AN 446
Study of Carbon Nanotubes by Resonant Raman Spectroscopy

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Introduction

Carbon nanotubes have attracted the interest of the nanotechnology scientific community since they can be semiconducting or metallic, based on their structure. The physical structure is usually characterized by the chirality of the nanotube (i.e. does it curve clockwise or counterclockwise). Conventially, the chirality can be described by the two integers (n, m) that specify the chiral vector, or equivalently by two other related parameters: the diameter of the nanotube (d_t) and the chiral angle θ.

Discussion

Resonant Raman spectroscopy with visible light is able to non-destructively determine the diameter of a single walled carbon nanotube (SWNT) by measuring the frequency of the vibration of its radial breathing mode (RBM) ω_{RBM}. The RBM frequency, ω_{RBM}, is related to the SWNT diameter d_t, by the formula:

$$d_t = 248/\omega_{RBM} \qquad (1)$$

In the literature it has also been shown theoretically, using the theory of resonant transitions, that the chirality (n,m) can be uniquely determined using Raman spectroscopy without the need for additional experimental measurements. The integers n and m also define the electronic properties of the SWNT, thus Raman spectroscopy is fully capable of determining the dimensions and metallic or semiconducting properties of SWNTs, even in an assembled device.

Figure 1 shows a Raman spectrum from a collection of SWNTs, acquired using 514.5nm excitation from an Ar^+ ion laser. In addition to the D-band, the G-band and the second order G'-band, the radial breathing mode (RBM) bands are shown in the low frequency region at 169cm^{-1} and 218cm^{-1} (see inset).

The observation of two RBM bands means that two distinct types of SWNTs were present in the volume probed by the laser (typically in the range of 1μm^3). The diameters of the SWNTs were calculated using equation (1) and were determined to be 1.46nm and 1.13nm, respectively. Theoretical calculations demonstrate that the SWNT with an RBM vibration at 169cm^{-1} (d=1.46nm) has a chirality (n, m) = (16, 4). This is metallic in nature (n-m is a multiple of 3). The SWNT with an RBM vibration at 218cm^{-1} (d=1.13nm) has a chirality (n, m) = (10,6) and is semiconducting (n-m is not a multiple of 3).

Raman spectroscopy can be an indispensable tool for the characterization of carbon nanotubes, both in the tube manufacturing process and also after the tubes are incorporated into actual devices.

(1) A. Jorio *et al*, Phys. Rev. Lett. **86**, 1118, (2001)

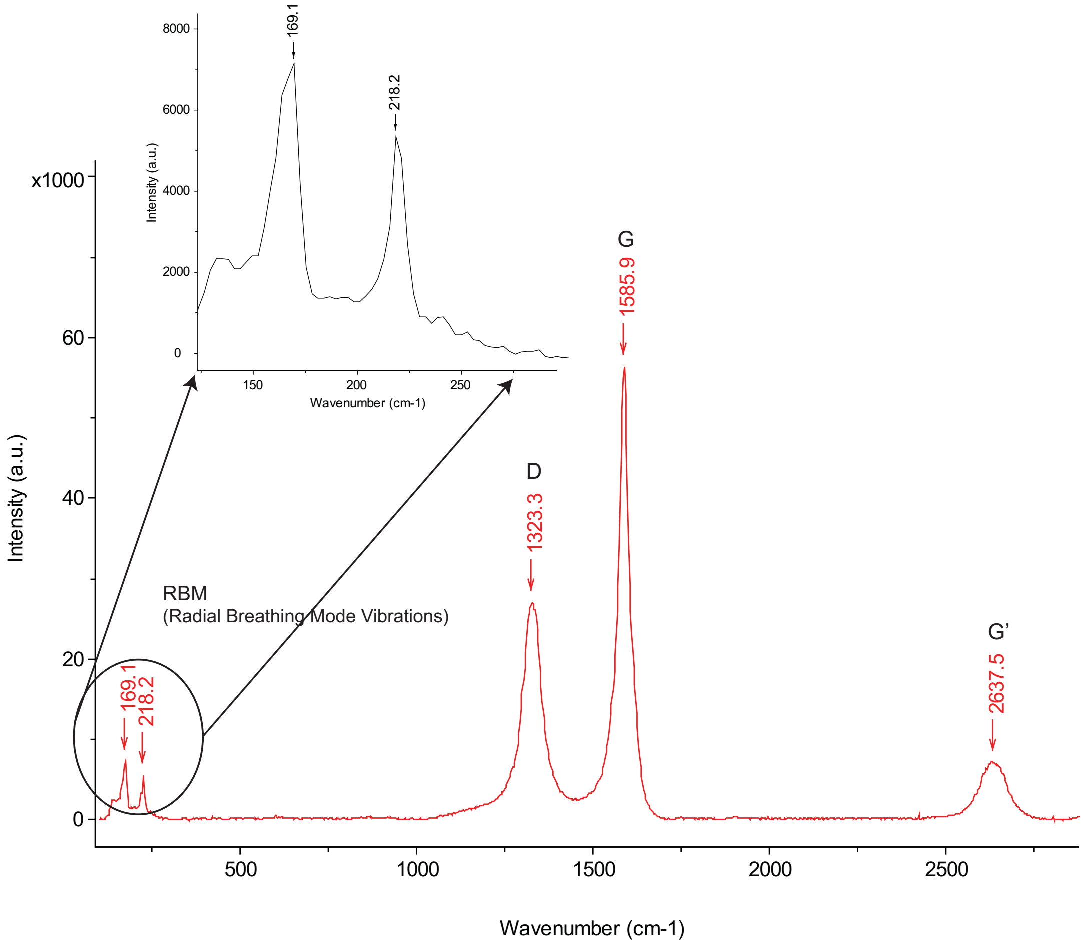

Figure 1. Raman spectrum from carbon nanotubes showing the presence of two different diameter tubes.