Emergence of Synthetic Rashba Spin–Orbit Coupling in Si Metal-Oxide Semiconductor

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Spin-orbit coupling has been playing a significant role in condensed matter physics including spintronics. Materials with large atomic numbers and/or lattice inversion symmetry have been intensively studied as spin–orbit coupled systems. Hence, Si has been out of the scope of the spin–orbit coupling study because of its small atomic number and lattice inversion symmetry. Here, we focus on Si metal-oxide semiconductor (MOS), where an interplay of a gate-electric field and carrier accumulation at the Si/SiO_2 interface can synthetically induce Rashba-type spin–orbit coupling. In this study, we observe spin lifetime anisotropy of propagating spins in n-Si induced by formation of an emergent effective magnetic field due to the Rashba-type spin–orbit coupling, when a gate voltage is applied to the n-Si MOS.

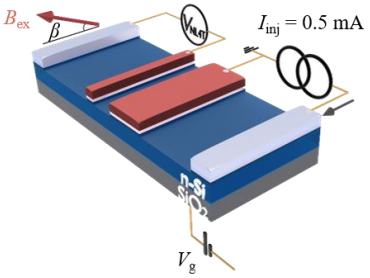

Figure 1. Schematic illustration of n-Si based non-local spin transport device and experimental setup.

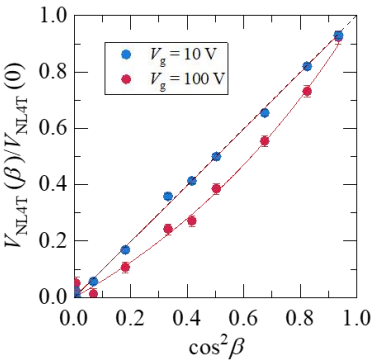

Figure 2. $\cos^2\beta$ dependences of normalized spin signal under V_g = 10 V (blue dots) and 100 V (red dots). Red lines indicate theoretical fits.

To investigate an anisotropy of spin lifetime in Si channel, spin precession measurement in an n-Si non-local spin transport device with an oblique magnetic field is exploited at 300 K (Fig. 1), where the spin current in non-degenerate n-type Si is electrically generated from one ferromagnetic electrode and detected in another ferromagnetic electrode. Gate voltage (V_g) is applied via the backside oxide of the silicon-on-insulator substrate. We carried out spin precession measurements with various tilt angles (β) of the magnetic field (B_{ex}). Angular dependence of the magnitude of the spin signal reveals the spin lifetime anisotropy, which is quantified by a ratio of an out-of-plane spin lifetime to an in-plane spin lifetime. Figure 2 shows $\cos^2\beta$ dependences of the normalized magnitude of spin signal ($V_{NL4T}(\beta)/V_{NL4T}(0)$) under V_g of 10 V (blue dots) and 100 V (red dots). Red lines indicate fits by a theoretical function [1]. Anisotropy ratios are 0.99 ± 0.02 and 0.75 ± 0.02 in V_g of 10 V and 100 V, respectively, indicating synthetic Rashba-type spin–orbit coupling is indeed induced by strong gate voltage application [2]. A more detailed discussion will be given in the presentation.

[1] B. Raes *et al.*, *Nat. Commun.* **7**, 11444 (2016).

[2] S. Lee, M. Shiraishi *et al.*, *Nat. Mater*. https://doi.org/10.1038/s41563-021-01026-y (2021).