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Imaging and Spectroscopy of Graphene Heterostructures

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Graphene on hexagonal boron nitride (hBN) is an example of a van der Waals heterostructure where the electronic properties of the composite material can be different from either individual material. The lattice mismatch and twist angle between graphene and hBN produces a moiré pattern in STM topographic images. For all angles, we have observed that the surface roughness of the graphene is reduced by at least an order of magnitude as compared to graphene on silicon oxide devices. Near the charge neutrality point, graphene breaks up into a series of electron and hole puddles due to potential fluctuations. Using scanning tunneling spectroscopy, we have shown that at large twist angles the potential fluctuations are reduced by an order of magnitude by the presence of the hBN [1]. Using heterostructures with graphite gates underneath the hBN [2], we have observed even further reduction in the potential fluctuations. At small twist angles, the hBN substrate produces a weak periodic potential which can have a wavelength of up to 14 nm. This periodic potential creates a new set of superlattice Dirac points at the wavevector of the potential. As the relative rotation angle between the graphene and hBN changes, the energy of this superlattice Dirac point changes. These new superlattice Dirac points have a reduced and anisotropic Fermi velocity. Using gate voltage dependent scanning tunneling spectroscopy, we have observed the effect of the new Dirac points on the local density of states in graphene [3]. Our latest results on other graphene heterostructures will also be discussed.

[1] J. Xue et al., Nature Materials 10, 282 (2011).
[2] B. Hunt et al., Science 340, 1427 (2013).
[3] M. Yankowitz et al., Nature Physics 8, 382 (2012).