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“Designer” spin-orbit interaction in graphene on semiconducting transition metal dichalcogenides

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Inducing a large spin-orbit interaction (SOI) in graphene while preserving the Dirac nature of electrons is of great interest to create new topological insulating states and to study a variety of spintronic effects. Earlier work succeeded in inducing SOI at the expenses of destroying the Dirac spectrum or of increasing the amount of disorder. We show that a very strong SOI can be induced while preserving an extremely high quality of graphene simply by using semiconducting transition metal dichalchogenides (TMDs) as substrates. Being extremely flat and having no unsaturated bonds at their surface, layered van der Waals materials like WS2, WSe2, and MoS2 are ideal substrates that allow very large carrier mobility values to be reached in graphene. The magnitude of SOI in these TMDs is enormous, reaching a large fraction of an eV in the valence band. We find that using semiconducting TMDs as substrates allows the SOI to be “imprinted” into graphene. This is shown experimentally by the occurrence of a fully developed weak antilocalization correction to the conductivity, with no sign of weak localization, observed in 100% of the devices investigated, irrespective of the carrier mobility, position of the Fermi level, whether graphene is mono, bi, or trilayer, alignment of the TMD and graphene lattice, and of the specific TMD used. In addition, a splitting in the frequency of the Shubnikov-de Haas resistance oscillations show that the induced SOI is due to a modification of the graphene band structure. The gate dependence of this splitting shows that the dominant SOI term is of the Rashba type and that its magnitude is approximately 10-15 meV, nearly three orders of magnitude larger than the intrinsic SOI present in graphene. Work done in collaboration with Z. Wang, D.-K. Ki, H. Chen, J.H. Khoo, D. Mauro, H. Berger, A.H. MacDonald, and L.S. Levitov