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Exploring the unusual electronic and magnetic properties of the heterostructures based on 2D materials

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The monolayer of two-dimensional (2D) materials has the thickness of one to several atoms. They have reached the structural limit. The representatives are graphene, MoS2, phosphorene, B2Se3, WTe2, ZrTe5 and SnS. They exhibit different physical properties such as Dirac fermions, spin-valley-locking, ultrahigh mobility, non-trivial topological order, Weyl fermions and strong ferroelectricity compared to bulk materials. We study the physical properties of heterostructures based on 2D materials constructed by either van der Waals or in-plane routes. (i) The giant Stark effect is observed in phosphorene/carbon nanotube heterostructures and the band gap of the semiconducting heterostructures can vary several-fold in response to external electric field (Eext). Furthermore, strong ferromagnetism with Curie temperature above room temperature is predicted for intercalated heterostructures. (ii) Due to the strong spin-orbit-coupling, giant magnetocrystalline anisotropy energy with an easy out-of-plane magnetization is realized in the lateral phosphorene/WSe2 heterostructures. The heterostructures can be either half-metallic or metallic depending on the edges and sizes. (iii) The electronic properties of phosphorene/graphene heterostructure can be highly tunable by the quantum size effects and the Eext. At strong Eext, Dirac fermions can be developed with Fermi velocities around one order smaller than that of graphene. Undoped and hydrogen doped configurations demonstrate three drastically different electronic phases, which reveal the strongly tunable potentials of this type of heterostructure. Graphene is a naturally better electrode for phosphorene. The transport properties of two-probe devices of graphene/phosphorene/graphene exhibit tunneling transport characteristics.

Biography

Xiao Qing Tian is Associate Professor of Condensed Matter Physics in College of Physics and Energy, Shenzhen University, China. He has published more than 60 articles in different journals.

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