Interface coupling and band topology in van der Waals materials

Kang L. Wang[1], Nai-Chang Yeh[2]
and Yingying Wu[1], Su Kong Chong[2]
[1]*Electrical and Computer Engineering, University of California, Los Angeles, Los Angeles, CA 90095, USA*
wang@ee.ucla.edu; [2]*Physics Departmetn, California Institure of Technology, CA 91125, USA*

Abstract
Van der Waals materials like graphene, transition metal dichalcogenides and topological insulators have been extensively investigated over the past decades due to their fascinating physical properties. The investigation of these materials and their heterostructures has spurred significant advances and new dimensions in modern materials research and nanotechnology. Among them, graphene-based heterostructures exhibit rich physics with exotic properties, which are promising for future electronic and spintronic devices. Spin splitting in graphene is required to develop graphene-based multifunctional spintronic devices with low dissipation and long-distance spin transport. Magnetic proximity effects are a promising route to realize exchange splitting in the material. By coupling graphene to an antiferromagnet, magnetism can be induced into graphene and a large exchange splitting energy around 134 meV can be obtained [1]. Besides antiferromagnets, graphene coupled to other 2D materials like transition metal dichalcogenides can enhance its spin-orbit coupling and result in a topological phase transition. Similarly, in a topological insulator, magnetism can be induced by magnetic doping and lead to the quantum anomalous Hall effect. By controlling the exchange energy of a magnetic-doped topological insulator *via* a perpendicular electric field, a reversible switching between topological and trivial insulating phases can be achieved. Additionally, strong electronic correlation can be induced in monolayer graphene by means of nanoscale strain engineering, leading to giant pseudo-magnetic fields (PMFs), flat bands and spontaneous symmetry breaking in graphene with periodic wrinkles [2]. Valley-Hall transistors built on such strained graphene are shown to demonstrate quantum valley Hall and quantum anomalous Hall effects with a range of Chern numbers in the absence of external magnetic fields. The topological phases and the underlying physics in all the aforementioned systems will be discussed.

REFERENCES

1. Yingying Wu, Gen Yin, Lei Pan, Alexander J. Grutter, Quanjun Pan, Albert Lee, Dustin A. Gilbert, Julie A. Borchers, William Ratcliff II, Ang Li, Xiao-dong Han & Kang L. Wang, Nature Electronics, 3, 604-611 (2020).
2. Chen-Chih Hsu, Marcus L. Teague, Jiaqing Wang & Nai-Chang Yeh, Science Advances, 6, aat9488 (2020).

FIGURES

Figure 1: (top) Large exchange splitting in a graphene/CrSe heterostructure. (bottom) Controlling the topological phase transition in a Cr-$(Bi,Sb)_2Te_3$ magnetic-doped topological insulator.