

fractions are presented in FIG. 9. The projected lengths of a given fraction tend to decrease with additional processing, such as with the concentration of like fractions or dialysis to remove the dense media, after the initial separation, despite most fractions being concentrated enough such that subtraction errors in the UV-Vis spectrum should be negligible. This is discussed in greater detail herein.

[0103] The length of the separated fractions was also determined using DLS, in VH scattering mode, from the extrapolated intercept at zero scattering vector for the inverse rotational relaxation time, which is equal to six times the rotational diffusion coefficient:

$$D_r = 3k_B T \left(\frac{\ln(\ell/2r) - 0.8}{\pi r \ell^3} \right). \quad (7)$$

The measured scattering for the fractions shown in FIG. 7 were plotted. The DLS experiment was repeated at a reduced, e.g. approximately one-third SWCNT concentration to look for any SWCNT concentration effects. The SWCNTs were found to behave similarly at the reduced concentration, indicating that the SWCNT concentration is not strongly affecting the effective size of the SWCNTs in the dispersion.

[0104] Specifically, referring to FIG. 8, values are shown for the UV-Vis-NIR projected length for the initial fractions as extracted from the tube and after centrifugal concentration, and then dialysis to remove the iodixanol, and as measured by AFM and DLS for fractions separated at 1257 Rad/s. Concentration and dialysis, necessary for DLS and AFM, both appear to modify slightly the average length of the SWCNTs remaining in solution. However, for UV-Vis-NIR projected average length values measured after these processes, the agreement with the AFM and DLS values is excellent. Error bars (1 standard deviation) are based on the instrument error and a 5% error in the slope of equation (7) for the UV-Vis-NIR projections; error bars for AFM were calculated from the counted SWCNTs.

[0105] AFM values are based on contour lengths measured for approximately 150 SWCNTs for each fraction. Images of several of the 1257 rad/s separated SWCNT fractions shown in FIG. 8 are presented in FIG. 9. The typical variance in the average length is approximately 20% for each of the measured fractions. The values measured using AFM show reasonable agreement to the values obtained via Equation (6) and from DLS. The differences may be explained by systematic difficulties in under-counting longer SWCNTs in AFM, as they tend to overlap other SWCNTs, and the length weighting of the UV-Vis-NIR and DLS techniques. Specifically, the difficulty in depositing individualized SWCNTs for imaging in AFM may affect the observed average length if there is preferential attachment or rearrangement on the surface with length, and from the increased likelihood that longer SWCNTs will overlap other SWCNTs in an image and thus not be counted. Specifically, as shown in FIG. 9, AFM images on mica of selected length separated SWCNT fractions are presented from the separation depicted in FIG. 7. These fractions were concentrated, and then dialyzed to remove the remaining iodixanol polymer and excess surfactant prior to deposition for imaging.

[0106] The change in the strength of the optical transitions, but not in the type distribution of the SWCNTs is observable both in the UV-Vis-NIR absorbance spectra, and in the NIR

fluorescence of the SWCNTs. Absorbance spectra, scaled by the value of the background subtracted absorbance at 775 nm, is plotted in FIG. 10A for the S-P95-02 grade CoMoCats shown in FIG. 7; the NIR fluorescence from E_{22} excitation of the unsorted CoMoCat SWCNTs, and fraction 6 of the separated material are shown in FIGS. 10B and 10C respectively. In both FIGS. 10B and 10C, it is clear that the relative distribution of the peaks changes insignificantly, despite the large increase in the intensity of the features in the longer fractions.

[0107] Specifically, in FIG. 10A, scaled absorbance spectra of the length sorted nanotube fractions shown in FIGS. 7 and 8 is shown. Below 400 nm and above 1200 nm the curves are affected by the absorption of the density medium. The strength of the intrinsic SWCNT optical features increases strongly with the SWCNT length, whereas the relative sizes of the features to each other do not change significantly across the fractions. These results indicate length separation without chirality separation. The absorption spectra for the SWCNT mixture prior to separation (dashed spectra) is also shown. In FIGS. 10B and 10C, NIR fluorescence contour plots are shown for the very dilute dispersions of unsorted SWCNTs (FIG. 10B), and fraction 6 from the 1257 Rad/s separation shown in FIGS. 7. The scale bars in FIGS. 10B and 10C indicate the real intensity increase in the fluorescence with the length separation. The relative sizes of the feature being unchanged indicates that no preferential type separation is occurring.

[0108] Given the high resolution of the SWCNT fractions generated by the 1257 Rad/s separation, as demonstrated in the previous figures, significant additional characterization of those fractions was performed. Dialysis of the separated fractions to remove the iodixanol allows for resonant Raman interrogation of the fractions without the presence of the richly featured iodixanol Raman scatter.

[0109] FIG. 11 illustrates Raman scattering from fraction 9, after dialysis to remove the iodixanol, of the 1257 Rad/s sorted CoMoCat fractions presented in FIGS. 7-12. The excitation wavelength was 514.5 nm. Strong features due to the RBMs, G, G', iTOLA, M⁺, and M⁻ bands are clearly visible. The D band is measurable at 1328 cm⁻¹, but is insignificant on the scale of the figure. The G/D band ratio is approximately 250:1 for fraction 9. Due to partial excitation of the metallic-type SWCNTs in the CoMoCat sample, some Breit-Wigner-Fano broadening of the G band is observed. The noise is less than the line thickness. A small background contribution, which did not affect the relative feature size, was subtracted.

[0110] Dialysis of the separated fractions also allows for the interrogation of the absorbance in the UV spectrum. In FIG. 12, the absorbance features attributable to the E_{33} excitation clearly become stronger and more distinct, as well as the E_{11} and E_{22} features, with the increase in the SWCNT length. The longer fractions are distinctly colored due to the large E_{22} features relative to the baseline absorbance in the visible region.

[0111] Specifically, FIG. 12 illustrates scaled absorbance spectra of length sorted fractions 9, 10, 11 and 13 after concentration and dialysis to remove the iodixanol density media. The SWCNT optical transitions are clearly increased by the length separation, whereas the π -plasmon type absorption is much less sensitive to the SWCNT length. E_{11} , E_{22} , E_{33} and overlapped E_{44} optical transitions are observed.

[0112] As in FIG. 10A, it can be seen in FIG. 12 that the relative distribution of chiralities in the sample is not significantly altered by the length separation process. Chirality