Review Paper on Carbon Nanotubes

Ms. Neha Gautam, Shalini Singh , Shruti
Department of E & C, Rajasthan College of Engineering for Women, Jaipur
nehagautam.27@gmail.com
shalini.singh1015@gmail.com
shruti.singh1114@gmail.com

Abstract: Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure, which finds its applications in nanotechnology, electronics, optics and other fields of material science and technology. In this article, we will be focusing on the types – single –walled, multi-walled and double-walled carbon nanotubes, ,its extraordinary properties such as thermal conductivity, mechanical and electrical properties, etc and applications of the carbon nanotubes in detail. Graphene which is the basic structural element of carbon nanotubes is also discussed .

Introduction

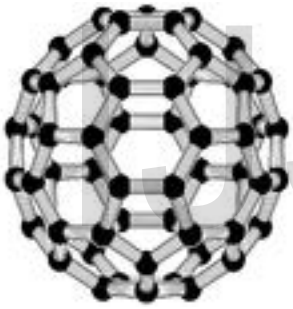

Figure I: Fullerene

Nanotubes which are made of nanomaterials , have recently become one of the most active reaserch fields in the areas of solid states physics, chemistry and engineering .Nano material is the matter whose length scale is approximately 1-100nm.A nanometer is one billionth of a meter i.e. (10)-9 m. However carbon nanotubes have been constructed with length to diameter ratio of up to 132,000,000:1.
Nanotubes are the members of the fullerene structural family . The name is derived from the long, hollow structure with the walls formed by one-atom-thick sheets of carbon, called graphene. Graphene is stronger and stiffer than diamond but cab be stretched like rubber.

These graphene shield are rolled at specific angle and discrete angle known as chiral angle. This chiral and radius decides the nanotube properties.

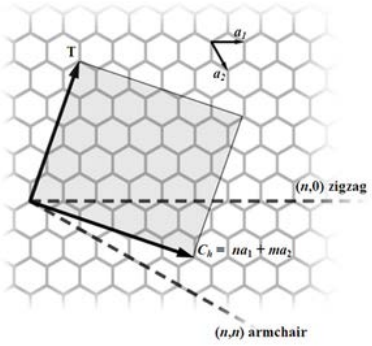

Figure II: carbon nanotube configuration with the chiral vector Ck.

Types of Carbon Nanotubes
Nanotubes, on the basis of the alignment , can be categorized into two types –
1. Single-walled nanotubes(SWNT)
2. Multi-walled nanotubes(MWNT)

Single-walled nanotubes(SWNT)

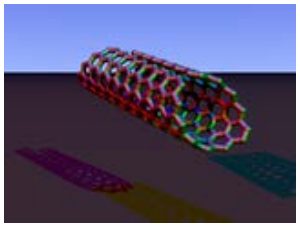

Figure III: SWNT

The SWNT , synthesized in 1993 by Iizima and ichihashi , are tubes of graphite capped at the ends . They have a single cylindrical wall .They have a diameter close to 1-2nm, however the length can be thousand times longer. SWNT is made by wrapping a one-atom-thick layer of graphene into a cylinder .The way the graphene sheet is wrapped is represented by a pair of parameters(n,m) ,where n and m denotes number of unit vectors along two directions in honeycomb crystal lattice of graphene if m=0 , they are called zigzag nanotubes, if n=m they are called armchair nanotubes. Otherwise they are called chiral. The diameter can be calculated as-

$$d = \frac{a}{\pi}\sqrt{(n^2 + nm + m^2)} = 78.3\sqrt{((n+m)^2 - nm)}$$

Where a=0.246nm

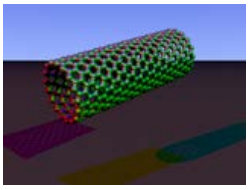

Figure IV: zigzag nanotubes

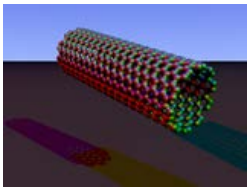

Figure V:Armchair nanotubes

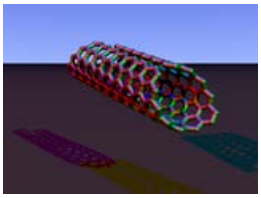

Figure VI: chiral

Properties of SWNT

1. They are more bendable yet harder to MWNT .

2. They can be twisted , flattened , bend into two small circles or around sharp bends without breaking .

3. They have unique electronic and mechanical properties which can be used in numerous applications such as field-emission displace, nanosensors, logic elements etc.

Multi-walled nanotubes (MWNT)

MWNTs consist of multiple rolled layers(concentric tubes) of graphene. Its outer and inner diameters of layers is between 2-25 nm and 1-3nm is respectively. The length is 1-100m.

Double-walled nanotubes (DWNTs) are special class of nanotubes because their morphology and properties are similar to those of SWNTs but their resistance to chemicals is significantly improved . They are comprised of exactly two concentric nanotubes separated by 0.35-0.40 nm. They may behave as a metal.

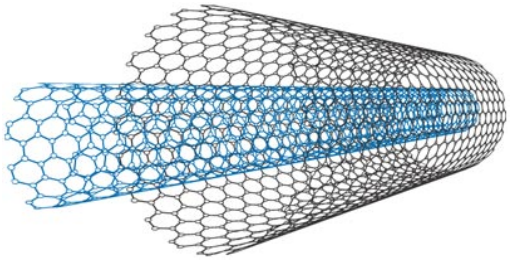

Figure VII:DWNTs

Properties of DWNTs

1. They have optical and Raman scattering characteristics of each wall.
2. On the basis of electronic type values of inner and outer walls they are of four types – (metallic-metallic), (metallic-semiconducting), (semiconducting-metallic) and (semiconducting- semiconducting).
3. They have improved life time ,current densities for field emission and high stability under aggressive chemical, mechanical and thermal treatments along with flexibility.

Applications of carbon nanotubes:

The applications of nanotechnology in different fields have distinctly different demands, and thus face different challenges , which require different approaches.

Its applications are derieved from-

1. The peculiar physical properties of nanotubes.

2. The huge surface area.

3. The small size that offers extra possibilities for manipulation and room for accommodating multiple functionalities.

Some of the important applications are –

1.phosphors for High-Definition TV- The resolution of the TV depends greatly on size of pixel. These pixels are made of materials called “phosphors” , which glow when struck by a stream of electrons inside the cathode ray tube(CRT).The resolution improves with the reduction in size of pixel , or the phosphors.

2. Next-Generation computer chips- Transistors , resistors and capacitors can be reduced in their size which leads to faster running of microprocessors

,which contains these componenets. Ex- nanowires for junctionless transistors.

3. Microbial fuel cell-It is a device in which bacteria consume water-soluble waste such as sugar, starch and alcohols and produces electricity plus clean water. The technology will make it possible to generate electricity while treating domestic or industrial wastewater. CNTs have chemical stability, good mechanical properties and high surface area which makes them suitable for designing electrodes of microbial fuel cells.

1. High energy density batteries- Nanotubes are used for separator plates and batteries which can hold more energy than their conventional counterparts.

2. High sensitivity sensors –

Sensors made of nanotubes are extremely sensitive to the change in their environment. These sensors are used in smoke detectors , ice detector on aircraft wings etc.

3. Kinetic energy penetrators with enhanced lethality – Nanocrystalline tungsten heavy alloys can be used in place of depleted-uranium(DU) penetrators in department of defense.

4. Tougher and harder cutting tools- Cutting tools made of nanomaterials are much harder, wear-resistant, erosion-resistant and last longer.

5. Aerospace components with enhanced performance characteristics – Due to their stronger, tougher and last longing property their used to make aircraft components.

6. Better future weapons platforms- Nanocrystalline composite materials are used to make railguns in electromagnetic launchers .

7. Longer lasting medical implants- Nanocrystalline zirconia, nanoceramics , nanocrystalline silicon carbide, etc can be used in place of titanium and stainless steal alloys in medical implants such as orthopaedic implants and heart valves.It is because they are wear resistant, corrosion resistant and biocompatible.

References-

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