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Abstract

Optoelectronics with Carbon-Nanotube Devices

By

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The carbon nanotube is a promising material for future micro- and nano-scale electronics because of its unique electronic properties, high carrier mobility and extraordinary capacity for high current density. In particular, semiconducting carbon nanotubes are direct bandgap materials with a typical energy gap in the order of 1 eV, which means they emit light in the near-infrared range, making them an attractive option in telecommunications applications. However, there have been few systematic investigations of electrically-induced light emission (i.e. electroluminescence) from carbon nanotubes, and their emission properties are not well understood.

In this dissertation, we explore the characteristics of electroluminescence in three different types of carbon-nanotube devices. The first is a single-tube field-effect transistor (CNTFET), whose emission has previously been found to have a very broad spectral shape and low emission efficiency. We analyzed the spectral shape in detail and found that a high electric field near metal contacts contributes most to the bias-dependent component of broadening, in addition to smaller contributions from tube nonuniformity, collisions with phonons, high temperature, etc.

In the second part of the study, single-tube light-emitting diodes were constructed by employing a split top-gate scheme. The split gate creates p- and n-doped regions electrostatically, so that electrons and holes combine between the two sections and can decay radiatively. This configuration created electron-hole pairs under much lower electric fields and gave us a greater control over carrier distribution in the device channel, resulting in much narrower spectral linewidths and an emission intensity several orders of magnitude larger than that of CNTFETs.

Finally, we extended the idea of the single-tube p-n diode and fabricated CNT film diodes from many purified tubes aligned in parallel. While the operating principle is somewhat different from that of single-tube diodes because of the presence of metallic tubes in the material, the film diodes nonetheless showed a rectifying behavior and much greater light intensity than single-tube devices. With their superior light output and robustness, they bring us one step closer to a real-world application of carbon nanotubes in optoelectronics.

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