Modulating the Dzyaloshinskii-Moriya interaction in magnetic heterostructures

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The Dzyaloshinskii-Moriya interaction (DMI) is an asymmetric exchange interaction at the interface between materials, stabilizing the chiral spin texture. The influence of the DMI has been studied less in heavy metal-ferromagnet heterostructures utilized in magnetic devices such as MRAM. Moreover, significant DMI energies in the heterostructure demonstrate that entirely exploring the mechanism is indispensable. Here we present how we can modulate the DMI energy by changing material sets and interface designs. First, to systematically control the interfacial DMI (i-DMI), we designed Pd/Pt/CoFeSiB/X structures with different Pd layer thicknesses. Depending on the thickness of Pd, the roughness of the magnetic layer gradually increased, and the perpendicular magnetic anisotropy and interfacial DMI (i-DMI) also changed accordingly. We confirmed that electron scattering by the roughened interface induced enhancement in i-DMI [1]. In another experiment, we inserted ultrathin MgO between the heavy metal-ferromagnet and adjusted the thickness to reveal the working principle of i-DMI. Experiments showed that as the thickness of MgO increased, the i-DMI decreased with Ruderman-Kittel-Kasuya-Yosida (RKKY)-type oscillation behavior rather than monotonic decay (Fig. 1). Our experimental and theoretical analysis reveals that MgO behaves like a conductor in the form of an extrinsic semiconductor, enabling the MgO spacer to possess electronic states similar to those in the adjacent sublayers [2]. These studies revealed that we properly engineered the i-DMI by modulating the interface condition, such as interfacial roughness and spacer thickness. Furthermore, recent studies emphasized the bulk DMI (b-DMI) in symmetry-breaking bulk structures such as ferrimagnetic films with compositional gradients and multilayered superlattices that induce significant chiral interactions [3]. We confirmed the increase in DMI energy by inserting PtCo alloys with and without a compositional gradient at the Pt/Co bilayer interface (Fig. 2). The results showed that the DMI originates from both the interface and the bulk. Our studies demonstrated how the DMI energy changes in various materials and interfaces, paving the road for controlling methods of DMI when designing magnetic devices.

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References

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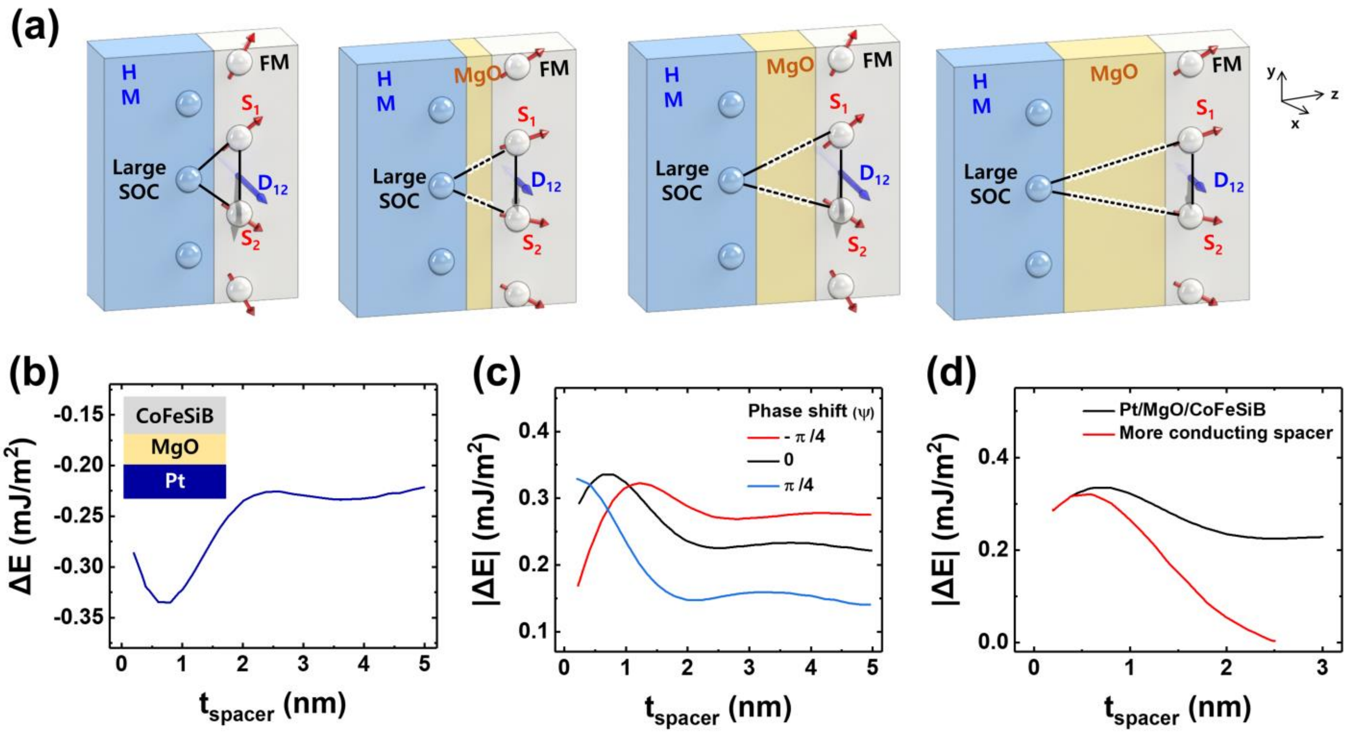

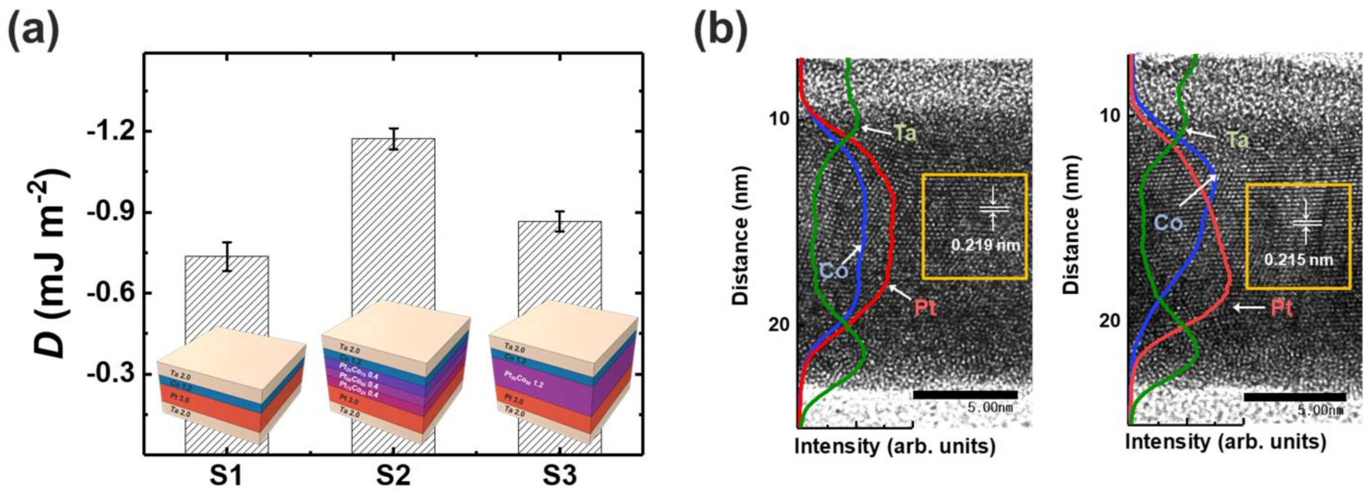

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