

ELECTROLUMINESCENCE IN CARBON NANOTUBE NETWORK FIELD-EFFECT TRANSISTORS

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Since the first report in 2003 [1], the electroluminescence properties of carbon nanotube field-effect transistors (FETs) have been explored with channels made of individual and bundle of carbon nanotubes (CNT) deposited on oxide layers or suspended over trenches. [2,3] These studies revealed electroluminescence from both ambipolar as well as unipolar p-type FETs. Two possible emission mechanisms have been proposed: direct bipolar recombination and impact excitation. [1,2] More recently, light emission from metallic nanotubes has also been reported and emission was discussed in terms of a thermally driven mechanism. [4,5] So far, there has been no report on the electroluminescence properties of CNT networks.

In this work, we explore the light emission properties of carbon nanotube network FETs. The channels consist of carbon nanotubes taken from different nanotube sources (laser ablation and CVD) and assembled in thin layers at densities near the metallic percolation threshold. We show that the emission of unipolar p-type network FETs is located at the drain (see figure below). This behavior is similar to what was already measured in long and individual nanotube FETs [6] and suggests that the emission involves bipolar recombination. Impact excitation thus appears to be negligible in those network FETs. Moreover, the light emission spectra show large resonance peak emission (~180 meV) that is consistent with excitonic radiation processes in CNTs. By comparing the spectra linewidths of the network FETs with that of individual carbon nanotubes (~80 meV), we proved that many nanotubes having different diameters emit simultaneously in network devices.

In order to investigate the population of CNTs that contributes to electroluminescence of network FETs, we compared the emission spectra of different sources with that of their corresponding absorption spectra. The figure below shows typical electroluminescence spectra and their corresponding absorption spectra for two sources (laser ablation and CoMoCAT). These results show an important red-shift between the emission maximum compared to that of the absorption spectrum, which is explained by energy or carrier transfer to the large diameter carbon nanotubes. [7] This important conclusion was also confirmed for network FETs made with double-wall carbon nanotubes. For the latter, additional peaks are also observed at higher energy. Possible explanations on the origin of this will be discussed.

Last, we also perform experiments on bundle FETs consisting of a mixture of metallic and semiconducting CNTs on an oxide. Our measurements revealed that only semiconducting carbon nanotubes produce a significant electroluminescent signal. To investigate further light emission of metallic nanotubes, we fabricated thick (100 nm) metallic carbon nanotube films. We observed that the spectral light emission response of these films is consistent with classical blackbody emission.

References:

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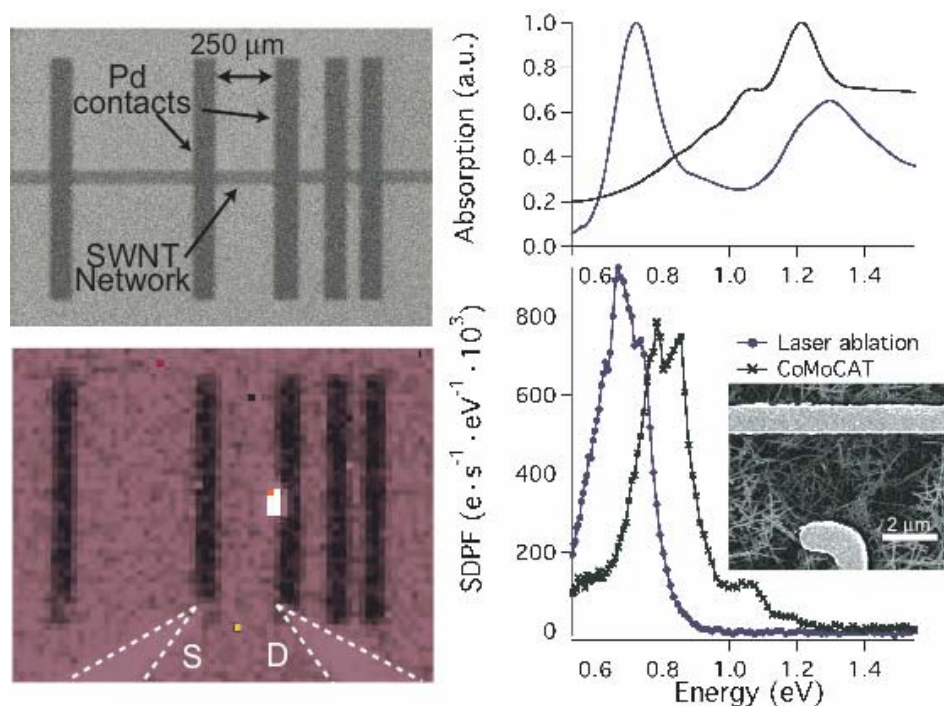


FIGURE Left-Top: SEM images of a long channel (250 μm) network FET made from laser ablation nanotubes. The width of the SWNT network is 100 μm. Left-down: near-infrared image of the light emission in a typical long channel unipolar p-type transistor. The light emission zone is always located at the drain (D) contact region. Right-Top: Absorption spectra recorded from networks made with CoMoCAT and laser ablation sources. Right-Down: corresponding electroluminescence spectra of the networks FETs from the same CNT sources. These spectra were acquired for $t_{\text{exp}}=2$ min using $V_d = -25$ V, $V_g = -20$ V and $V_d = -55$ V, $V_g = -20$ V for the laser ablation and CoMoCAT spectra, respectively. The electrode spacing is 3 μm for the laser ablation network and 1 μm for the CoMoCAT network device. Insets: SEM image of the device made with laser ablation nanotube.