Fall 2015 Joint Colloquium
Materials Department & Materials Research Laboratory

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Friday, December 4th, 2015
11:00 am, ESB 1001

Pizza served afterwards.

Band structure engineering in van der Waals heterostructures

van der Waals heterostructures consist of layered stacks of two dimensional materials. Unlike 'grown' heterostructures, van der Waals heterostructures allow experimental control not only of the vertical stacking order but also of the rotational alignment between adjacent layers. I will discuss the most elementary such heterostructure, consisting of a double layer of graphene and its insulating isomorph, hexagonal boron nitride [1]. In the regime of large angular mismatch, the high purity crystalline hBN provides an ideal substrate for graphene, allowing us to access the intrinsic properties of this gapless semimetal. Using careful device design and large magnetic fields, we can tune the electronic structure of the graphene so that it transforms from gapless semimetal to a two dimensional topological insulator [2]. In this state, the two dimensional bulk of the graphene does not conduct, but current can be carried around the edge by helical edge states—one dimensional conductors in which the carrier spin is locked to the direction of propagation. By balancing the applied magnetic field against an intrinsic tendency of the graphene towards antiferromagnetic order, we can create a novel one dimensional conductor in which the band gap and associated spin texture can be tuned *in situ*.

At low twist angles, in contrast, the hBN substrate leads to a dramatic modification of the graphene band structure [3]. Graphene and hBN are not lattice matched, so that even at zero twist angle, the interplay between the lattices results in long-wavelength moiré patterns. The moiré pattern acts as a superlattice potential for the graphene electrons, leading to the formation of artificial Bloch minibands. More surprisingly, low twist angle heterostructures are found to be high mobility semiconductors, with gaps of order 50 meV. While the semiconducting behavior is not yet quantitatively understood, its origin can be traced to the breaking of the symmetry of the carbon sublattices in the graphene by the underlying hBN substrate.

References

[1] C. R. Dean, et al., *Nature Nanotechnology* **5**, 722-726 (2010)
[2] A.F. Young et al., *Nature,* **505** 528-532 (2014).
[3] B. Hunt**,** et al., *Science* **340** 1427-1430 (2013)

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