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Topological Electronic Structures and Spintronics Applications for Silicene and Other Spin-Orbit Thin Films[1]

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While spin-orbit coupling plays a critical role in generating topologically insulating phases, it also provides a novel route for realizing spin-split states in nonmagnetic materials without the need for exchange coupling. Two-dimensional thin films with significant spin-orbit coupling strength enable potential applications for spintronics devices because the spin-splitting energy can be controlled by an external field (gating). Moreover, spin-orbit coupling can induce nontrivial topological phases, i.e. quantum spin Hall phases, which could harbor back-scattering-free spin-polarized current at the edge. Recently, we have shown via first-principles calculations that field-gated silicene possesses two gapped Dirac cones exhibiting nearly 100% spin-polarization, situated at the corners of the Brillouin zone. Band gaps as well as the band topology can be tuned with an external electric field perpendicular to the plane, which breaks the inversion symmetry of the system due to the presence of buckling in the honeycomb structure. Using this fact, we propose a design for a silicene-based spin-filter that would enable the spin-polarization of an output current to be switched electrically, without the need to switch external magnetic fields. Our quantum transport calculations indicate that the proposed designs will be highly efficient (nearly 100% spin polarization) and robust against weak disorder and edge imperfections. We also propose a Y-shaped spin/valley separator that produces spin-polarized current at two output terminals with opposite spins. Ge, Sn, and Pb counterparts of silicene are shown to have similar properties, but their larger spin-orbit coupling results in larger energy differences between the spin-split states making these materials better suited for room temperature applications. Other spin-orbit thin films will be discussed. Our investigations demonstrate that spin-orbit thin films present great potential for manipulating spin/valley degrees of freedom efficiently, moving us a step closer to realizing the dream of spintronics applications.

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