Optical properties of carbon nanotubes

Within materials science , the optical properties of carbon nanotubes refer specifically to the absorption , photoluminescence (fluorescence) , and Raman spectroscopy of carbon nanotubes . Spectroscopic methods offer the possibility of quick and non @-@ destructive characterization of relatively large amounts of carbon nanotubes . There is a strong demand for such characterization from the industrial point of view : numerous parameters of the nanotube synthesis can be changed , intentionally or unintentionally , to alter the nanotube quality . As shown below , optical absorption , photoluminescence and Raman spectroscopies allow quick and reliable characterization of this " nanotube quality " in terms of non @-@ tubular carbon content , structure (chirality) of the produced nanotubes , and structural defects . Those features determine nearly any other properties such as optical , mechanical , and electrical properties .

Carbon nanotubes are unique " one @-@ dimensional systems " which can be envisioned as rolled single sheets of graphite (or more precisely graphene) . This rolling can be done at different angles and curvatures resulting in different nanotube properties . The diameter typically varies in the range 0 @.@ 4 ? 40 nm (i.e. " only " ~ 100 times) , but the length can vary ~ 10 @,@ 000 times , reaching 55 @.@ 5 cm . The nanotube aspect ratio , or the length @-@ to @-@ diameter ratio , can be as high as 132 @,@ 000 @,@ 000 : 1 , which is unequalled by any other material . Consequently , all the properties of the carbon nanotubes relative to those of typical semiconductors are extremely anisotropic (directionally dependent) and tunable .

Whereas mechanical , electrical and electrochemical (supercapacitor) properties of the carbon nanotubes are well established and have immediate applications , the practical use of optical properties is yet unclear . The aforementioned tunability of properties is potentially useful in optics and photonics . In particular , light @-@ emitting diodes (LEDs) and photo @-@ detectors based on a single nanotube have been produced in the lab . Their unique feature is not the efficiency , which is yet relatively low , but the narrow selectivity in the wavelength of emission and detection of light and the possibility of its fine tuning through the nanotube structure . In addition , bolometer and optoelectronic memory devices have been realised on ensembles of single @-@ walled carbon nanotubes .

Terminology

This article uses the following abbreviations :
Carbon nanotube (CNT)
Single wall carbon nanotube (SWCNT)
Multiwall carbon nanotube (MWCNT)
However , C is often omitted in scientific literature , so NT , SWNT and MWNT are more commonly used . Also , " wall " is often exchanged with " walled " .

Electronic structure of carbon nanotube

A single @-@ wall carbon nanotube can be imagined as graphene sheet rolled at a certain " chiral " angle with respect to a plane perpendicular to the tube 's long axis . Consequently , SWCNT can be defined by its diameter and chiral angle . The chiral angle can range from 0 to 30 degrees .

However , more conveniently , a pair of indices (n , m) is used instead . The indices refer to equally long unit vectors at 60 ° angles to each other across a single 6 @-@ member carbon ring . Taking the origin as carbon number 1 , the a1 unit vector may be considered the line drawn from carbon 1 to carbon 3 , and the a2 unit vector is then the line drawn from carbon 1 to carbon 5 . (See the upper right corner of the diagram at right .) To visualize a CNT with indices (n , m) , draw n a1 unit vectors across the graphene sheet , then draw m a2 unit vectors at a 60 ° angle to the a1 vectors , then add the vectors together . The line representing the sum of the vectors will define the circumference of the CNT along the plane perpendicular to its long axis , connecting one end to the other . In the diagram at right , Ch is a (4 , 2) vector : the sum of 4 unit vectors from the origin directly to the right , then 2 unit vectors at a 60 ° angle down and to the right .