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CARBON NANOTUBES AND ITS APPLICATIONS

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ABSTRACT

Carbon nanotubes are the technology that imagination by many scientists in the different country. There are small strengths, dimensions, and the remarkable physical properties of the carbon nanotubes that structures make a very unique material with a whole range of various applications. There are discussing some of the important application of materials science use in carbon nanotubes. There are discuss the pharmaceutical applications of nanotubes, electronic and electrochemical application of nanotubes, mechanical strengths of nanotubes in high performance composites and field emitters based upon nanotube. There are another application of nanotubes such as metrology and biological application of nanoprobes and chemical investigations and formation of other nanostructures. Applications of nanotubes device and electronic properties was treated in the book. The challenges that happen after wards in act of realizing then some applications such as manufacturing, processing, and cost considerations are discussed in the various points of view. Carbon nanotubes are widely applicable in the pharmaceutical field for the treatment of many types of diseases.

INTRODUCTION: A carbon nanotube is made of carbon, a tube-shaped material and nanometer scale used for measuring its diameters. The thickness of a nanometer is about one-billionth of a meter, or one ten-thousandth of a human hair. In the carbon nanotube graphite layer is rolled-up with continuous unbroken hexagonal mesh in the chicken wire. At the apexes of the hexagons carbon molecules are found. Diameters of the carbon nanotubes have ranging from <2 nm up to 55 nm. The lengths of carbon nanotubes are typically several microns. But in recent advancements the length of nanotubes found longer, and measured in centimeter**.**

Carbon nanotubes are the property of existing in more than one form of carbon with a shaped of cylindrical nanostructure and also known as buckytubes. The ratios of nanotubes have been made with diameter and length up to 1:132,000,000, which is larger than any other material. The cylindrical shape of the carbon molecules have make a highly potentially and useful in many applications such as pharmaceuticals field, electronics, in nanotechnology, and other fields of materials science, also in potential uses in architectural fields. Carbon nanotubes have been applied in the construction of body armor. There are extraordinary strengths of the nanotube used as thermal conductors and also unique electrical properties.

The structures of nanotubes are belonging from the fullerene family, which also includes the spherical buckyballs. The last portion of a carbon nanotube may be covered with a hemisphere of the buckyball structure. The diameter of a nanotube is few nanometers that approximately 1/55,000th of the width of a human hair and length up to 20 centimeters [1].

Types of carbon nanotubes:

(a) Single-walled nanotubes (SWNTs): The diameter of single-walled nanotubes (SWNTs) has approximately to 1 nanometer, and length of the tube about many millions of times longer. Single-walled nanotubes are wrapping with layer of graphite which one-atom-thick layer called graphene into a seamless cylinder. The wrapped graphene sheet is represented by a pair of indices (*n*, *m*) known as the chiral vector.

There are important varieties between the single walled nanotubes that exhibit electric properties but the multi-walled carbon nanotube (MWNT) variants are not able to share this property. There are band gap can vary from zero 3 eV and its electrical conductivity can show semiconducting or metallic nature in the single walled nanotubes, whereas MWNTs are zero-gap metals. Single-walled nanotubes are the most portrait electronics beyond the micro electromechanical scale currently used in electronics.

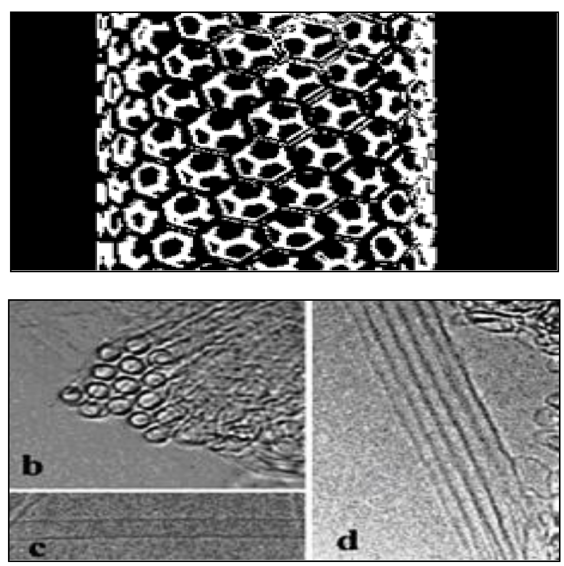

FIG. 1: STRUCTURE OF SINGLE-WALLED (SWNT) (a-d)

(a) Shows a schematic of an individual helical SWMT.

(b) Shows a cross-sectional view (TEM image) of a bundle of SWNTs [transverse view shown in (d)]. Each nanotube has a diameter of ∼1.4 nm and the tube- is distance in the bundles is 0.315 nm.

(c) Shows the high-resolution TEM micrograph of a 1.5 nm diameter SWNT.

SWNTs can be used as excellent conductors because the electric wire used as the building block systems [2-3]. Single walled nanotubes are also applicable in the development of the intramolecular field effect transistors (FET). FETs have recently possible for production of the intramolecular logic gate by using Single walled nanotubes [4]. There are both a p-FET and an n-FET involve to create a logic gate. In SWNTs, p-FETs exposed to oxygen and n-FETs save the half oxygen which exposure from the SWNTs, while another way exposes the half to oxygen.

Then both both p and n-type FETs are involve in a single SWNT that acts as a NOT logic gate within the same molecule. Single-walled nanotubes are declining precipitously in price, from around $1500 per gram and retail prices of around $50 per gram of as-produced 40–60% by weight SWNTs [5-6].

(b) Multi-walled nanotube: Multi-walled nanotubes (MWNT) are made of multiple rolled layers or concentric tubes of graphite. There are two types of models which can be explained the structures of multi-walled nanotubes. According to the Russian Doll model, the graphite sheets are arranged in concentric cylinders, e.g. a (0, 9) single-walled nanotube (SWNT) within a larger than (0, 18) single-walled nanotube. According to the Parchment model, a single graphite sheet is rolled in around the MWNTs, similar a rolled newspaper or scroll of parchment. The interlayer of multi-walled nanotubes distance is close to the distance between graphene layers in graphite 3.4 Å.

The morphology and properties of double-walled carbon nanotubes (DWNT) must be important in the specific place because they are similar to SWNT but its resistance to chemicals is significantly also improved. This is especially important when grafting of chemical functions is required at the surface of the nanotubes to add properties in the CNT. The covalent function will break when some C=C double bonds, leaving hole in the structure on the nanotube in the case of SWNT. There are modifying both its electrical and mechanical properties in SWNT. Only the outer wall is modified of the DWNT. In 2003 CCVD technique was used for the synthesis of DWNT on the gram scale process and there were reduction of oxide solutions in hydrogen and methane [7].

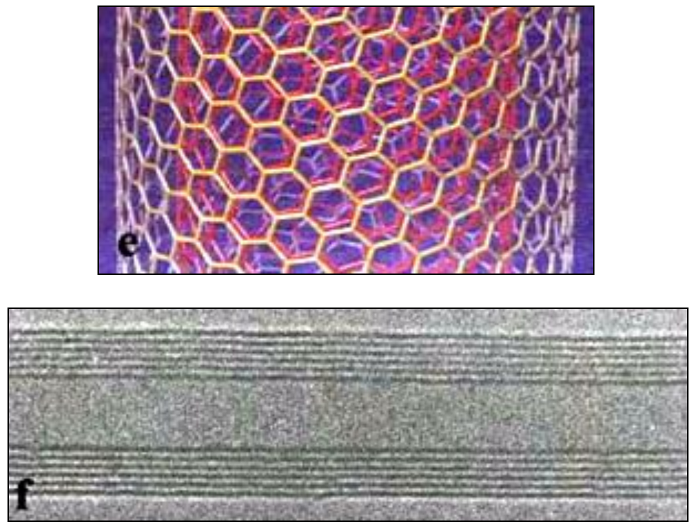

FIG. 2: MULTI-WALLED (MWNT) CARBON NANOTUBES (e, f)
(e) Is the schematic of a MWNT
(f) Shows a high resolution TEM image of an individual MWNT. The distance between horizontal fringes (layers of the tube) is 0.34 nm (close to the interlayer spacing in graphite)

Properties:

Strength: In the respect of tensile strength and elastic modulus carbon nanotubes are the strong and stiff materials research by the scientist. The covalent sp^2 bonds obtained between the individual carbon atoms for the better results of strength. The tensile strength of a multi-walled carbon nanotube was found to 63 gigapascals (GPA) in 2000 [8]. Low density of a carbon nanotubes have been found for a solid of 1.4 to 1.5 $g \cdot cm^{-3}$ [9]. The specific strength of a carbon nanotube was found to 49,000 $KN \cdot m \cdot kg^{-1}$ as compared to high-carbon steel's 155 $KN \cdot m \cdot kg^{-1}$ that known for better materials.

Under compression carbon nanotube are not strong strength material because of its complete structure and high aspect ratio tend to undergo buckling and torsional or bending stress [10].

Hardness: Diamond is considered as the hardest material. Under specific conditions of high temperature and pressure, graphite changes into diamond. There are syntheses of super-hard material by compressing SWNTs to required 24 GPa at room temperature. Nanoindenter was used for the measured of the hardness this material and required as 62–152 GPa pressure. The hardness of boron nitride and diamond samples was found to be 62 and 150 GPa, respectively. The bulk modulus hardness of compressed SWNTs was found 462–546 GPa. The value of diamond was 420 GPa [11].

Kinetic: Multi-walled carbon nanotubes are made of multiple concentric graphite layers of nanotubes precisely nested within another. There are different telescoping properties of an inner carbon nanotube core may slide in its outer shell of nanotube and it almost without friction. There are creating an atomically perfect linear nanotube or rotational bearing. There are examples of molecular nanotechnology, that precise positioning of atoms in nanotubes to create useful machines. These properties are utilizing to create the world's smallest rotational motor [12]. A gigahertz mechanical oscillator is also envisaged as other application.

Electrical: Band structures compound using tight binding approximation for (10, 2) CNT (semiconducting), (6, 0) CNT (zigzag, metallic) and (10, 10) CNT (armchair, metallic). By the unique electronic structure of graphene that can also affects its electrical properties in the structure of carbon nanotubes. There are given (*n, m*) in the nanotube if $n = m$, is metallic in the nanotube; if $n - m$ is a multiple of 3 and then the nanotube is semiconducting. In nanotube semiconductor has a very small band gap; and the nanotube is a moderate semiconductor. Then all armchair ($n = m$) nanotubes are metallic, and nanotubes (6, 4), (9, 1), etc. are semiconducting [13].

This rule has exceptions in the case that electrical properties of the carbon nanotube can strongly influence by the curvature effects in small diameter. According to the metallic calculations that a (5, 0) SWCNT should be semiconducting in the respect of nanotube. There are metallic finite gap between chiral and zigzag SWCNTs with small diameters in tube. Metallic nanotubes are carrying an electric current density of 5×10^9 A/cm^2 which is 1,000 times greater than metals such as copper [14].

The interconnected inner shells of multiwalled carbon nanotube has high superconductivity with a transition temperature T_c = 12 K. The T_c values of single-walled carbon nanotubes or MWNTs are magnitude lower for ropes with usual and non-interconnected shells [15].

Thermal: Both SWNTs and MWNTs are hoped to be very good thermal conductors along with the tube that exhibit a property called as "ballistic conductors", but both good insulators laterally to the tube axis. The thermal conductivity of the SWNT has measurements at the room-temperature along its tube axis of about 3600 W·m^{-1}·K^{-1} [16]. Copper is a good thermal conductivity that compare to SWNTs which transmits 385 W·m^{-1}·K^{-1}. At the room-temperature thermal conductivity of SWNTs has across its axis of about 1.52 W·m^{-1}·K^{-1}, [17] which is about a good thermally conductive as soil. The temperature stability of carbon nanotubes is required in air about 750 °C and in vacuum about 2800°C [18].

Defects: The crystallographic defect can affects as with any material properties. In the carbon nanotube defects can obtain in the form of atomic vacancies. Defects such as high level can lower the tensile strength of carbon nanotube up to 80 %. The

Stone Wales defect can creates a heptagon and pentagon pair by rearrangement of the C=C bonds in the carbon nanotube. There are very small structures of carbon nanotubes, that the tensile strength of the carbon nanotube is dependent on its weakest segment in a similar chain. The weak link of the strengths becomes the maximum strength of the chain in a carbon nanotubes segment.

The electrical properties of the tube's can also affect by the crystallographic. There are a common result obtain in lower conductivity defective in the nanotube region of the tube. A defect in armchair-type nanotubes which conduct electricity can cause the surrounding region to the semiconducting, and magnetic properties can reduced by the single monoatomic vacancies [19].

Toxicity: In nanotechnology that toxicity of carbon nanotubes has been determining one of the most squeezing questions. Unfortunately, some research has only just started to solve this problem. CNT has considerable impact on the reactivity, parameter such as surface charge, size distribution, surface chemistry, structure, surface area and agglomeration state as purity of the sample. The available data clearly show that, there are some specific condition such as nanotubes can cross membrane barrier.

There are toxicity effects such as inflammatory and fibrotic reactions that can induce by the raw materials if reach in the different body part [20]. In a study by Alexandra Porter, he shows that carbon nanotubes can go in human cells and accumulate in cytoplasm and causing human cell death [21].

Nanotube synthesis and processing: Carbon nanotubes are consisting of rolled graphite sheets with different nanometer range in diameters and micrometer range in lengths. They are different from those of other carbon allotropes, such as diamond, graphite and fullerenes. There are two types of carbon nanotubes (a) single walled carbon nanotubes (SWCNTs) (b) multiwalled carbon nanotubes (MWCNTs). Both SWCNTs and MWCNTs are usually made by various types of composition such as laser ablation of carbon, carbon-arc discharge and chemical vapor deposition.

Carbon nanotubes properties can be tuned by changing the diameter. SWCNTs consist of a cylindrical tube which wrapped by a single graphite seamless sheet. But SWCNTs are presently production only on a small scale and extremely very expensive. MWCNTs comprise an array of such nanotubes that are concentrically nested like rings of a tree trunk [22-23].

The MWCNTs is composed of 3–25 layers of concentric graphite, the range of diameters from 10 to 55 nm and length more than 15 µm. The other way, SWCNTs is much thinner than the MWCNTs, with diameter ranging from 1.0 to 1.5 nm. All the current synthesis methods which used production of SWCNTs result found in major concentrations of impurities [24].

Applications of Carbon nanotube (CNT):

Cancer Treatment: Cancer is one of the most ravaging diseases that approximately more than 10 million new cases found every year from different countries. There are current treatments of cancer by various methods such as radiation, surgery and chemotherapy that successful in several cases. These appropriate methods are also killing healthy cells and cause toxicity to the patient.

The spread of cancer cells between organs, a process called as metastasis which is responsible to cause of most cancer death. It would therefore be desirable to develop methods to directly target cancerous cells without affecting normal ones [25]. In the drug delivery systems used recent advances to promise for enhance cancer therapy [26].

In advanced drug delivery system there are CNT"s considered as antitumor agents when conventional drug combined with in, then obtained enhancement their chemotherapeutic effect. It has been found that Paclitaxel loaded PEG-- carbon nanotube sare promising for cancer therapeutics [27].

There are aqueous solutions of SWCNTs on exposure to radiofrequency (RF) field experiences efficient heating. This property has been achieved by Gannon *et al* for a noninvasive and selective thermal destruction of treatment for human cancer cells with very less effect or no toxic effects to normal cells. There are carbon nanotubes capable of leading to new suitable directions and approaches in therapeutic human cancer cells [28].

In the next generation of cancer treatments the photo-thermal therapy used and nanomaterials technology has been recently important as an efficient strategy for cancer treatments. SWCNTs are used for potent candidate for the photo-thermal therapeutic agent. It generates sufficient amounts of heat when goes to excitation state with near infrared light (NIR, lambda = 700-1100 nm) which is easily cross to biological systems including skins.

SWCNTs sidewall is highly hydrophobic; they are practically not soluble in water. So SWCNTs are functionally active by covalent or non covalent routes that will help in open the CNT bundles and make them soluble in water [29]. There are demonstrated that DOX loaded SWCNTs (PL-SWCNT- DOX) induced significant treatment for U87 cancer cell death and cell apoptosis. There are the main advantages of SWCNTs which used as drug deliver at the particular site such as drug carrier compared to free drug which is the potential to target delivery for selective destruction of different types of cells and reduce the toxicity to non-targeted cells of different site.

The above method used for the treatment of cancer cells provides an easily to make formulation of the SWCNT–DOX complex which extremely high drug-loading efficiency. They are highly higher than obtained conventional liposome's and dendrimer drug carriers [30]. Carbon nanotubes are an important new stings and this work as a boost to control against cancer after researchers adopted this technology and found that they can improve a treatment against cancer called adoptive immunotherapy.

Apply conventional adopted immunotherapy techniques which can take few weeks, but using carbon nanotubes technology then reduced this time up to two thirds. The researchers found that the antigens of the cancer cell collected around defects on the surface of the carbon nanotubes by using fluorescence resonance energy transfer (FRET) microscopy [31].

Bioengineering: There are many applications of bioengineering proposed by the carbon nanotubes technology, such as energy storage and conversion devices, conductive and high strength composite, radiation sources, sensors, nanometer-sized semiconductor devices and hydrogen storage media [32-33]. The principal of SWCNTs and MWCNTs applied in the industrial and academic for research activity. There are different electronic device focused using in the research activity such as field emission electron source for, lamps, flat panel display and gas discharge tubes applied for surge protection, microwave generations and x-rays.

There are high potential energy applying between a coated surface of carbon nanotube and an anode. They produce high local field effect then results found in small change in radius of the nanofiber tip and small change in length of the nanofiber. These local field effects cause electrons to tunnel the nanotube tip into the vacuum.

Cardiac Autonomic Regulation: There are many times single-walled carbon nanotubes used in the cardiac autonomic regulation. Single-walled carbon nanotubes are portion of physicochemical properties with fine component which may damage cardiovascular autonomic control that proved after the study in rats. Many times SWCNTs may alter the baroreflex function, then affecting the autonomic cardiovascular control regulation [34].

Platelet Activation: The main applications of SWNTs are platelet activation in the macro and microcirculatory thrombus formation. There are platelet P-selectin expression method used in the study on platelet activation *in vitro*, micro and macrocirculatory thrombus formation. This activity has been reported that SWCNTs when injected into anaesthetized mice or rat, light/dye-induced thrombus formation was noted and then platelet activation found [35].

Blood platelets are activate by MWNTs inducing extracellular Ca^{2+} influx that could be prevented SKF 96365 and 2-APB blockers that comes in the calcium channel blockers. Platelet activation is induced by carbon nanotube that associated with a marked relax of platelet membrane microparticles and secretion of markers CD62P and CD63.

Tissue Regeneration: Carbon nanotubes are composed with various polymers, (such as polylactide and poly-D, poly-l-lactide, Llactide-co-glycolide copolymer) which have been applied as scaffolds in tissue regeneration. Many types of biodegradable polymer are combined with carbon nanotubes that provide new view point in the development of scaffold nano-devices and nanomaterials [36]. There were prepared composite materials comprised of a collagen matrix with embedded carbon nanotubes by mixing solubilized collagen with solution having carboxylated SWCNTs.

Living smooth muscle cell were integrated at the collagen stage to produce cell-seeded collagen carbon nanotubes composite matrices. They accomplished that such collagen carbon nanotubes composite mixtures may be useful as scaffolds in tissue regeneration [37]. It is reported that new composite material considered by combining MWCNTs with craft collagen matrix showed good mechanical characteristics due to the favorable properties of MWCNTs [38].

Recent advancement of carbon nano tube in the pharmaceutical field: A microcapsule carbon nanotube provides targeted delivery of therapeutic application in various diseases. However, their efficacy is limited due to the problems face during their delivery to target tissues. In recent era there are various developments take place in carbon nanotube in different field like carbon nanotube based tissue engineering, where the interaction between living cells/tissues and nanotube takes place and in the organ regeneration techniques.

The better mechanic strength and chemical inert of carbon nanotube also makes it ideal for blood attuned applications, especially for cardiopulmonary bypass surgery.

The applications of carbon nanotubes in these cardiovascular surgeries led to a remarkable development in mechanical strength of entrenched catheters and reduced thrombogenicity after surgery [39].

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