Surface Rashba-Edelstein Spin-Orbit Torque tuned by organic monolayer

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The spin-orbit coupling is central to magnetism and spintronics. It describes the relativistic interaction between the electrons' spin and momentum degrees of freedom, which has a dramatic impact on both the equilibrium and nonequilibrium properties of condensed matter. Of particular recent interest is the interplay between the spin-orbit coupling and space inversion symmetry, which triggers a variety of phenomena, such as chiral spin textures and spin-momentum locking. In systems with broken inversion symmetry, the spin-orbit coupling lifts the electron-spin degeneracy. This phenomenon, the Rashba effect, has been observed across various surfaces and interfaces. The Rashba effect couples the spin and charge transport through the spin-momentum locking; an in-plane charge current induces a transverse spin accumulation. This phenomenon, the Rashba-Edelstein (RE) effect or the inverse spin galvanic effect, can generate spin-orbit torques (SOTs), which allow electric manipulation of magnetization in metallic heterostructures. A prototypical spin-orbitronic device with broken inversion symmetry is a Pt/Co bilayer, where the strong spin-orbit coupling in the Pt layer plays a key role in the generation of the SOT. The SOT in such spin-orbitronic devices has been generally attributed to two mechanisms: the bulk spin Hall effect and interface RE effect. Despite a theoretical prediction of a strong Rashba effect at Pt surfaces [1], the SOT originating from the surface transport has been neglected. The direct evidence of the surface RE SOT, as well as the Rashba spin-splitting of Pt surfaces, has been lacking.

In this study, we report the observation of the SOT arising from the surface RE effect of an ultra-thin Pt film by using spin-torque ferromagnetic resonance measurement (Fig. 1(a)). The crucial evidence was obtained by molecular tuning of the symmetry-breaking strength of the Pt surface shown like Fig. 1(b), which was confirmed through the work function of the Pt surface (Fig. 1(c)). We found that the damping-like (DL) SOT in a Pt/Co bilayer is manipulated by decorating the Pt surface with self-assembled organic monolayers, while the field-like (FL) SOT is unaffected by the molecular self-assembly. This result is consistent with the prediction of the SOT arising from the surface RE effect and spin-transfer mechanism. These results therefore illustrate the crucial role of the surface spin-orbit coupling in metallic spin-orbitronic devices, providing a way for molecular tuning of the SOTs.

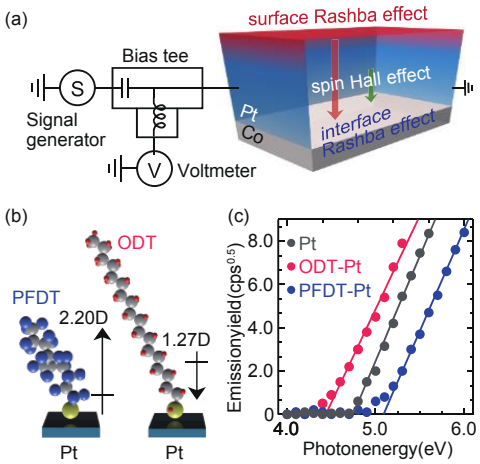

Fig. 2. (a) A schematic illustration of the Pt/Co bilayer. (b) A schematic illustration of ODT and PFDT molecules on the Pt surface. The arrows represent the dipole moment of the SAM-forming molecules. (c) Square root of photoelectron emission yield as a function of scan energy measured with an atmospheric photoelectron spectrometer for the pristine Pt/Co bilayer (black), PFDT-Pt/Co biilayer (blue), and ODT-Pt/Co bilayer (red). The solid lines are linear fits, from which the baseline intercept gives the work function of the trilayers.

[1] A. Bendounan, *etal.*, Phys. Rev. B **83**, 195427 (2011).