The effect of trigonal warping on resonance Raman excitation of DWCNTs

R. Pfeiffer[1], Ch. Kramberger[1], H. Kuzmany[1], and H. Kataura[2]
[1] Institute of Materials Physics, Vienna University Strudlhofgasse 4, A-1090 Wien, Austria
[2] Department of Physics, Metropolitan University Tokyo Tokyo, Japan

Single-walled carbon nanotubes (SWCNTs) filled with C_{60} fullerenes, so-called C_{60} peapods, were heated to about 1300 °C for several hours in a dynamic vacuum to produce double-walled carbon nanotubes (DWCNTs). In this way it was possible to transform the C_{60} cages into thin SWCNTs inside an unperturbed environment in the interior of the outer SWCNTs. Fig. 1 shows a HRTEM image of our DWCNT sample. Two crossed DWCNTs are easily observable.

A characteristic feature in the Raman spectra of carbon nanotubes is the radial breathing mode (RBM) of the tubes which scales in frequency inversely proportional to the diameter. Similarly, the transistion energies between the van Hove singularities scale, in general, also inversely with the tube diameter. The spectra of the DWCNTs show the RBMs of the outer tubes around 180 cm^{-1} while the RBMs of the inner tubes can be observed between 250 cm^{-1} and 400 cm^{-1}. Due to the diameter distribution the RBM of the outer tubes is smeared out and no RBM of a single tube can be seen. Since the inner tubes are thinner there are less possible diameters and one can observe sharp RBMs of single tubes.

In this work we concentrated on the resonances of the RBMs of the inner tubes when excited with different lasers within a small energy range. For this we used a dye laser with a Rhodamin 6G dye as the active medium. Between 2.182 eV and 2.000 eV eleven spectra were recorded. From these spectra one can see that the various RBMs show very sharp resonances.

The most striking result is that the resonance maximum of the RBM of the (7,3) tube with diameter 0.70 nm and RBM frequency at 346 cm^{-1} occurs for smaller excitation energies than the resonance maximum of the thicker (8,3) tube with diameter 0.77 nm and RBM frequency at 316 cm^{-1}. This observed unexpected behavior is explained by a trigonal warping effect.

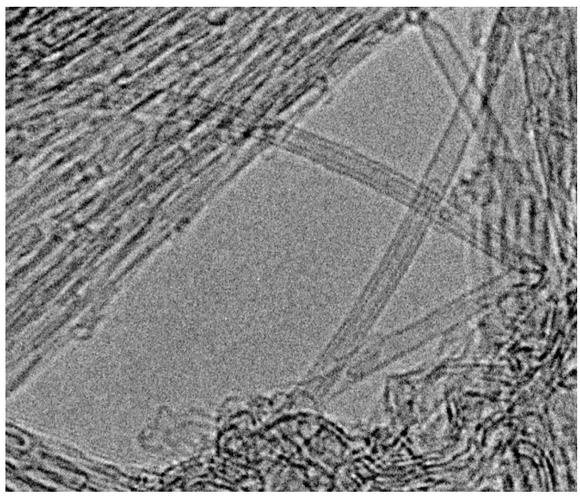

Fig. 1. HRTEM image of our DWCNT sample. One can see two crossed DWCNTs within a rather clear area.