Research Article

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Electronic Properties of Carbon Nanotubes

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Abstract

Nanotubes result from a combination of structural characteristics giving them exceptional physical and chemical properties. New ideas for the use of these structures emerge regularly, even though few of them have so far found real industrial applications. The possibility of seeing these ideas concretized depends essentially on the ability to control their growth, their structure and to master their manipulation. Here we present an overview of the electronic properties of these nanomaterials.

1. Introduction

Carbon nanotubes were discovered in 1991 by Professor Iojima, laboratories NEC, by using advanced electron microscopy techniques, nanotubes, have been constantly be research around the world, because their unsurpassed properties offer many applications [1]. The scientific community already based on high hopes for these nanomaterials to share their exceptional intrinsic properties, they will pave the way for a new industrial revolution already named by journalists as "nano revolution."

Carbon nanotubes (CNTs) present one of the first commercial applications of nanotechnology revolution. Since their development, these nano-objects there are considerable interest given their exceptional intrinsic properties and characteristics dimensionnelles. These nanotubes have a particular crystalline structure, tubular, hollow and close, composed of atoms arranged in a regular pentagons, hexagons and / or heptagons, obtained from some materials, particularly carbon and boron nitride. They exist two types of carbon nanotubes: Single Wall Carbon Nanotubes (SWNT) and Multi Wall Carbon Nanotubes (MWNTs), the MWCNTs consist of several graphene sheets rolled concentrically spaced about 0.33 nm [2,3]. MWCNTs diameter varies according to the number of sheets, of 1.3 nm to 100 nm and their lengths can reach µm. For (SWNT) mono sheets, their structure may be represented by a graphene sheet wound on itself and closed at both ends by a hemisphere.

The diameter (SWNT) may vary from e 0,7 nm to 2 nm or more depending on the synthesis method used, the length may reach about several micrometers or even several centimeters. The way the graphene sheet is folded over itself defines a parameter called helicity or chirality, which determines the structure of the SWCNT. Chirality can characterize various types of existing and SWCNTs can be represented by a vector whose coordinates are shown as n and m. The graphene sheets form a nanotube when wound so that the origin (0,0) and the point (n, m) overlap. a1 and a2 are the unit vectors of the network and θ (a1, a2) represents the chirality angle (θ between 0 and 30°) ,that SWCNTs classify into three main families: the zigzag nanotubes (θ =0°, m or n = 0), the armchair nanotubes (θ = 30 °, m = n) and chiral nanotubes (0 <θ <30°or m ≠ n ≠ 0) [4].

About the prospects of application, they are used in electronics (transistors, diodes), biology or chemistry even for storage of molecules and many other applications [5]. For the properties of these nanomaterials, they have properties unmatched in several areas, such as electrical properties, mechanical, chemical, thermal, and several of other properties.

2. Experimental Methods

Theoretical calculations predicted that the carbon nanotube should have a metal or semiconductor behavior depending on their chirality and diameter [5]. These conduction properties are inherited from the particular structure of the graphite tape.

The graphene sheet is a semiconductor band-gap zero: the valence band and conduction meet exactly at the Fermi level and to the six corners of the first Brillouin zone. The graphite should be metallic, but is in fact; semi-metallic because its electron density at the Fermi level is very low. The winding of a graphene sheet on it self creates periodic boundary conditions perpendicular to the axis of the nanotube. Therefore a limited number of wave vectors is allowed in that direction. It depends on the diameter and winding the graphene sheet on it self. If the boundary conditions include the corners of the Brillouin zone, the behavior of the nanotube is metallic. This is the case of all nanotubes type "chair" and a third of nanotubes "chiral"and "zig-zag" (Figure 1).

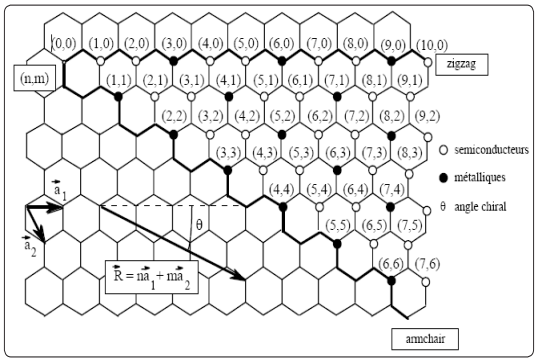

Figure 1: Electronic properties of the carbon nanotubes

In other cases the band structure has a band gap, in a first approximation, inversely proportional the radius of the nanotube.

These properties have been confirmed experimentally by measuring the tunnel current between the tip of an STM (Scanning Tunnelling Microscope) and a nanotube, which provides a direct estimate of the electron density. In addition, the STM allows to image the atomic structure of the nanotube and thus to determine their chirality and diameter. The transport properties can be correlated to the structure of the nanotube.

Metallic nanotubes have only two-dimensional conduction bands which cross the Fermi level, the full current flows through these two bands and theory predicts the conductance (G0 =2e2/h) equal to twice the fundamental unit of conductance.

The coherence length of conduction is significant and may reach the length of a nanotube (> μm).

3. Results

The nanotube is therefore a prototype of one-dimensional quantum wire. Potential applications of these properties are in the field of nanoelectronics, not only the use of the nanotube as a molecular thread, but also as an active electronic element.

4. Conclusion

If carbon nanotubes are so successful is because they have properties unsurpassed in many areas, also potential applications of these properties are in the field of nanoelectronics, not only the use of the nanotube as a molecular thread, but also as an active electronic element.

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