De-Roping of Carbon Nanotube Bundles

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Personal Details
After successfully completing three years at DIT Kevin Street, I graduated with the Technician Diploma in Applied Science (Physics Option) for which I was awarded a Distinction. Following this I decided to further my studies and pursue a Degree in Physics & Physics Technology. My main areas of academic interest include nuclear physics, biophysics, acoustics, solid-state physics and the physics of materials. Outside of college my hobbies would include tennis, reading, cinema and socialising.

Project Summary
Carbon nanotubes were first discovered by the Japanese electron microscopist S. Iijima in 1991. Since their discovery extensive research has been carried out in laboratories all over the world. Single-Walled Carbon Nanotubes (SWNTs) have an impressive list of attributes. They can behave like metals or semiconductors, can conduct electricity better than copper, can transmit heat better than diamond and they rank amongst the strongest materials known. SWNTs can be considered as one-dimensional structures because of their large length to diameter ratio. The length of a carbon nanotube is on the micron scale and the diameter of nanotubes typically ranges between 0.7nm and 2nm (1nm is about 1 ten-thousandth the diameter of a human hair). Carbon nanotubes are formed when a graphene sheet, which is a single atomic layer of graphite, is curled into a cylinder and the carbon atoms join seamlessly to each other.

As carbon nanotubes form, they typically aggregate into bundles, termed ropes, which consist of SWNTs held together by weak van der Waals attractive forces. For successful applications of carbon nanotubes the exfoliation of nanotube bundles into individual tubes is necessary (see figure 1).

The aim of this project was to use solvents and surfactants combined with ultra-sonication techniques to separate the tubes from their aggregated bundles. Raman spectroscopy was used as the principle diagnostic tool for determining any debundling that may have occurred.

Raman spectroscopy is a form of vibrational spectroscopy and is the dominant experimental technique used for studying SWNTs, as it is able to probe and characterise nanostructures. The spectrum for the SWNT is a simple and well-established Raman signature, which makes it easy to examine. Regardless of the tube type (semi-conducting or metallic), the net result of debundling is an apparent up-shift in the RBM frequency for SWNTs using the same excitation frequency.

Figure 2, shows the Stokes spectra for the variation between the raw HiPco sample and those that were treated with solvent at excitation energy of 488nm. From theory it is known that ultra sonication with the addition of solvent causes the tubes within a sample to become more dispersed. The solvent influences the stability of the dispersed tubes in the system. From figure 2, it can be seen...
that the G-line of the raw HiPco sample displays both metallic and semiconducting properties whereas the treated samples display only semiconducting properties. An explanation for this could be that the solvent is dissolving only the semiconducting tubes. If the solvent dissolved the semiconducting tubes, these tubes would remain at the surface of the solutions whereas the metallic tubes would fall to the bottom. The samples that were drop cast onto the glass slides for Raman analysis where all removed from the surface of the solutions.

Figure 3 shows the Stokes region RBM of both the raw and treated HiPco tubes. The spectral shape of the RBM for the raw sample is quite similar to that of the sample dissolved in ethanol, but upshifted. The dominant peak of the raw sample occurs at 202cm\(^{-1}\) and the dominant peak of the sample dissolved in ethanol occurs at 205cm\(^{-1}\) indicating that the ethanol did cause some dispersion of the bundles to occur. The shape of the RBM for the nanotubes in toluene differs considerably from the raw sample but there is an observable upshift in the lower peak. The lower peak for the raw untreated sample occurs at 162cm\(^{-1}\) and the lower peak for the sample dissolved in toluene has been upshifted to 171cm\(^{-1}\); this again shows that some debundling did occur.

Similar behaviour could be seen between the raw HiPco tubes and the solvent treated tubes at other wavelengths. Debundling was also seen in the surfactant treated tubes at each of the laser wavelengths employed. The overall conclusion that can be taken from this project is that Raman spectroscopy can be used to detect debundling within SWNT samples.