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Interplay Between Transport and Optical Properties in Carbon Nanotube $p-n$ Diodes

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The $p-n$ junction diode is the basis for nearly all-modern semiconductor electronics. It is the basis for transistors and optical devices. For any new material system, therefore, a proper characterization of the $p-n$ junction is crucial for their development into electronic devices. In this talk, I will demonstrate the formation of $p-n$ junction diodes along individual single-walled carbon nanotubes (SWNTs). The $p-n$ junction is formed using a novel electrostatic doping technique using a pair of split gate electrodes, and can exhibit *ideal diode* behavior, the theoretical limit of performance for any diode. The low background leakage currents coupled with a built-in electric field region to transport the quasi-particles makes these diodes ideal for studying the optical response of SWNTs. I will show that the photocurrent spectroscopy of these diodes is able to provide a comprehensive probe of the excited states in SWNTs. A series of narrow excitonic resonant peaks is observed over a wide spectral range, including the first exciton peak (E_{11}), which defines the optical gap. At an intermediate energy the onset of continuum (electronic band gap) is observed and demonstrate large exciton binding energies. Because of the large exciton binding energies, the large photocurrent derived from E_{11} excitons is not expected. Here, I will describe several characteristics related to these peaks such as the origin of the quasi-particle (electron and hole) currents, quantum efficiency, and the role of many-body effects in determining the dark (ideal diode) and excited (excitonic) states of SWNTs.