Silicene-Based Tunable Spin Electron Source of Nearly 100% Spin-Polarization under an Electrical Field

Spintronics has drawn tremendous attention in the past decade because of the high potential for spin transport electronics in the next generation semiconductor industry as well as for future quantum computing machines. Currently, one of the core topics in spintronics is how to efficiently generate a spin current of nearly 100% spin polarization. Earlier efforts concentrated on searching for magnetically doped semiconductors and half-metallic materials such as CrO_2, Fe_3O_4, $SrRuO_3$, and so on, in which only one spin channel is conducting with the other insulating. To date, however, most of the half-metals studied are magnetic materials and a large part of them are transition-metal oxides, making their adoption by the semiconductor industry difficult. Consequently, controllable non-magnetic spintronic devices are highly desirable.

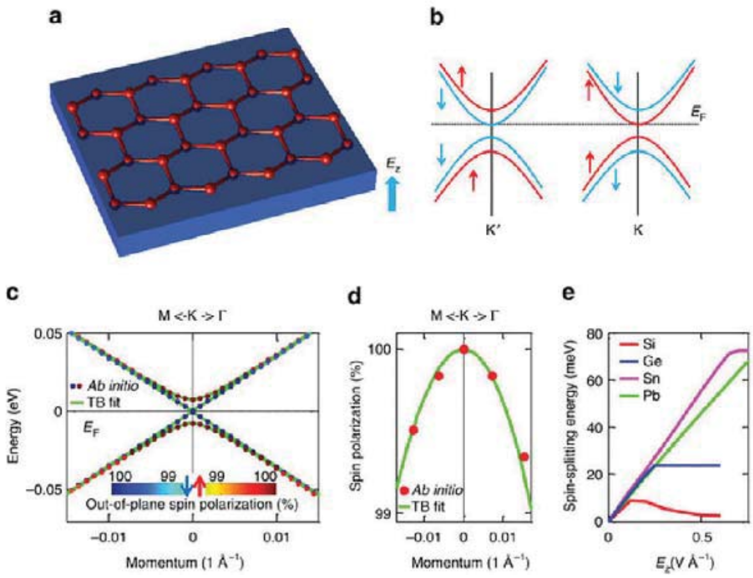

Fig. 1: Nearly fully spin-polarized states of silicene. a, Low-buckled 2D honeycomb structure of silicene. Due to the buckling, the inversion symmetry can be removed by an external out-of-plane electric field Ez or when the thin film is placed on a substrate. b, Schematic spin-resolved band structure of silicene around K and K' points in the presence of an out-of-plane electric field, Ez<Ec. The red and blue arrows indicate the spin direction. The band structure (c) and spin-resolved wavefunction (d) in the critical phase Ez=Ec. The tight-binding model (green lines) is seen to faithfully reproduce the band dispersion and the nearly 100% electron intrinsic spin polarization near the K-point obtained by first-principles calculations (red dots). e, The spin splitting energy for silicene, and Ge, Sn, Pb counterparts as a function of Ez obtained by first-principles calculations.

A team of researchers from Taiwan and Northeastern University, U. S., has proposed a new device to generate nearly 100% spin polarized electrons based on gated silicene. Silicene, a silicon version of graphene, is a one-atom-thick 2D crystal of silicon with a hexagonal lattice structure the same as that of graphene but with atomic bonds buckling rather than being flat (Fig. 1(a)). This buckling confers advantages on silicene over graphene because it generates both a band gap and polarized spin-states that can be controlled with a perpendicular electric field. Recently silicene has been synthesized. Using first-principles calculations, the research team predicts that field-gated silicene possesses two gaped Dirac cones exhibiting nearly 100% spin-polarization and are situated at the corners of the Brillouin zone. A design consequently is proposed for a silicene-based spin-filter that should enable the spin-polarization of an output current to be switched electrically without external magnetic fields. The quantum transport calculations indicate that the proposed designs will be highly efficient (nearly 100% spin polarization) and robust against weak disorder and edge imperfections. The authors also propose a Y-shaped spin/valley separator that produces spin-polarized current at two output terminals with opposite spins.

Reference

[1] W. –F. Tsai, C. –Y. Huang, T. –R. Chang, Hsin Lin, H. –T. Jeng & A. Bansil "Gated silicene as a tunable source of nearly 100% spin-polarized electrons" Nat. Commun. 4, 2525 (2013).