TERAHERTZ CONDUCTIVITY OF LOW-DIMENSIONAL CARBON NANOSTRUCTURES

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Low-dimensional carbon nanostructures – single-walled carbon nanotubes (SWNTs) and graphene – offer new opportunities for terahertz (THz) science and technology. Metallic SWNTs and graphene are zero-gap systems with a linear, photon-like energy dispersion, which leads to a plethora of exceptional properties, including unusual nonlinear and non-equilibrium electrodynamic properties that are expected for new THz device applications. THz dynamic conductivity measurements allow us to probe the dynamics of such photon-like electrons, or Dirac fermions. Here, we use THz time-domain spectroscopy and Fourier transform infrared spectroscopy (FTIR) to investigate THz carrier dynamics in films of highly-aligned CVD-grown SWNTs and large-area graphene grown from solid state carbon source.

Experimental results demonstrate extremely anisotropic THz conductivity in aligned SWNTs. When the THz polarization is perpendicular to the alignment axis, no absorption is observed, while there is strong absorption (OD ~ 1) when the polarization is parallel to the alignment direction. We Fourier-analyzed the data and determined the complex conductivity tensor elements of this one-dimensional electronic system. The real part of the parallel conductivity increases with increasing frequency, which disobeys the Drude model used to describe the free carriers in conventional conductors. After broadening the bandwidth via FTIR, it exhibits a peak in the FIR range, whose origin is currently under debate. Unlike SWNTs, the THz & FIR conductivity of graphene shows a Drude-like frequency dependence, through which the two important semiconductor parameters, mobility and Fermi energy, could be extracted out. We found that after thermal annealing, the Fermi level of graphene shifted toward the Dirac point. In addition, by applying an external gate voltage, we were able to electrically tune its Fermi level, which in turn modulated the transmission of THz waves.