Electron Phonon Coupling Effects in Nanotubes

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Electron-phonon coupling (EPC) is a key physical parameter in nanotubes. Here we discuss its effects on phonon dispersions, Raman spectra and electron transport. The main EPC effect on the phonon dispersions is the presence of Kohn anomalies. These are distinct features of the phonon dispersion in metallic systems, associated to the presence of a Fermi surface [1]. Graphite has two Kohn anomalies for the Gamma-E_{2g} and K-A'_1 optical modes [2]. Their strength is proportional to the EPC square [2]. Kohn anomalies are enhanced in metallic nanotubes due to their reduced dimensionality, but absent in semiconducting nanotubes [2,3]. At 0 K all metallic nanotubes are not stable and undergo a Peierls distortion. We show that the Peierls distortion temperature decreases exponentially with the tube diameter [3]. For nanotubes generally used in experiments, with diameters larger than 0.8 nm, we find that this temperature is smaller than 10^{-8} K [3]. We then show that EPC is the major source of broadening for the Raman G and G^- peaks in graphite and metallic nanotubes [3]. The EPC explains the difference in the Raman spectra of metallic and semiconducting nanotubes and their dependence on tube diameter [3]. We dismiss the common assignment of the G^- peak in metallic nanotubes to a Fano resonance between phonons and plasmons. We assign the G^+ and G^- peaks to TO (circumferential) and LO (axial) modes, the opposite of what often done. We then present five independent approaches to directly measure the optical phonons EPC in graphite and nanotubes from their phonon dispersions and Raman spectra. This allows us to quantify the EPC effects on high field electron transport in nanotubes. High field measurements show that electron scattering by optical phonons breaks the ballistic behavior. From our EPCs we derive a simple formula for the electron mean free path for optical phonon scattering in high-field transport [4]. The comparison with the scattering lengths fitted from experimental I-V curves shows that hot phonons are created during high-bias transport [4]. Their effective temperature is thousands K and sets the ultimate limit of ballistic transport [4].

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