**Characterization of Carbon Nanotubes Grown Directly in a Field Emission Electron Microscope**

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We have recently shown that individual single wall carbon nanotubes (CNTs) can be grown on metallic tips in a field emission microscope (FEM) which allows direct observation from the nucleation stage till the end of the growth [1]. In this talk I will review our progress with this synthesis method and discuss the comportment of the as-grown CNTs as field emission sources and nano-mechanical oscillators.

The growths are carried out in extremely low pressures of ~$10^{-7}$ Torr of acetylene which gives the lowest recorded growth rates of ~0.05 nm/sec and the possibility of interactive control of the growth rate by varying the pressure and temperature. The most notable fact is that the CNTs most often rotate axially during their growth, thus supporting a proposed 'screw-dislocation-like' (SDL) model [2]. Detailed analysis shows that we directly observe the insertion of individual carbon dimers at the CNT base [1] which causes a rotation of the CNTs and corresponding FE patterns. The growths tend to terminate abruptly likely due to catalyst poisoning when the nanotubes are in the 30-200 nm range. The CNTs on tips are quite unique as mechanical oscillators and field emission sources.

The mechanical resonances of these singly clamped nanotubes can be measured directly in-situ by observing the enlargement of the FE pattern when in resonance [3]. Vibration frequencies $\upsilon_0$ up to 2 GHz and estimated Q factors up to 25800 have been measured at room temperature [3]. These CNTs have the largest mechanical figure of merit M, defined as $M = Q\upsilon_0/V$ at room T where V is the volume of the cantilever.

FE voltages as low as 80 Volts and FE currents up to 3 µA can be achieved, the later appearing to be a record for SWNTs. Interestingly, we observe clear evidence of the influence of Coulomb blockade on the I(V) characteristics depending on the CNT length.

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