Interacting Dirac Fermions and Neutrino-Like Oscillation in Twisted Bilayer Graphene

Mei-Yin Chou[1,2], Lede Xian[1], Zhengfei Wang[1,3]

[1]School of Physics, Georgia Tech, Atlanta, 30332, USA
[2]Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei, 10617, Taiwan
[3]Department of Materials Science and Engineering, University of Utah, Salt Lake City, 84112, USA
meiyin.chou@physics.gatech.edu

Abstract

It has become possible in recent years to fabricate and manipulate two-dimensional nanomaterials in the laboratory that are as thin as one to few atomic layers. A well-known example is graphene, where the Dirac-Weyl Hamiltonian for massless fermions describes the low-energy quasiparticles. Intriguing physics has been found in these few-layer systems, and phenomena originally associated with particle physics can now be observed in condensed matter systems. In this talk, I will focus on our recent theoretical and computational studies of a few representative systems. In particular, the quasiparticle states in rotated bilayer graphene systems act as massless fermions with two "flavors", and interlayer coupling induces neutrino-like oscillations and anisotropic transport. The mixing between layer states and energy eigenstates due to interlayer coupling in twisted bilayer graphene is responsible for such oscillatory behavior. The quasi-particle oscillation takes place in a specific energy window in which wave packet transport is anisotropic. These two-dimensional atomic layer systems provide a unique platform to probe the rich physics involving multiple interacting massless fermions.

Figures

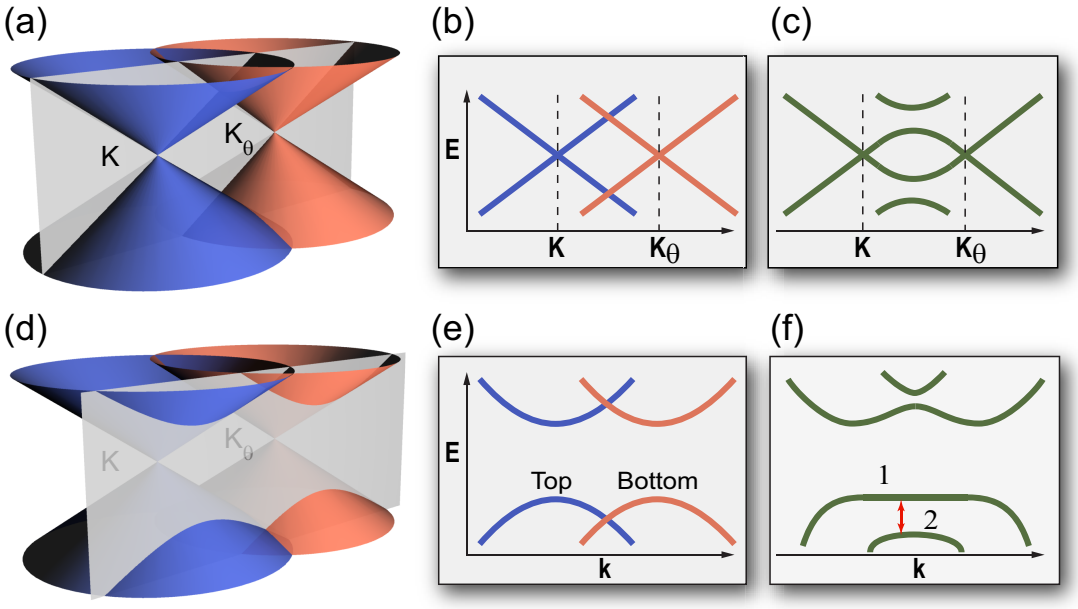

Figure 1. Schematic illustration of interlayer interaction in twisted bilayer graphene. (a) A plane cutting through the Dirac points of the two Dirac cones associated with the two twisted layers. The energy bands on the cross section shown in (a) are drawn in (b) and (c) for cases without and with interlayer interaction, respectively. (d) A plane cutting through the two Dirac cones without including the two Dirac points. The energy bands on the cross section shown in (d) are drawn in (e) and (f) for cases without and with interlayer interaction, respectively.

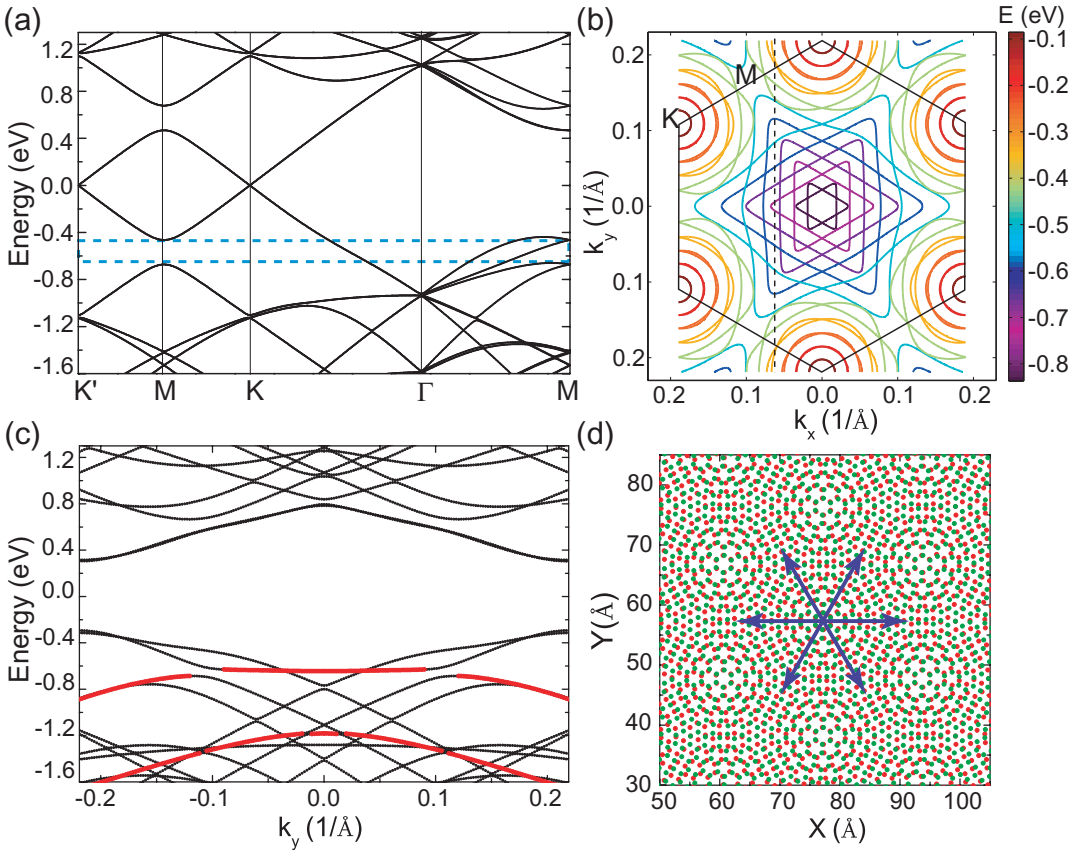

Figure 2. Electronic structure of twisted bilayer graphene with a twisted angle of 7.34°. (a) Band structure calculated by a tight binding model. The strong coupling energy region is highlighted by a blue dashed box. (b) Band contour of the top two valence bands in the first Brillouin zone. (c) Band structure along the dash line in (b). Flat bands are highlighted in red. (d) Atomic coordinates of the twisted bilayer system in real space with the arrows indicating the directions of wave packet propagation.