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Pressure-induced reversible transformation in single-wall carbon nanotube bundles studied by Raman spectroscopy

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Abstract

We report our high-pressure Raman studies on single-wall carbon nanotube bundles carried out up to 25.9 GPa. The intensity of the radial modes decreases more drastically as compared to that of the tangential modes. The former could be followed up in pressure runs to 3 GPa. The most intriguing observation is the anomalous pressure behaviour of the 1594 cm^{-1} tangential mode between 10 and 16 GPa. This feature, as well as the pressure dependence of intensity, peak position and linewidth, are reversible on decompression. The anomalous pressure dependence is argued to be associated with faceting of the tubes in the bundle, showing their remarkable resilience.

1. Introduction

Novel properties such as unusual mechanical strength and one-dimensional electronic transport in single-wall carbon nanotubes (SWNT) have been studied actively in recent years, both experimentally and theoretically [1]. Experimental studies have been made possible due to the synthesis of bundles of aligned SWNT with narrow-size distribution in large quantities by laser pulse vaporization [2], followed by the electric arc method [3]. A SWNT made from rolling a graphene sheet up into a cylinder with caps made up of C_{60} hemispheres can be specified in terms of chiral vector $n\vec{a_1} + m\vec{a_2}$ and chiral angle θ given by $\tan^{-1}(\sqrt{3}\,m/(m+2n))$. Here $\vec{a_1}$ and $\vec{a_2}$ are primitive lattice vectors of a 2D hexagonal honeycomb lattice and m,n are integers. The tube has chiral symmetry for $n \neq m \neq 0$ and achiral tubes with $m = 0$ and $n = m$ are called zigzag and armchair tubes, respectively. The diameter of the SWNT is related to the (n,m) values by $d = a[3(n^2 + m^2 + mn)]^{1/2}/\pi$, where a is the nearest C–C distance ($= 1.42$ Å). Recent scanning tunneling spectroscopy experiments [4,5] have verified the theoretical predictions that the electronic properties of SWNT are given by one-dimensional density of states. These isolated tubes can be semiconducting or metallic, depending on their diameter and the chiral angle [1]. Isolated tubes are metallic when $(n-m)/3$ is an integer. Intertube interaction between the tubes in a

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