Optical Spectroscopy of Single and Multilayer Graphene

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Optical Spectroscopy provides a powerful tool to probe the structure and dynamics of electronic excitations in graphene. We first present results on the optical absorption of monolayer graphene in the infrared and visible spectral regions. Like the Manchester group, we find a flat absorption spectrum from 0.5 eV to the visible. The Magnitude of the absorbance is give by $\pi\alpha$ = 2.3 %, where α is the fine structure constant, as predicted by a simple theory of interband transitions. At lower photon energies, however, we can see clear departures from this universal absorption associated with the effect of finite carrier concentration.

We also have performed measurements on few-layer graphene samples. For low photon energies, we see the development of a more complex band structure and the onset of new interband transitions. We can understand the spectra in terms of a zone-folding scheme applied to the 3-D band structure of graphite. The case of bilayer samples is of particular interest. We show from spectroscopic measurements that the application of a strong dc filed across the bilayer can significantly alter its band structure, giving rise to a band gap as large as 200 meV. The possibility of producing graphene with a band gap is of considerable importance both for fundamental studies and applications.

Optical spectroscopy with femtosecond pulses also permits one to probe the dynamics of these excitations. After creation of electron-hole pairs by an ultrafast pump pulse, equilibration of the carriers among themselves and with strong-coupled optical phonons is found to occur on a sub-picosecond time scale, while full thermalization occurs on the picosecond time scale. On a still slower time scale, we observe heat flow from excited graphene layers into the substrate.