Antisymmetric interlayer exchange coupling in Pt/Co/Ir/Co/Pt with in-plane spatial inversion breaking

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Metallic superlattices consisting of Co/Cu/Co and Co/Ir/Co are representatives to show the interlayer exchange coupling (IEC), and had been studied from 1980 to 1990 [1]. These metallic superlattices garner attention again from the perspective of the systematic investigation of the relationship between the spin-orbit torque (SOT) and the antiferromagnetic structure [2]. In addition, the systems consisting of the non-magnetic (NM) layer with large spin-orbit coupling induce the antisymmetric exchange interaction such as the Dzyaloshinskii–Moriya interaction at the interface of a ferromagnetic (FM) layer and a NM layer. In addition to these symmetric exchange interactions, recently, the long-range antisymmetric exchange interaction (antisymmetric IEC) between FM layers via a NM interlayer was observed in a metallic superlattice when the in-plane spatial inversion was broken in the film structure [3-6]. However, the mechanism of the antisymmetric IEC has not been understood well, and the systematic experiments exploiting the well-controlled structural asymmetry are indispensable. In this study, we investigated the magnetic structure induced by the symmetric and antisymmetric IEC by designing the in-plane spatial inversion asymmetry of the wedge-shaped Pt/Co/Ir/Co/Pt structure.

The 9 mm square-size double-wedged Ta (1 nm)/Pt (2 nm)/Co (t_{Co})/Ir (t_{Ir})/Co (0.5 nm)/Pt (2 nm)/Ta (1 nm) film was deposited on a SiO_x substrate using DC magnetron sputtering equipped with a linear shutter. The t_{Co} and t_{Ir} were continuously varied from 0.6 nm to 1.6 nm and from 0 to 1.5 nm, respectively, and the wedged-Ir layer was formed in the perpendicular direction to the wedged bottom Co layer. The double-wedged thin film was patterned into the Hall bar-shaped electronic devices, and the magnetic properties were investigated using the anomalous Hall effect (AHE). The IEC of the Co/Ir/Co system was confirmed from the periodic change of the saturation field ($\mu_0 H_s$) against t_{Ir}. The AHE under the application of an in-plane magnetic field (H_{ip}) of 50 mT was also measured. The hysteresis loops of the AHE were largely shifted, indicating the existence of the antisymmetric IEC. The largest difference in the switching field shift ($\Delta\mu_0 H_{sw}$) between the opposite H_{ip} direction was obtained to be 14.8 mT for the device with t_{Co} ~ 0.80 nm and t_{Ir} ~ 0.27 nm, which was an order of magnitude larger than the values reported previously (0.7~1.7 mT [4,6]). Similar to the t_{Ir} dependence of $\mu_0 H_s$, the $\Delta\mu_0 H_{sw}$ was monotonically decreased from t_{Ir} ~ 0.27 nm to t_{Ir} ~ 0.87 nm and increased over t_{Ir} ~ 0.87 nm. This result suggests the correlation between the symmetric and antisymmetric IEC. We will also discuss the influence of the antisymmetric IEC on the SOT magnetization switching.

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