Exotic transport properties of monolayer and bilayer graphene

Ando T.

Department of Physics, Tokyo Institute of Technolocy
2-12-1 Ookayama, Meguro-ku, Tokyo 152-8551.Japan
e-mail: ando@phys.titech.ac.jp

Graphene, fabricated recently, has been attracting much attention since the observation of transport properties including the half-integer quantum Hall effect. The electron motion in graphene is governed by Weyl's equation for a neutrino or the Dirac equation with vanishing reSt mass characterized by a velocity which is about 1/300 of the light velocity. The pseudo-spin wave function exhibits a sign change due to Berry's phase when the wave vector is rotated around the origin and therefore has a topological singularity there. This singularity is the origin of the peculiar behavior in transport properties of graphene, such as the minimum conductivity in the absence of a magnetic field, the half-integer quantum Hall effect, the dynamical conductivity, and antilocalization behavior. A very singular diamagnetic response is another example.

There have been various theoretical and experimental investigations on dominant scattering mechanisms, including effects of charged impurities and environmental dielectric screening effect, resonance scattering effects due to strong and short-range scatterers, etc. A recent theoretical study showed that the minimum conductivity is sensitive to effective potential range of dominant scatterers in agreement with experiments. The appearance of effective vector potential due lattice distortion was recently demonstrated in deformed graphene.

Inter-layer interaction in bilayer graphene destroys the linear dispersion into an approximate parabolic dispersion with a trigonal warping. Electronic states of multi-layer graphene depend critically on the number of layers. This becomes clear if we consider only the major coupling terms and neglect other small parameters considered in bulk graphite. In fact, for odd-layer graphene, the Hamiltonian can be decomposed into those of bilayers with different interlayer coupling and that of a monolayer graphene, while for even-layer graphene, the Hamiltonian can be decomposed into those of bilayers only. This decomposition is quite useful for understanding main features of electronic states in multi-layer graphene. A perpendicular electric field or asymmetry between two layers opens up an energy gap in bilayer graphene. Interfaces between monolayer and bilayer graphenes were shown to exhibit peculiar dependence on incident angle, giving rise to valley polarization of transmitted electron, and characteristic Landau-level structure.