ORIGIN OF THE TERAHERTZ ABSORPTION PEAK IN SINGLE-WALLED CARBON NANOTUBES

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Single-walled carbon nanotubes (SWNTs) are promising for high-frequency electronics and terahertz (THz) applications, as well as for fundamental studies of finite-frequency dynamics of one-dimensional electrons. Previous studies of dynamic conductivities of various types of SWNTs have revealed a pronounced and broad absorption peak in the THz frequency range, whose origin has been a matter of controversy. Both the effects of curvature-induced band gaps and plasmonic absorption due to finite lengths have been proposed to be important, but a consensus has not emerged. The curvature-induced band-gap scenario predicts several experimental signatures: (1) existence only in non-armchair "metallic" tubes, (2) strong tube diameter dependence of the THz peak position, (3) strong temperature dependence, and (4) suppressed by doping. On the other hand, the plasmonic absorption theory predicts that the peak should (1) be enhanced by doping and (2) exhibit a length dependence. Both of these theories predict the same polarization dependence. To examine all these signatures, we have studied the THz absorption peak in highly-aligned and length-controlled CVD grown SWNT films as well as highly metallic and semiconducting enriched SWNTs prepared via the density gradient ultracentrifugation (DGU) technique, through Fourier-transform infrared spectroscopy and THz time-domain spectroscopy.

Except the polarization dependence that can be interpreted by both theories, all other four signatures of the curvature-induced band gap scenario are disproved by our observations. Therefore, it can be ruled out from the candidate theories of the THz absorption peak. The plasmonic resonance theory is supported by the fact that the THz peak is enhanced by doping. However, no clear length dependence of the peak position was observed. Further investigations are needed for fully understanding the origin of this absorption peak.