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Electrically-Induced Infrared Emission from Carbon Nanotube Devices

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The optical properties of carbon nanotubes (CNTs) are currently the focus of intense study. CNTs are direct band gap materials and their optical spectra have long been attributed to transitions between free particle bands. We show that studies of electrically-excited infrared (IR) emission from single nanotube molecules provide new insights into the electron-hole interactions in quasi-1D systems. We demonstrate strongly-enhanced electroluminescence from a partially suspended CNTFET operated under unipolar transport conditions [1]. In our devices, carriers are generated locally, when a single type of carrier is accelerated under high local electric fields at intra-molecular junctions to energies sufficient to create strongly correlated e-h pairs (excitons). This excitation mechanism contrasts with emission from radiative recombination of carriers (electrons and holes) injected from the opposite ends (source and drain) of a CNTFET operated under ambipolar transport conditions. The new excitation mechanism is about 1000 times more efficient than recombination of independently injected electrons and holes, and it results from weak electron-phonon scattering and strong electron-hole binding caused by one-dimensional confinement. We show that the light emission intensity increases exponentially with the drive current in partially suspended CNTFETs, while in 3D materials light emission is usually proportional to the product of the electron and the hole currents. The strong Coulomb interaction between electrons and holes in a 1D CNT creates bound excitons whose binding energies are more than an order of magnitude larger than those in 3D materials, preventing them from dissociating under electrical fields thus contributing little to drive current compared with that in 3D. Finally, the much higher exciton density achieved in our devices than that in typical photoluminescence experiments allows us to detect emission from higher excitation states in CNTs.

[1] J. Chen, V. Perebeinos, M. Freitag, J. Tsang, Q. Fu, J. Liu, Ph. Avouris, *Science* 310, 1171 (2005).

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