on I and H_x for both stacking structures. According to an early study [1], the shift amount corresponds to the effective magnetic field H_{eff} originating from spin-orbit torque and/or OT exerted on domain walls, which were created during magnetization reversal. The H_{eff} increased (decreased) almost linearly with increasing I under a positive H_x for Pd/CMG (Pd/CMS), which indicates the H_{eff} is equivalent to H_z for both stacks, and the direction of H_{eff} in Pd/CMG is opposite to that in Pd/CMS. Recent first-principles calculations have predicted Pd has a positive spin Hall conductivity and a negative orbital Hall conductivity [2], and the direction of H_{eff} in Pd/CMS is in agreement with that induced by the predicted spin current. These results indicate OT dominates the torques induced by in-plane current in Pd/CMG.

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References

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