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Carbon Nanotubes and Their Growth Methods

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Abstract

Carbon Nanotubes (CNTs) are the allotropes of carbon which belong to the fullerene structural family. These are cylindrical structures with at least one end closed with a buckyball structure hemisphere. They are few nano meter in diameter and have tensile strength of ~63GPa and young's modulus of ~1TPa. On the basis of structures carbon nanotubes can be classified as Single-walled (SWNT), Multi-walled (MWNT), Polymerized SWNT, Nanotorus and Nanobuds. Carbon Nanotubes can behave as metal or as a semiconductor depending on the nature of its helix. They are good thermal conductors along their axis but act as insulators in the lateral direction. Major manufacturing techniques employed for fabrication of CNTs are Arc discharge, Laser Ablation and Chemical vapor deposition. Carbon Nanotubes are extending our ability to fabricate devices such as molecular probes, pipes, wires, bearings, springs, gears and pumps

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Keywords: Carbon Nanotubes, CNT Growth Methods, Arc Discharge Method, Laser Ablation, Chemical Vapour Deposition.

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1. Introduction

The Carbon nanotubes (CNT) are tubular structures made of carbon atoms, having diameter of nanometer order but length in micrometers. Right from its discovery, Qian D. et al. (2002) shows exciting quotations about CNT, viz.

- "CNT is 100 times stronger than stainless steel and six times lighter..."

- "CNT is as hard as diamond and its thermal capacity is twice that of pure diamond..."

- "CNT's current-carrying capacity is 1000 times higher than that of copper..."

- "CNT is thermally stable up to 4000K..."

- "CNT can be metallic or semiconducting, depending on their diameter and chirality..."

However, it is important to note that all those superlative properties were predicted for an atomically-perfect ideal CNT which is far from the CNTs we are practically producing today.

Despite a huge progress in CNT research over the years, we are still unable to produce CNTs of well-defined properties in large quantities by a cost-effective technique. The root cause of this problem is the lack of proper understanding of the CNT growth mechanism. There are several questions at the growth level awaiting concrete answer. Till date no CNT growth method could be robustly established. Hence this paper is devoted to review the present state of CNT synthesis and growth mechanism.

1.1. Carbon nanotubes

Carbon Nanotube (CNT) is tubular form of carbon with diameter as small as 1nm and length of few nm to microns. CNT is configurationally equivalent to a two dimensional graphene sheet rolled into a tube. Its Young's modulus is over 1 TPa and the tensile strength is an estimated 200 GPa. Depending on the atomic arrangement of the carbon atoms making up the nanotube (chirality), the electronic properties can be metallic or semiconducting in nature, making them widely used in several applications due to their unique electrical, mechanical, optical, thermal and other properties. The application of CNTs is usually given by the CNTs structure according to Dresselhaus MS. et al. (1995) & Jan Prasek (2011) (number of walls, diameter, length, chiral angle, etc.), which gives them the specific properties. The possible applications of CNTs include conductive films, solar cells, fuel cells, supercapacitors, transistors, memories, displays, separation membranes and filters, purification systems, sensors, clothes etc.

1.2. Classification

On the basis of structure carbon nanotubes are of five types:

- **Single Walled Nano Tube**: Most single-walled nanotubes (SWNT) have a diameter of close to 1 nanometer, with a tube length that can be several thousands times the diameter.
- **Multi Walled Nano Tube:** Multi-walled nanotubes (MWNT) consist of multiple layers of graphite rolled on themselves to form a tube shape.
- **Polymerized SWNT:** These are the solid-state manifestation of fullerenes and related compounds and materials. Many single walled nanotubes intertwine to form polymerized SWNTs, which are comparable to diamond in terms of hardness.
- **Nanotorus:** A nanotorus is a theoretically described carbon nanotube bent into a torus (donut shape). Nanotori have many unique properties, such as magnetic moments 1000 times larger than previously expected for certain specific radii.