

Strain Measurements for Single-Walled Carbon Nanotubes in Film and Solution States by Photoluminescence

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In this abstract we describe photoluminescence (PL) studies as a function of temperature on nanotubes both dispersed in solution with the surfactants polyvinylpyrrolidone (PVP) and Surfactin, and for dry drop cast films of PVP-wrapped nanotubes. Significant differences are observed between the solution and film samples due to the differing effects of strain.

The electronic structure of single-walled carbon nanotubes (SWCNTs) can be modulated by covalent functionalization, chemical doping, gas absorption or encapsulation of molecules or crystals inside the tubes. Mechanical deformation of nanotubes is another attractive idea since it allows us to reversibly and rapidly control bandgaps without changing their bonding or charge state. It has been shown theoretically that the strain-induced bandgap shifts depend strongly on the nanotube chiralities and their magnitudes vary monotonically with chiral angle [1]. Experimentally, we have shown that photoluminescence (PL) can be used to probe the strains produced by solution freezing and polymer swelling and hence deduce tube chirality [2].

Room temperature PL spectra for the drop cast film show distributions of strong spectral peaks with positions shifted in energy relative to those observed in the solution samples. The distribution of spectral peaks indicates the presence of suspended individual SWCNTs, with the shift in energy attributed to an increased strain brought about by the drying effect in creating the drop cast film. Both solution and film samples show comparable PL signals on cooling to 4K and exhibit further shifts in the PL positions by as much as 30meV. Comparisons of the PL peak shifts with temperature shows considerable differences between the solution and film samples. The fitted strains induced by the environmental change for the surfactin- and PVP-wrapped HiPCO SWCNTs (from Carbon Nanotechnologies) are found to be predominantly uniaxial, indicating the strains are not strongly surfactant dependent but are due to the different rates of thermal expansion in SWCNTs and ice [3]. In contrast the SWCNTs in the dried PVP-polymer matrix experience significantly larger strains, with a substantial increase in the torsional stress component in particular. This result demonstrates that modification of the environment surrounding the tubes (ice vs polymer) can be used to control the magnitude and the character of the strain applied to the tubes.

References

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