International Journal of Mechanical Engineering and Technology (IJMET)
Volume 14, Issue 05, Sep-Oct 2023, pp. 1-12. Article ID: IJMET_14_05_001
Available online at https://iaeme.com/Home/issue/IJMET?Volume=14&Issue=5
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

A REVIEW ON CARBON NANOTUBES: PREPARATION, PROPERTIES AND APPLICATIONS

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ABSTRACT

Carbon nanotubes (CNTs) have achieved attention in recent times because of their extraordinary physicochemical properties like strength, flexibility, sensors, conducting etc. Carbon nanotubes (CNTs) are known as nano-architectured allotropes of carbon, having graphene sheets which are rolled up into cylinder that forms carbon nanotubes. In the field of nanotechnology, carbon nanotubes are the one of the most unique invention. The eye-catching features of carbon nanotubes are their electronic, mechanical, optical and chemical characteristics, which open a way to future applications. Carbon nanotubes can be single walled and multi walled which can be produced in various ways. The most common techniques used nowadays are: arc discharge, laser ablation and chemical vapour deposition. In this review article, the applications of CNTs in various technologically important fields are discussed in detail.

Keywords: Nanotubes, Nanotechnology, SWCNTs and MWCNTs, Nanomedicine, Graphene, Nanocapsule.

Cite this Article: Fatima Unisa Siddiqui and Sanjay Rathore, A Review on Carbon Nanotubes: Preparation, Properties and Applications, International Journal of Mechanical Engineering and Technology (IJMET), 14(5), 2023, pp. 1-12.
https://iaeme.com/Home/issue/IJMET?Volume=14&Issue=5

1. INTRODUCTION

A Carbon Nanotube is a tube-shaped material, Carbon nanotubes (CNT) are the base of made of carbon, having a diameter measuring on the nanotechnology. Carbon with an atomic number of 6 nanometer scale. Carbon nanotubes (CNTs) containing plays a vital role in nanotechnology. They were composites are very auspicious for the continuous discovered by Iijima [7]. Carbon nanotubes are made growth of telecommunication market on account of their many idiosyncratic chemical and physical properties [1,2].

The forth coming generation computer devices, wireless LAN devices, consumer electronics, wireless antenna systems, and cellular phone systems are few up of carbon and it is a tube shaped material which have very small diameter measured by nanoscale [8]. Graphenes which are rolled up into cylinder that forms carbon nanotubes [6]. The diameter of nanotubes is about 10 thousand times smaller than the diameter of a portable device applications that require these human hair [9]. In recent years carbon nanotubes are composite materials, because nanocomposites have the potential to significantly surpass the physical properties of conventional bulk materials. Carbon is the chemical element with atomic number 6 and has six electrons which fill 1 s2, 2 s2, and 2p2 atomic orbital and can hybridize in sp, sp2, or sp3 forms. Nanometer size sp2 carbon bonded materials such as grapheme [3], fullerenes [4], and carbon nanotubes [5] have encouraged to make inquiries in this field. Graphene is known as 2D single layer of graphite in the list of carbon nanomaterials which is stronger material than diamond because it contains sp2 hybridisation which is stronger than the sp3 hybridisation in diamond [6].

2. CARBON NANOTUBES

Carbon nanotubes (CNT) are the base of nanotechnology. Carbon with an atomic number of 6 plays a vital role in nanotechnology. They were discovered by Iijima [7]. Carbon nanotubes are made up of carbon and it is a tube-shaped material which have very small diameter measured by nanoscale [8]. Graphenes which are rolled up into cylinder that forms carbon nanotubes [6]. The diameter of nanotubes is about 10 thousand times smaller than the diameter of a human hair [9]. In recent years carbon nanotubes are the most exciting areas of research [10].

The nanosized carbons (or nanocarbons) which comprise fullerenes, graphene and CNT [11]. Special priority is given to graphene and CNTs, as they play a pivotal role in current advances based on nanomaterials, including conductive and high-strength composites [12] artificial implants [13], sensors [14], drug delivery systems [15], energy conversion and storage devices [16] radiation sources [17] and field emission displays [18], hydrogen storage media [19] and nanometer-sized semiconductor devices [20], probes [21], and interconnects [22]. CNTs have excellent mechanical, thermal and electronic properties which make nanotubes ideal, not only for a wide range of applications [23] but as a test bed for fundamental science [24]. In another area, it is thought that their massive thermal conductivity can be utilized to make thermally conductive composites [25]. Nanotubes might be used as membrane material for batteries and fuel cells, as anode for lithium-ion batteries, as capacitor and chemical sensors/ filters [26]. A great amount of electrical conductivity and their relative inertness make them potential candidates as electrodes in electrochemical reactions also [27,28]. Wider surface area of nanotubes in both inside and outside, can be employed to 6 support reactant particles in catalytic conversion reactions [29]. For probe microscopies nanotube tips have also been designed as well as they also possess hydrogen storage capability [30].

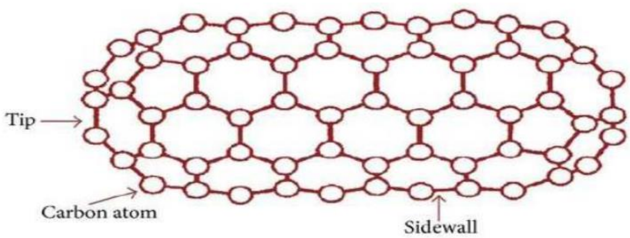

Figure 1: Structure of Carbon Nanotube.

3. CLASSIFICATIONS OF CARBON NANOTUBES

3.1. Single Walled Carbon Nanotubes (SWCNTs)

It consists of single layer of graphene and requires catalyst for its synthesis. SWCNTs are of poor purity and doesn't have any complex structure which can easily be twisted [31].

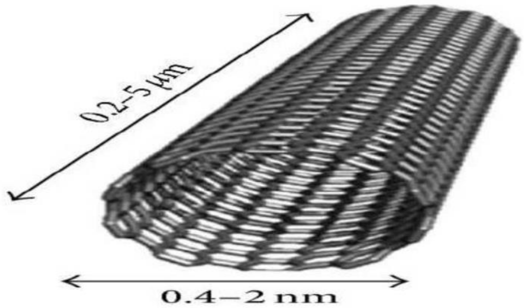

Figure 2: Single Walled Carbon Nanotube.

3.2. Multi walled Carbon Nanotubes (MWCNTs)

It consists of multi-layer of graphene and doesn't require any catalyst for its synthesis. The bigger MWCNT can contain hundreds of concentric layers which are separated by a distance of about 0.34 nm [32], where the measurement of length of a C–C bond in a graphene sheet of SWCNT is 0.142 nm [33]. The synthesis of DWNT was first proposed in 2003 by the CCVD technique on the gram-scale, from the selective reduction of oxide solutions in methane and hydrogen [34].

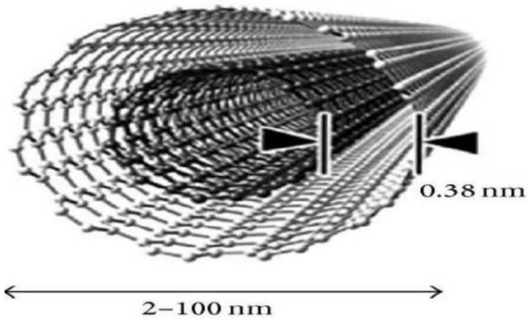

Figure 3: Multi Walled Carbon Nanotube

Table 1: Difference between SWCNT and MWCNT [35]

SWCNT	MWCNT
It contain single layer of grapheme.	It contain multiple layer of grapheme.
It can't be produced without catalyst .	Can be produced without catalyst.
It can be easily twisted.	Can't be easily twisted.
It has simple structure.	It has complex structure.
It has less purity.	It has more purity.
It is more pliable.	Less pliable.
Bulk production is difficult.	Bulk production is easy.

4. METHODS OF PREPARATION CARBON NANOTUBES

4.1. Plasma Based Synthesis Method (Arc Discharge Method)

For best quality of nanotubes plasma based method or arc discharge method can be used which involves two graphite electrode in presence of helium and a current of 50 ampere is passed through two graphite electrodes which causes vaporization of graphite; some part of it condense on reaction vessel and some of it condense on cathode. Carbon nanotubes are deposited on cathode and If we want single walled carbon nanotubes then Co, Ni metals can be introduced in anode [8,36]. The yield of SWNTs is strongly affected bytemperature and it increases as increasing temperature. The SWNT bundles with 7-20 nm of diameters and the production of 45.3 g/h were prepared at the temperature of 600oC [37].

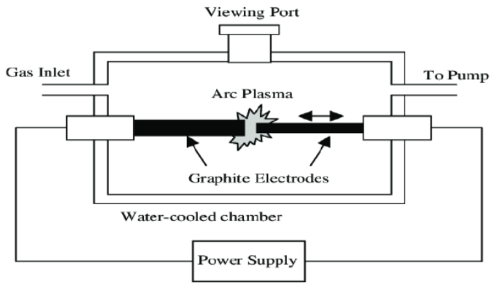

Figure 4: Arc Discharge Method.

4.2. Laser Method

In 1996 Laser was used for production of carbon nanotubes with 70% purity and presently this method is used for production of carbon nanotubes. This process comprises of graphite rods and it contain 50:50 catalyst mixture of Co and Ni at 12000C and argon is flowing through it for sample preparation [38] and in this method metal catalyze the growth of singlewalled carbon nanotubes and also many side products are formed. We can get nanotubes if we cool down the vaporized species [39].

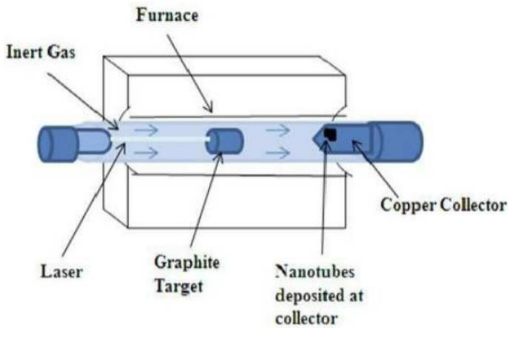

Figure 5: Laser Method.

4.3. Chemical Vapor Deposition

In the above methods, there are two major difficulties i.e. ordered synthesis and large scale production [40]. Chemical vapor deposition method was introduced in 1996 for production of carbon nanotubes [41] which is used to produce large amount nanotubes. The methods of Arc discharge and laser vaporization can be mentioned as high temperature (>3000K) and short time reaction (μs-ms) techniques, but the catalytic CVD is a medium temperature (700- 1473K) and long time reaction (typically minutes to hours) technique. CNTs do not grow on a patterned or conventional substrate [42]. This method involves lower temperature and we get the well-organized carbon nanotubes [43].

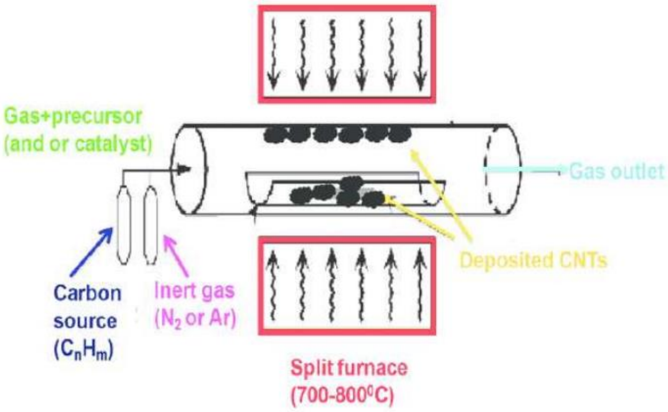

Figure 6: Chemical Vapor Deposition.

5. PROPERTIES OF CARBON NANOTUBES

CNTs have excellent electronic [44], optical [45], thermal [46], chemical, and mechanical properties [47,48]. Considering their chiral vector, carbon nanotubes containing a small diameter are either semiconducting or metallic. The variations in conducting properties are caused by the molecular structure which results in a different band structure and thus a different band gap. These differences in conductivity can easily be derived from the graphene sheet properties [49]. The specific heat of MWNTs from 10 to 300 K [50] revealed linear dependence of the specific heat on the temperature over the entire temperature interval. By dint of the sp2 carbon-carbon bonding CNTs show high mechanical strength [51]. Young's modulus value of the nanotubes have 1000 GPa, (approximately five times higher than that of steel), are considered as the best for a variety of applications [52]. Compared to steel CNTs can have a breaking strain or tensile strength of approximately 63 GPa, which is approximately 50 times greater than steel [53].

6. APPLICATIONS OF CARBON NANOTUBES

6.1. Drug Delivery

Carbon nanotubes are used in drug delivery carriers for treatment of cancer [54] and these nanotubes are reported for targeting of amphotericin B to cells [55]. 6.2. Tissue Generation Carbon nanotubes are used for generation of tissue and in recent years carbon nanotubes are best for tissue generation because they are biocompatible, resistant to biodegradation and enhancing the organ generation [56].

6.3. Detection of Toxic Proteins

By changing the electrical signals, the CNTs are used as a measuring platform for various toxic proteins which will immobilized on the CNTs [57]. The Scanning Electron Microscope (SEM) and the Electrochemical Chemiluminescence (ECL) are used to test the bonds of proteins with antibodies on CNTs platform.

6.4. As Bone Substitutes

Due to unique properties such as high tensile strength, CNTs can act as bone substitutes and implants when filled with calcium and shaped/arranged in the bone structure [58-59]. 6.5. Preserve of Drugs Carbon nanotubes are antioxidant in nature so they can be used to preserve drugs that are easily oxidized [60].

6.6. Gene Therapy

Carbon nanotubes are used for Gene therapy by DNA delivery to cure the gene which can Cause harmful disease by introducing DNA into cells [61-62].

6.7. As Lubricants

They can be used as lubricants or glidants in tablet manufacturing because of nanosize and sliding nature of graphite layers which bound with van der waals forces [63].

6.8. Genetic Engineering

In genetic engineering, Carbon nanotubes and Carbon nanohorns can be used to manipulate genes and atoms in the development of bioimaging genomes, proteomics and tissue engineering [63].

6.9. Diagnostic Tool

Protein-encapsulated or protein/enzyme filled nanotubes, because of their fluorescence ability in presence of specific biomolecules have been tried as implantable biosensors [64]. When nanocapsules filled with magnetic materials, radioisotope enzymes can be used as biosensors. Nanosize robots and motors with nanotubes can be used in the study of cells and biological systems [65].

6.10. Cancer Cell Identification

Nanodevices are being created that have the ability to develop cancer treatment, detection, and diagnosis and nano-structures can be so small (less than 100 nm) that the body possibly will clear them too quickly for them to be efficient in imaging or detection and so can enter cells and the organelles inside them to interact with DNA and proteins. Castillo et al., by using a peptide nanotube-folic acid modified graphene electrode, enhance the detection of human cervical cancer cells overexpressing folate receptors [66-72].

6.11. Biomedical Applications

The DNA sequences in the body can be identified by CNT-based nano-biosensors [73] and CNT-based pressure sensors can be used in eye surgeries, kidney dialysis machines, respiratory devices, and hospital beds [74,75]. The polymer composites based on CNTs because of their strength, stiffness, and relatively low operating voltage, can be used as artificial muscle devices [76]. CNTs play a vital role in the identification of cancer cells [77].

6.12. Carbon Nanotube-Based Diodes

CNTs (SWNTs) can form perfect p–n junction diodes due to their excellent mechanical and electrical properties [78]. The use of CNTs In lieu of conventional transistors and diodes significantly increases the current-carrying capability of the devices, while reducing the operational temperature. SWNT diodes exhibit excellent power conversion efficiencies when illuminated because of improved diode properties [79].

6.13. Batteries

Most portable electronic devices use rechargeable lithium-ion batteries and these batteries release charge when lithium ions move between two electrodes - one of which is graphite and the other is metal oxide. Researchers at the University of North Carolina have demonstrated that battery storage capacity can be doubled by replacing graphite with SWCNTs. CNT infused paper is used to make Ultra-thin flexible batteries [80].

6.14. Others

Applications of carbon nanotubes encompass many fields and disciplines such as medicine, nanotechnology, manufacturing, construction, electronics, and the following application can be noted: high-strength composites nanoprobes and sensors [81-87], actuators [88], energy storage and energy conversion devices [89], electronic devices [90], hydrogen storage media [91] and catalysis [92].

7. DRAWBACKS OF CARBON NANOTUBES

A Costly nanotechnology [53] and also hard to maintain high quality and lower impurities as well acumen manpower needed [93]. Huge amount of energy is required to complete the process in ARC DISCHARGE and LASER method [94].

8. CONCLUSIONS

This review paper is based on production, properties applications and limitations of carbon nanotubes. In this study we discuss about various methods of production of carbon nanotubes. Researchers taking keen interest in carbon nanotubes and likely to give more advancement in coming future and there is much about carbon nanotubes that is still unknown. More research needs to be done regarding the environmental and health impacts of producing large volume of them. There is also much effort to be done towards cheaper mass production and incorporation with other materials before many of the current applications being researched can be commercialized. There is no doubt however that carbon nanotubes will play an important role in a wide range of commercial applications in the very near future.

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Citation: Fatima Unisa Siddiqui and Sanjay Rathore, A Review on Carbon Nanotubes: Preparation, Properties and Applications, International Journal of Mechanical Engineering and Technology (IJMET), 14(5), 2023, pp. 1-12

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