Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 5, Issue 7; October-December, 2018, pp. 592-595

http://www.krishisanskriti.org/Publication.html

A Systematic Study of Production and Properties of Carbon Nanotubes Belonging to Nanotechnology

Dr. Ali Ahmad Ansari

*Assistant Professor of Physics, Deptt. of Physics, KCET, Veriadangi,
Kishanganj, Bihar-855107, India
E-mail: aliahmadansari456@gmail.com*

Abstract—*The present paper reports a systematic study of production and properties of carbon nanotube belonging to nanotechnology.*

Nanotechnology is the new emerging technology that stands forefront in the multidisciplinary fields such as science research and technology development. Nanotechnology uses carbon nanotube as nonmaterial for the fabrication of different nano devices. Carbon nanotubes (CNTs) are one of the most promising materials in the field of nanotechnology and are being produced by three methods: electric arc discharge, laser ablation and chemical vapour deposition. CNTs possess unique electrical, mechanical, chemical, thermal and optical properties, due to which these materials are suitable for various applications[1]. The CNTs production is increasing in proportion to their usage. Since materials at the nanoscale behave differently than they do in their massive form, hence these CNTs are subjected to intense toxicological scrutiny. Research has proved that exposure to CNTs have negative effects on human health. The present paper attempts to give the systematic study of production and properties of carbon nanotubes based on nanotechnology.

This knowledge will be useful in formulating exposure standards for CNTs[2].

Keywords*:-Nanotechnology, carbon nanotubes; production, methods, properties.*

INTRODUCTION

Nanotechnology is the emerging field of science, which deals with nanoparticles (1nm=10-9 m) and their production. CNTs are nanoparticles with a size range of 1-100 nm (ISO/TS 27687, 2008), with unique electrical, thermal, mechanical and vibrational properties, having a wide range of applications in the fields of electronics, computers, aerospace and other industries. Humans get exposed to high concentrations of these particles during the manufacturing process and usage of nano based products. CNTs are a form of carbon with a cylindrical shape and are first observed by Endo (1975), and later by Lijima (1991) in the soot produced by the arc-discharge synthesis of fullerenes. These tubes are made up of thick sheets of carbon called grapheme which were rolled up to form a seam less cylinder[3]. Different kinds of carbon nanotubes are shown below. Single walled nanotube is demonstrated in fig.1. Doubled walled nanotube is demonstrated in fig. 2.

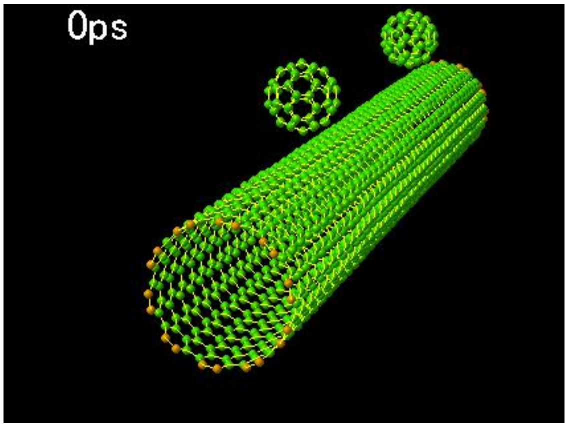

Fig. 1: Single walled CNT

Fig. 2: Multi Walled CNT

Synthesis:--

CNTs are synthesized by various methods like arc-discharge, laser ablation, chemical vapour deposition (CVD), high pressure carbon monoxide (HiPCO), CoMoCat etc. An energy source (electricity, heat from a furnace or high light intensity) is added to carbon source for the synthesis of CNTs, which may vary depending on the synthesis method (Donaldson et al. 2006). Though the CNTs are synthesized by different methods (Table 2), CVD, HiPCO and present, the CNTs are classified as single walled, double walled and multiwalled carbon nanotubes[4].

PRODUCTION OF CNT

CNTS are finding wide range of applications, there by their production is also being increased by the companies.

CoMoCat are the most widely used methods for production of CNTs due to their high yield, purity and low cost of production and the reason for fewer yields of CNTs in arc discharge and laser ablation is due to the evaporation of carbon source at high temperatures.

1. Electrical arc discharge

It is the oldest method used for the production of CNTs. Pure and metal doped graphite electrodes are used for the synthesis of MWCNTs and SWCNTs respectively (Popov 2004). The electrodes are temporarily brought into contact and an arc is struck. Low pressure (between 50 and 700 mbar) and controlled atmosphere composed of inert (like helium or argon) gases are maintained for the production. In the inter electrode zone, high temperature is maintained, so that the carbon sublimes from positive electrode (anode) and is consumed. A constant gap (1mm) is maintained between the two electrodes which can be done by adjusting the position of anode. Plasma formed between the electrodes, can be maintained constant for prolonged periods by controlling the distance between the two electrodes and the voltage (25-40 V). After de-pressurisation and cooling the reaction chamber, nanotubes together with by-products can be collected (Shifrina 2011; Szabo et al. 2010).[5]

2. HiPCO--

In the year 1999, Richard E Smalley and his co- workers developed a high pressure carbon monoxide method (HiPCO) for the synthesis of CNTs. In this process a continuous gas phase carbon monoxide acts as feedstock and iron carbon monoxide (Fe (CO)5) acts as a catalyst. Thinner SWCNTs with high purity, less structural defects and high intrinsic selectivity were obtained (Shifrina 2011).

3. CoMoCat

In 2000, Kitiyanan suggested another method in which a mixture of cobalt and molybdenum was used as a catalyst and hence, this process was named after the unique catalyst. At high temperatures (between 700°C-950°C) carbon monoxide decomposes into simple carbon and carbon dioxide (Shifrina 2011). The advantage of this method is that it reduces the formation of by-products as compared to arc discharge and laser ablation methods[6].

4. Chemical vapour deposition method

The catalyst material (most commonly nickel, cobalt, iron or a combination) is heated to high temperature in a tube furnace and a hydrocarbon gas is passed through the reactor in controlled manner for a definite period of time. The hydrocarbon gas dissociates into individual components in the furnace and supplies the necessary carbon atoms for the CNT growth. Low temperatures (500-800°C) yield MWCNTs and high temperatures (600-1200°C) yield SWCNTs. Commercially available CNTs are often synthesized by this process.

PROPERTIES

CNTs, due to their tiny size exhibit many interesting and unique properties.

1. Mechanical properties

CNTs are made up of sheets of grapheme and the C-C bond in a grapheme layer is probably the strongest chemical bond known in nature. CNTs are the strongest and stiffest materials yet discovered in terms of tensile strength and elastic modulus[8].

a. Tensile Strength

The tensile strength of CNTs is due to the covalent sp2 bonds formed between the individual carbon atoms. The CNTs can sustain extremely high tension force of about 130 GPa (gigapascals) where as the steel can withstand <5 GPa. Yu et al. (2000) tested the tensile strength of SWCNTs and MWCNTs and is found to be 13-52 GPa and 63 GPa respectively. The tensile strength of a single layer of MWCNTs is 100 times stronger than that of steel[7].

b. Elasticity

The CNTs are elastic and they can withstand stress. The elasticity can be measured experimentally by calculating the Young's modulus. Lourie and Wagner (1998) reported Young's modulus of 2.8-3.6 TPa (terra pascal) for SWCNTs and 1.7-2.4 TPa for MWCNTs.

2. Electronic

CNTs possess unusual electronic properties and act as conductors of energy. The diameter and helicity (n, m) of carbon atoms in the nanotube shell are believed to determine their conductivity (metallic or semiconductor). Theoretical calculations for electronic properties by Hamada et al. 1992; Mintmire et al. 1992; Saito et al. 1992 showed that CNTs are very sensitive due to their geometrical structure. Theoretically it was determined that metallic nanotubes (where the energy gap between the valence and conducting states is zero) can carry an electric current density of 4× 109 A/cm2 (ampere per square centimetre) which is 1000 times higher than copper (Hong et al. 2007)[9].

3. Thermal

CNTs are very good thermal conductors due to their geometrical structure. The thermal conductivity of CNTs was evaluated both theoretically and experimentally at room temperature. Theoretically it was predicted that CNTs exhibit a thermal conductivity of 6600 W/m K which is larger than graphite (> 2000 W/m K) or diamond (3320 W/m K) (Berber et al. 2000). The measured value of thermal conductivity for bulk samples of SWCNTs is over 200 W/m K (Watts per meter Kelvin) and for individual MWCNTs is over 3000 W/m K (Hone 2004).[10]

4. Optical

CNTs possess unique optical properties and can be studied using a variety of theoretical tools. The calculated optic and nonlinear properties are important for various applications. Light absorption, photoluminescence and Raman spectroscopy measurements are needed to observe the optical properties. The optical properties can be detected by spectroscopic studies. The optical properties of CNTs can be derived from electronic transitions within one- dimensional density of states. Optical responses of semiconducting species are greater than the metallic nanotubes. CNTs have light emitting capacity and vary between metallic and semiconducting CNTs. Health effects of CNTs[11] Though the CNTs have unique properties and are useful for many industrial applications, effects on human health were investigated because materials at the nanoscale behave differently from their original form. CNTs can enter into the human body through various routes like skin, lungs and digestive tract. After gaining entry, they can accumulate in different body parts and can bring out changes. Many CNT toxicity studies have been conducted both in vivo and in vitro to determine the fate and effect of CNTs in the body. However among them, most of the studies were conducted in lung cell model as it is the most sensitive organ[12].

5. Toxic Properties of CNTs:

To investigate the effects of CNTs, researchers exposed various cell lines and animal subjects to CNTs, produced by different methods possessing diverse lengths, diameters and aspect ratios. The parameters, specific surface area and size of CNTs were measured using Brunauer Emmet Teller method and Transmission electron microscopy respectively.

The toxicity effects of SWCNTs & MWCTs on living cells and systems were analysed.[13]

6. Cytotoxicity of CNT

Cytotoxicity of CNTs (SWCNTs & MWCNTs) can be assessed by 3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide (MTT), lactate dehydrogenase (LDH), sodium 3'-(phenyl amino- carbonyl-3,4-tetrazolium)-bis (4-methoxy-6-nitro) benzene-sulphonic acid hydrate (XTT), Alamar Blue (AB), neutral red, Alkaline Phosphatase (ALP)[14]

assays and staining techniques such as trypan blue exclusion, Hoechst, propidium iodide, YO-PRO1, Diamino-2-Phenyl Indole dihydrochloride (DAPI), annexin V , and Bromodeoxy uridine (BrdU) antibody stains and methods like DNA fragmentation, caspase-3 and 3/7 activity measurement etc.[15]

CONCLUSIONS

As the CNTs possess unique physico-chemical properties and high economic potential they are be used in many products and their production is also being increased to meet the market demand. Due to their small size, the nanotubes can get entry easily into the human body through lungs, skin and gut. Compared to other organs as lung is the most sensitive organ, most of the studies were conducted on lung cell model. It is evident from the literature that CNTs are toxic to humans and there exists inconsistency among the reports on cytotoxicity of CNTs. It may be due to variation in the synthesis methods, purification method, mode of CNTs exposure i.e., as suspension in the media (or) immobilisation (or) aerosol etc., route of administration, dimensions, metallic content, dispersion media, membrane permeability of a particular cell line and dosage of CNTs used in that particular study and surface chemistry of the nanotubes and experimental materials used in the study. CNTs are able to cause oxidative stress, inflammation; cell damage, granulomas etc., and these effects have been also observed as dose and time dependent. Even though many studies have been conducted there is no clear evidence for the cytotoxicity of CNTs. Owing to their similarity to asbestos and other pathogenic fibres which have toxicity associated with their needle-like shape, further research is needed in this area in order to release the nanobased products into the market safely. Workers who are exposed to airborne CNTs need to take proper measures in order to protect themselves from the effects of CNTs in the body. The end users of CNT based products must also keep the effects of CNTs in mind before using them and their usage must be in controlled level.

ACKNOWLEDGEMENT

I am indepted and grateful to my supervisor Dr Amita Sherma, Associate Professor of Physics, Deptt. Of Physics, BRABU Muzafferpur Bihar for their constant guidance and encouragement for research work. My thanks to Dr. B Roy Professor and head University Deptt. Of Physics BRABU Muzafferpur Bihar.

My thanks are also due to Dr V K Thakur Professor and former head. Dr Madan Jee.

Dr. R.B. Chaudhry, Dr L K Jha. Dr S N Chutterjee. Dr. Bhagwan Prasad for encouragement and suggestion for research work.

REFERENCES

[1] Carbon nanotubes seminar reported byShuhab-U-Tariq-1SIO3EC109(2007)
[2] AC-2007-1088: Road To Nano Technology education in engineering Technology: an area of interdisciplinary studies.
[3] Physics of carbon nanotubes by M. S. Dresselhaus and R. Saito. MIT.
[4] Nanotubes for electronics by Philip G. Coilins and Phaedon Avouris.
[5] Modern Engineering Physics(2008).
[6] Feynmann R. P. There's plenty of room at the bottom.Eng.Sci 1960; 23:22-36
[7] Electronic structure of atomically resolved carbon nanotubes baserd on nanotechnology, Vol-5, PP. 221-226(2018).
[8] Theoretical study of electronic transport through bent carbon nanotubes. Ph.D thesis. BRABU, Muzafferpur(2017).
[9] Exceptionally High young's modulus observed from individual carbon nanotubes, Nature. 1936.381:680-7
[10] Application note:Preparation of carbon nanotube catalyst. First nano santa Barbara, California 93111.
[11] www.firstnano.com
[12] http://www.nanotech-now.com
[13] First nano lnc. Manufacture of Easy tube Nanofurnace.
[14] http://www.azonano.com
[15] www.sciencedaily.com