Optical Spectroscopy of Carbon Nanotube *p-n* Diodes

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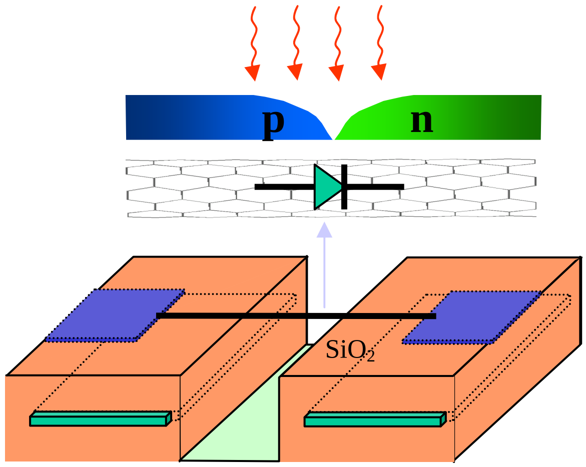

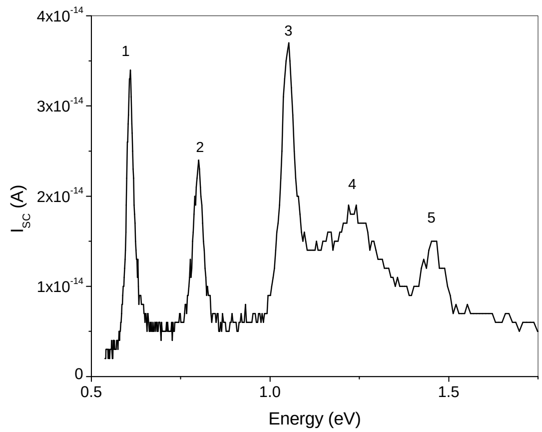

The *p-n* junction diode is the basis for nearly all-modern semiconductor electronics. It is the basis for most transistors and optical devices. The *p-n* structure is also useful for studying fundamental materials properties. Here, we show that a carbon nanotube *p-n* diode can provide a comprehensive probe of the optical and electronic transitions in SWNTs.

The *p-n* doping is achieved using a split gate structure that electrostatically dopes the two ends of a single nanotube. The resulting diode can exhibit an ideal diode behavior, the theoretical limit of performance for any diode. In the photocurrent spectra, an alternating sequence of resonant peaks from the dissociation of excitons and exciton-phonon bound states is observed, for the lowest and higher electronic subbands. At an intermediate energy, the onset of continuum is observed that allows measurements of exciton binding energies. The measured binding energies are large (>0.25eV), and both the binding energy and the onset of continuum follow the inverse diameter relation as expected from general theory of optical transitions in nanotubes.

In addition to the energy levels revealed in the photocurrent spectra, detailed transport measurements provide a complete set of energy levels of the *p-n* structure. Specifically, we demonstrate that bandgap renormalization, the shrinkage of the fundamental bandgap due to many-body exchange-correction properties of interaction electrons, dramatically alters the electronic structure, resulting in formations of heterointerfaces along a homogeneous material.