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CARBON NANOTUBES: A novel approach in the field of biomedical science.

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ABSTRACT: Carbon nanotubes (CNT) are a notable and unique invention in the field of nanotechnology. Crystal formations are quite similar to the nuclear atomic configuration of diamond and graphite. While diamond is owned by sp3-hybridized carbon, graphite is the property of sp2-bonded carbon. CNT development started in 1991. Important characteristics of CNTs include their light weight, tiny size, superior strength, and great conductivity. CNT is helpful in a variety of materials, including metallic surfaces, polymers, and ceramics. When it comes to CNTs' potential applications, they include nanotechnology, nanomedicine, vacuum electrical devices, biosensors, membranes, and capacitors. Carbon nanotubes (CNTs) are materials that resemble tubes and have a diameter that is measured in nanometers. They are made of graphite sheets, and the graphite layers resemble a continuous, unbreakable hexagonal mesh structure with carbon molecules appearing at the hexagonal structures' apexes. Carbon nanotubes can be classified as single-walled (SWCNT), double-walled (DWCNT), or multi-walled (MWCNT) depending on the number of carbon layers present. There are three basic ways to create carbon nanotubes (CNTs), including chemical vapour deposition, electric arc method, and laser deposition method. Carbon nanotubes have a number of distinguishing characteristics, including high elasticity, high thermal conductivity, low density, and greater chemical inertness. Carbon nanotubes have an important place in the sciences of nanotechnology, electronics, optics, and other materials science because of these fascinating features. Positive applications of carbon nanotubes include water treatment, sensing, and medication delivery. Their surface can be functionalized to provide highly soluble compounds that can then be derivatized with active molecules to make them compatible with biological systems. With the use of surface functionalization, different chemicals or antigens can be attracted to or adsorb to surfaces, where they can then be directed towards a certain cell population for therapeutic or immune response purposes. The characteristics of carbon nanotubes and their clinical uses, including medication delivery and medical diagnostics, are covered in this article. In this article, the antibacterial and antifungal properties of carbon nanotubes are also discussed.

KEYWORD: Nanotechnology, Sp3-hybridized carbon, Carbon nanotubes, Biosensors, Medication

I. INTRODUCTION:

The discovery of Carbon Nanotubes brings revolutions in the field of pharmaceutical technology. Each invention or scientific discovery at the nanoscale is made possible by nanotechnology. Nanotubes in nanotechnology have sparked curiosity from both fundamental research and a forward-thinking viewpoint. Allotropes of carbon exist in CNTs. They have a tubular shape and are constructed of graphite. The field of nanotechnology and medicines can benefit from CNTs because they have a variety of unique features. They have a wide diverse variety of electrical, thermal, and structural properties and are nanometres in diameter and several centimetres in length. These characteristics differ depending on the type of nanotube, which is determined by its diameter, length, chirality or twist, and wall type. Their distinct surface area, stiffness, strength, and resilience have generated a lot of interest in the pharmacy industry. Carbon plays a significant function in the formation of CNTs. The element carbon can be found in everything and everywhere. The sixth element on the periodic table, carbon, is found in group IV. It produces more compounds than any other element due to the outermost valance electrons that are partially occupied. When seen from a microscopic perspective, nanotechnology will serve as the foundation for other emerging technologies.[1]

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, 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 Iijima (1991) in the soot produced by the arc discharge synthesis of fullerenes. These tubes are made up of thick sheets of carbon called graphene which were rolled up to form a seam less cylinder. On the basis of number of tubes present, the CNTs are classified as Single walled (SWCNTs), double walled (DWCNTs) and multiwalled (MWCNTs) carbon nanotubes.[1,2]

Carbon nanotubes (CNTs) are very promising for the continuous growth of telecommunication market due to their many unique chemical and physical properties. Next-generation computer devices, consumer electronics, wireless LAN devices, wireless antenna systems, and cellular phone systems are few portable device applications that require these composite materials, because nano composites have the potential to significantly surpass the physical properties of conventional bulk materials. As heavy heat transfer materials have delayed the development of portable devices, it is required to develop light-weight, flexible, inexpensive, and wearable composite materials, which has high heat conductivity.[3] Therefore, to develop the CNT-composite materials, cellulose is considered due to being bio source, light-weight and biologically compatible.

The problems in developing the composites would be dispersion of nanotubes in solvents, CNT-polymer interactions, manufacturing cost, and performance of the composite. Cellulose has attracted much attention with expertise in diverse areas as a renewable source based biodegradable polymer and will be medium for displaying and transmitting information owing to its potential compostibility, mechanical stability under atmospheric conditions, and ability to absorb liquid. Carbon nanotubes (CNTs) are regarded as one of the most versatileadditives of composites because it can improve mechanical, thermal, and electricalcharacteristics of cellulose [4,5,6]. Especially, homogeneous distribution of CNTs in the cellulose matrix would contribute to improve its characteristics [6]. However, the nonreactive surface and strong aggregation properties of CNTs due to van der waals attractive force have limited the effectiveness of CNTs with cellulose during the time of mixing. Previously it is found that chemical modification of CNT is the most successful dispersion technique which forms carboxyl functional groups on the surfaces and the ends. This carboxyl functional group binds the CNTs with cellulose very tightly. On the other hand, chemical modification would considerably alter their desirable properties. Therefore, CNT dispersion in solvents is prerequisite to utilize the unique multifunctional properties of CNTs in case of preparation of CNT/cellulose composites. For this purpose, in this report, biofriendly material, gelatin is used to disperse the CNTs before mixing with cellulose. Gelatin wraps the surface of CNTs enabling their dispersion in water and does not affect the physical properties of CNTs while enabling their dispersion in aqueous solutions.[7] CNTs form a conducting network using their electron donating and accepting ability in the composite. These CNT/cellulose composite materials have some outstanding properties such as mechanical toughness, electrical and thermal conductivity, and the usage of the materials that have been investigated [9]. In this study, CNT sheets have been prepared by the paper making process which is on the easy, simple, and readily scalable process. Previous study has also not focused on sustaining the structure of the CNTs for making composite. Here, it is considered by using gelatin to disperse CNT before mixing with cellulose.Besides this, we have concentrated on the good environmental stability of composite and low cost combined with the easiness of preparation.[8] The resulting CNT/cellulose papersheets show high electrical conductivity, strong microwave absorbing properties, thermal stability, and wettability. To the best of our knowledge, no study has yet investigated the properties of composite by increasing the amount of CNTs. This study reports that the composite properties are improved by increasing amount of CNTs and it can be the product of any size and shape by maintaining the CNT/cellulose ratio. Composite materials with carbon nanotube and graphene additives have long

been
considered as exciting prospects among nanotechnology applications. However, after nearly two decades of work in the area, questions remain about the practical impact of nanotube and graphene composites.[10] This uncertainty stems from factors that include poor load ransfer, interfacial engineering, dispersion, and viscosity-related issues that lead to processing challenges in such nano composites. Moreover, there has been little effort to identify selection rules for the use of nanotubes or graphene in composite matrices for specific applications.

II. TYPES OF CARBON NANOTUBES:

Carbon Nanotu bes are classified in following two types:-

- Single Walled Carbon Nanotubes (SWNTs)
- Multi Walled Carbon Nanotubes (MWNTs)

1. 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 tensile strength of SWNTs is found to be 13-52 GPa .According to Young's modulus elasticity of SWNT is 2.8-3.6 TPa .The measured value of thermal conductivity for bulk samples of SWNTs is over 200 w/m k .0.35-0.40 nm. They may behave as a metal. [11]

Properties of SWNT:

- They are more bendable yet harder to MWNT .
- . They can be twisted , flattened , bend into two small circles or around sharp bends without breaking .
- They have unique electronic and mechanical properties which can be used in numerous applications such as field-emission displace, nanosensors, logic elements etc.

2. MWNT:

MWNTs consist of multiple rolled layers (concentric tubes) of graphene. Its outer and inner diameters of layers is between 2-100m.The tensile strength of MWCNT is found to be 63 GPa .The electricity of MWCNT 1.7-2.4 according to Young's modulus .And the conductivity of MWCNT is over 3000 W/m. Double-walled nanotubes (DWNTs) are special class of nanotubes because their morphology and properties are similar to those of SWNTs but their resistance to che significantly improved. [11]

Properties of MWNT:

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

III. CARBON NANOTUBE MORPHOLOGY:

Carbon nanotubes are mainly belonging to the fullerene family of carbon allotropes.They are cylindrical molecules and are primarily consist of a hexagonal arrangement of SP2 hybridized carbon atoms .The carbon nanotubes can also be mentioned as hollow cylinders formed by rolling single or multiple layers of graphene sheets into seamless cylinders . These cylindrical structures have two forms that are SWNT and MWNT.[14]

IV. CARBON NANOTUBE STRUCTURE:

Carbon nanotubes has different structure, the structure like regular shapes, cones, tubes etc. But only two types of structures are most significant. Those are –SWNT (single walled nanotube) and MWNT (multipled walled nanotube). From the name itself the structure of a SWNT is conceptualized that here a one atom thick layer of graphene into a seamless cylinder. Its diameter is close to 1 nm. Again the MWNT can define as Russian dolls that are made of SWNTs concentric cylindrical graphene tubes.[17]

V. CARBON NANOTUBE CHAIRALITY:

Chirality of a SWNT is obtained from its chiral vector C that is defined by a pair of integers (n , m) obtained from the arrangement of the graphene hexagons with respect to the SWNT axis

.The armchair configuration with chiral vectors (n,m) is characterized by the perpendicular shape of the chair to the tube axis , where as the zigzag conformation is characterized by vectors (n , 0) and has a V – shaped perpendicular to the tube axis . All other vectors compositions are described as chiral or helical. The chirality of SWNTs determines their conductivity, allowing for their potential development into a wide variety of SWNT based electronic switching devices.

VI. CARBON NANOTUBE SOLUBILITY AND DISPERSION:

For biocompatibility the solubility of CNT in aqueous solvents is must require .The carbon nanotube composites in remedial delivery must meet the fundamental requirement. Simultaneously it is essential that such CNT dispersions be uniform and stable to obtain accurate concentration data. In this regard, the solubilisation of pristine CNTs in aqueous solvents remains an obstacle to realizing their potential as pharmaceutical excipients because of the rather hydrophobic character of the graphene sidewalls , coupled with the strong p-p instructions between the individual tubes , which cause CNTs to assemble as bundles .[18] To successfully dispersing medium should be capable of both wetting the hydrophobic tube surfaces and modifying the tube surfaces to decrease tube aggregation. For basic approaches have been used to obtain dispersion:

- Surfactant – assisted dispersion
- Solvent dispersion
- Functionalization of CNT side walls , and
- Biomolecular dispersion

VII. PROPERTIES OF CARBON NANOTUBES:

Since carbon nanotubes tiny in their sizes but it exhibits many interesting and unique properties. Those are discussed below –

- Mechanical properties :

CNTs are made up of sheets of graphene and the C-C bond in a graphene layer is probably the strongest chemical bond in nature. CNTs are the strongest and stiffest materials yet discovered in terms of tensile strength elastic modulas . The tensile strength of CNTs is due to the covalent sp2 bonds formed between the individual carbon atoms . The CNTs can sustain exteamly high tension force of about 130 GPa (gigapascals) . The CNTs are elastic in nature and they can be withstand stress . The elasticity can be measured experimentally by calculating Young’s Modulus.[18]

- Electric :

CNTs possess unusual electronic properties and act as conductors of energy. The diameter and helicity of carbon atoms in the nano shell are believed to determine their conductivity. The theoretical calculations can be done due to their geometrical structure. [19]Theoritically it was determined that metallic nano tubes can carry an electric current density of 4*10 9 A/cm2 which is 1000 times higher than copper.

- Thermal :

CNTs are very good thermal conductors due to their geometrical structure. The thermal conductivity of CNTs was evaluated both theoretically and experimentally .It was predicted that CNTs exhibit a thermal conductivity of 6600 W/m k which is larger than graphite or diamond.[19,20]

- Optical :

CNTs possess unique optical properties and can be studied using a variety of theoretical tools. The calculated optic and non linear properties are important for various applications. Light absorption, photoluminescence and needed to observe the optical properties. [21]The optical properties can be determined 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 very between metallic and semiconducting CNTs.[22,23]

VIII. OPERTUNITIES AND CHALLENGES OF CARBON NANOTUBES:

Carbon nanotubes (CNTs) are one of the wonders of modern science discovered. CNTs have been regarded as the stiffest and the strongest material ever developed and received considerable interest in research because of their unique atomic structure, dimension and attractive properties. In the past decade, researchers made several attempts and efforts exploiting the exceptional properties of CNTs toward the development of CNTs applications. Nowadays the carbon nanotubes derived products have smeared into our life step by step, and before long, they will function as essential components for technological innovations. A recent direction of research has been to try to gain further understanding by the use of computational methods and models which appeared with the advancement of computer technology. In this paper, a summary of recent research achievements related to the carbon nanotubes and their applications in nanomaterials.[24]

IX. HEALTH BENEFITS OF CARBON NANOTUBES:

Though the CNTs have unique properties and are useful of many industrial applications, effects on human health were investigated because materials at the nano scale 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. Due to rapid evolution of complicated disease in our modern world, the existing methods of diagnosis, drug delivery and treatment are becoming less effective. Therefore, modern health care requires more sophisticated and effective carriers for the same. This review article provides information regarding Carbon Nanotubes (CNTs), its application in the diagnosis and effective treatment of several complicated diseases such as cancer. Currently available drug carriers including polymer based devices, liposomes, emulsions, microparticles, nanoparticles though effective, but posses certain limitations which could be overcome by the utilization of CNTs. The carriers also have impediments like incapability to penetrate cell membrane and to enter cytoplasm. Use of CNTs can easily overcome these limitations. This suggests the success of CNTs as effective tool in modern health care.[25] Carbon nanotubes (CNTs) with their special properties are regarded as unique materials in various health fields such as biomedicine and pharmacology. Recently, the potential application of CNTs in drug and gene delivery has been clearly demonstrated (e. g. drugs are encapsulated in CNTs, and then they are injected into cell and are released there).Furthermore, CNTs are promising candidates for forming the basis of new biological and medical devices such as pace makers and biosensors.3 For example, the CNT-based electrochemical biosensors have been used for detecting chemical redox interactions. Additionally, CNTs are used as scaffolds to promote cell adhesion, growth, differentiation, and proliferation. These scaffolds provide mechanical strength, chemical stability, and biological inertness. Another application of CNTs can be intracellular and extracellular recording.

The benefits and the utilizations of CNTs may raise concerns about their biocompatibility and possible adverse effects on cardiovascular system. They may alter the autonomic nervous system (ANS) and spontaneous heart rate variability (HRV).According to inhalation studies on particles, it has been predicted that nano sized particles will have higher pulmonary depositions and biological activities compared with larger particles. Therefore, some nano materials may affect the deposition site and distant responses throughout the body. In general, the cytotoxicity of CNTs depends on their structure, dose, concentration, manufacturing method, functional group, etc. Several in vitro and in vivo studies demonstrated that CNTs might induce oxidative stress and cytotoxic effects. These nano materials may cause pulmonary inflammation.The investigation of cardiovascular adverse effects of single-wall carbon nanotubes (SWCNTs) on respiratory exposure shows that they lead to formation of pulmonary granulomatous and production of cardiovascular toxicity. A toxicity investigation of multi-walled carbon nanotubes (MWCNTs) in human shows that not only they induce inflammatory and fibrotic reactions but also they lead to protein exudation and granulomas on the peritoneal side of the diaphragm.One of the in vitro studies about CNTs cardiovascular effects showed that exposure to CNTs increase the risk of cardiovascular diseases by affecting normal cardiac electrophysiology.[26]

Another study shows that oropharyngeal aspiration of MWCNT causes increased susceptibility of cardiac tissue to ischemia/reperfusion injury without a significant pulmonary inflammatory response; therefore MWCNTs can be the cardiovascular system risk. Generally, there is concern that nanomaterials could have a major impact on the cardiovascular system, although the effects of exposure to newly developed nanomaterials on the cardiovascular system remain elusive and no definitive data are available about these nanomaterials effect on the cardiovascular autonomic control. [27] Inhaled nanoparticles in the lungs may cause systematic inflammation through oxidative stress, which mediates endothelial dysfunction and atherosclerosis. In addition, nanoparticles can translocate into the blood stream, be taken up by endothelial cells, and directly induce injury of endothelial cells.

X. METHODS OF PRODUCTION OF CARBON NANOTUBES:

- Arc discharge method :

The arc discharge method is the most effective method of producing carbon nanotubes. This method producing CNT, produces the supreme quality of carbon nanotube. Iijima described the synthesis of the tube in 1991 utilising the arc discharge evaporation technique, which is similar to the previous arrangement strategy used for the synthesis of fullerene. The arc discharge process has a yield rate of (>75%). When compared to another approach, the arc discharge method produces CNTs with fewer structural flaws at high temperatures (over 1,700). On the negative end (cathode) of the carbon base electrode, carbon needles with diameters ranging from 4 to 30 nm and lengths of up to 1 mm were produced for the synthesis of CNT. The chamber is made up of metal catalysts including cobalt, nickel, and iron as well as graphite as a cathode and evaporated carbon molecules as an anode.[28] The current that is immediately transferred through the arcing process is generated by a connected source. The chamber is heated to about 4000 K and placed under pressure. Two graphite rods were connected to the power source by a few millimetres. The carbon starts to vaporise and create a hot plasma after being turned on by keeping the power at 100 amps. The synthesis of CNT using the arc discharge method can be carried out in one of two ways: either with or without the presence of catalytic precursors. Fe-Ni, Co-Ni, Co-Cu, Ni-Cu, Fe-No, Ni-Ti, Ni-Y, etc. are frequently used in SWNTs. It is possible to create MWNTs without using catalytic precursors.[29] The arc was produced in a reactor with helium gas between two graphite electrodes. The primary benefit of the arc-discharge method is its ability to produce a significant quantity of nanotubes. This gives one person less control over how the nanotubes are arranged, which results in poor CNT characterisation and function. Purification of the product is crucial since CNT becomes impure when a metallic catalyst is present.

- Laser ablation method:

The yield of CNT is reduced by 70% utilizing a limited amount of Ni and Co at 1200 C using the laser ablation process by Thess et al. [3] in 1996. The quartz's internal graphite is what the laser's ultimate goal is to vaporize. The strength of the laser pulse causes the tubes' diameter to expand and become thinner. Due to helium or argon, laser ablation maintains constant pressure. The structure and chemical composition of the target materials are the attributes that are affected by laser ablation techniques. The various laser properties like peak power, energy fullerene, oscillation wavelength, repetition rate,flow, pressure owing to buffer gas, pressure in the chamber, chemical composition, and ambient temperature are some of the different laser features. This approach produces SWNTs with higher manufacturing quality and purity. The arc-discharge approach and the laser ablation method are equivalent from this angle, but in the laser method, the necessary force is provided by a laser that heats a pure graphite pellet containing catalyst elements. This technology is cost-effective due to the utilisation of highly purified graphite rods and laser energy. The daily production of nanotubes using arc-discharge processes is insufficient. [30]

- Thermal synthesis process:

Plasma-based synthesis is a basic term for techniques like laser ablation and arc discharge. Thermal energy is managed during the thermal process, and the heat never rises above 1200^{o} C. Plasma-enhanced CVD is an example of a comparable method. Materials used as active catalysts, such as Fe, Ni, and Co. CNTs are reliant on carbon feedstock in this situation. Active feed stocks like Mo and Ru can occasionally be added to create CNTs. The simplest method for producing CNT using chemical vapour deposition is thermal synthesis. These procedures include flame synthesis, monoxide synthesis, and chemical vapour deposition.

- Chemical vapour disposition:

For the aforementioned synthesis approaches, there are still two significant issues, such as the necessity for high temperatures, large-scale manufacturing, and several filtering purifications. For the production of nanotubes, CVD was found in 1996.[31] The technique allows for precise development control and massive nanotube synthesis. Chemicals that are volatile can undergo a reaction to transform into the necessary solid films. The fullerene is processed by CVD under air pressure. Here, two different fullerene configurations—horizontal and vertical—are used. Place the substrate in an oven and heat it to a temperature between 700 and 900 °C. Add acetylene, methane, or ethylene, which are carbon-bearing gases, gradually, and then introduce nitrogen into the response chamber. Argon and hydrogen are the carrier gases for these carbon gases, which are referred to as catalyst mixtures. Nanotubes are moulded throughout the procedure. 90% efficiency and yield of the synthesised product.[32]. Due to the broken of the carbon-containing apparatus gas is being apart and the carbon becomes visible at the edge of the nanoparticles where the nanotubes start to produce.[31,32]

- Vapour phase growth:

A more sophisticated and modified method of CVD is vapour phase growth. This process will produce CNT in a chamber containing a catalytic metal but no substrate [33]. With the use of two furnaces located in the reaction chamber at low temperatures, ferrocene serves as a catalyst in this method. In the first furnace, tiny catalytic particles are created during the procedure, and when they reach the second furnace. To create CNTs in the second furnace, carbons are rapidly injected into the catalyst by diffusion. The reactant was fed gradually into the chamber and, in certain instances; argon flow was also used as a catalyst.

- Flame synthesis method:

Using a flame is another approach that could be used to create CNTs. Utilising the flame serves as a synthesis medium that simultaneously delivers energy and chemical species, resulting in the production of various forms of carbon in nano level. Fuel (gases like methane ($CH4$), ethylene ($C2H4$), acetylene ($C2H2$), etc. is combined with an oxidizer to create a flame, which produces a different gaseous mixture that includes carbon dioxide ($CO2$), water vapour ($H2O$), carbon monoxide (CO), hydrogen ($H2$), saturated and unsaturated hydrocarbons ($C2H2$, $C2H4$, $C2H6$), and radicals.[35] For the deposition of solid blackcarbon, catalysts must offer reaction sites. The flame synthesis method is an autothermal process that, when compared to other methods, may supply temperature to achieve the favourable conditions for synthesis. A flame can be injected with the catalyst that has been vaporised. Commercially, flames are utilised to produce solid carbon forms like carbon black and printing ink because they are scalable. This approach is helpful in determining both the structure and rate of development of CNTs. CNTs form similarly to how the CVD process does.

- Plasma enhanced chemical vapour deposition (PECVD):

This CNT synthesis technique allows for a decrease in temperature. The PECVD approach is superior than CVD for controlling the development process and lowering the temperature to a low level. In PECVD, the plasmatic energy successfully breaks up gas molecules, and at low temperatures, CNTs begin to develop. Its increased development rates are two orders of magnitude higher. The most important component in the creation of SWNT is plasma. As the input power increased during PECVD, the plasma mode of an atmospheric pressure radio-frequency discharge (APRFD) reactor transitioned from mode (60 W) to mode (100 W). When an ion strikes the initial electrodes, an electron is generated, and the electric field also produces secondary electrons in the plasma sheet. An external magnetic field constrains the CNT growing tool to direct the ferromagnetic iron bearing. The built-in electric field that appears in a plasma sheath while modifying the developing CNTs along the electric field is a benefit of adopting the PECVD process.

XI. PURIFICATION OF CARBON NANOTUBES:

Purification is accomplished after synthesis by removing undesirable components such amorphous carbon, carbon nanoparticles, leftover catalyst, and other graphitic impurities. Metal nanoparticles, fullerenes, nanocrystalline graphite, and amorphous carbon that are coating the nanotube dividers contaminate the tubes as they are being synthesised. Where possible, contaminants should be removed using gentle purification techniques so as not to damage the carbon nanotubes. Oxidants used in this purification process include $HNO3$ and $KMnO4/H2SO4$. The raw materials contain impurities such as aerogel, catalyst particles, and amorphous material that is used to coat the catalyst nanoparticles. The process will happen in both physical and chemical where it develops three-step purification methods that involve the room-temperature, selective oxidation of carbon by hydrogen peroxide ($H2O2$). Metal and mesoporous silica particles are eliminated during MWNT treatments. 95% of the carbon particles remain after the purifying procedure has been completed. The majority of procedures are employed to both demonstrate the purifying process and remove contaminants. The methods that will be covered include filtration, sonication, and chromatography in chemical procedures, as well as liquid phase and gas phase in those physical methods.

- Chemical purification methods:

The most often used purification method involves oxidising created CNTs in both wet and dry circumstances. For the dry state, oxidation is processed by air, oxygen, or other gases at a controlled temperature. For the wet condition, oxidation is handled by the solution of concentrated acids or powerful oxidants. Amorphous carbon and carbon particles are supposed to be eliminated more quickly and easily by this method than CNTs are since they have a higher oxidation reaction rate than it does. The presence of dangling bonds in amorphous carbon results in a high-energy oxidative activity for this material. In the meanwhile, the significant curvature of a pentagonal carbon ring will be attributed to the carbon nanoparticles' increased reactivity. Single-walled carbon, like C60, becomes more reactive and oxidising as its diameter decreases [34]. The nanotubes' tips are due to oxidation, open. Pentagonal carbon ring tips are less chemically stable than the cylindrical tube's hexagonal carbon ring structure. The availability of five-member rings in the hexagonal array thus proves to be more important of the CNT tips at the time of oxidation during purification.[37]

- Physical purification method:

By using an unconventional method like ultra sonication, filtration, and chromatography to purify the CNTs, this physical purification is employed to reduce the harm caused by direct oxidation.

XII. APPLICATION OF CARBON NANOTUBES:

- Biomedical applications of CNTs:

CNTs can have many applications because of the advantageous properties that make them an appropriate material for biomedical application as they are more biocompatible as compared to others, fast electron transfer kinetics, ultra-light weight, chemical inertness, high tensile strength, wide number of antibacterial and antifungal properties, act as protein carriers, contains exposed functional groups etc. They also hold semi and metallic conductive properties that make them a suitable material for various applications such as clinical diagnostics, food safety, environmental monitoring. CNTs also play a significant role in the fabrication of sensors for detecting various pathogenic bacteria and helps in the treatment of cancer as well. CNTs even have a wide number of antimicrobial activity.[38]

- Drug targeting:

Multiwalled carbon nanotubes are used in drug targeting as well as in controlled release of drug. Targeted drug delivery can be defined as when a lively therapeutic drug agent is delivered to the precise part for extended period. Carbon nanotubes are used in drug delivery due to their hydrophobic nature that allow CNTs to stay in the circulation system for the extended period. Carbon nanotubes have utilized for target and controlled drug delivery due to variable stimuli that can be controlled through carbon nanotubes such as magnetic stimuli, electric stimuli, change in temperature and several others. Carbon nanotubes act as a carrier for the transport of various biomolecules also such as proteins, DNA, RNA, Immuno active compounds and lectins.[39]

- Cancer diagnosis and treatment:

Multiwalled carbon nanotubes have been utilized in cancer diagnosis as well as treatment. The cancer treatment procedure employing MWCNTs. Multiwalled nanotubes (09.2 nm average diameter) had improved affinity of tissue, specifically for non-reticular endothelial tissues, as compared to broader multiwalled carbon nanotubes (39.5 nm average diameter). Authors concluded that higher aspect ratio of narrow multiwalled nanotubes might be beneficial in biological application owing to higher tissue accumulation.[39]

- Antibacterial activity of CNT :

Researchers found that MWCNTs has great antibacterial potential. Anti-bacterial properties of MWCNTs depend on various factors such as surface functional molecules, density, diameter, length and purity of carbon nanotubes . The aspect ratio of MWCNTs greatly influenced the antibacterial property of MWCNTs as short tube enables more interaction with the microorganisms as compared to long tube MWCNTs. As shorter tubes do more interaction with the cell membrane which changes the osmolarity of the membrane . However, the same thing gets reverse in liquid medium. In liquid medium the short tube aggregates encompass a smaller number of cells as compared to long tube aggregates. Long tube aggregates can encompass a greater number of cells during aggregation process. Diameter also plays an important role as small diameter leads to more close interaction with the microbes while large sized diameter leads to less interaction with the microbes. Therefore, aspect ratio of MWCNTs played an important role in determining the anti-bacterial property of MWCNTs. MWCNTs can show its antibacterial property by various ways. However, the exact mechanism behind the antibacterial property of MWCNTs is yet to be understood. There are various ways by which MWCNTs acts onto the microbial surface. First, change in the integrity of cell membrane by forming close association with the membrane surfaces . Second, inducing ROS generation which ultimately leads to the cell death and DNA damage. Third, impurity associated with the MWCNTs can also be an integral part of its antibacterial property. In vitro anti-bacterial activity of nanocomposites i.e. chitosan, its derivatives and derivative 4/MWCNT against both gram positive bacteria (E. faecalis and S. epidermidis) and gram-negative bacteria. Bacteria (E. coli) namely as gram positive bacteria was assessed by agar diffusion technique]. It was concluded that cationic property of nanocomposite due to amalgamation of polymer along with the MWCNT leads to the rupturing of bacterial cell membrane and leakage of all components from the cell matrix occurs. The leakage brings the change in the permeability of cell membrane and other functions of cell also get stopped. Although pH plays an important role in the mechanism as low pH facilitate more protonation of functional group associated with the polymer . MWCNTs is inducing the generation of reactive oxygen species as all fullerenes compound has a closed cage like structure and conjugation happens through π electron configuration . MWCNTs enters into the bacterial nuclei and combines with the DNA which can produce the ROS which ultimately leads to the cell death. The synergistic effect of both chitosan and MWCNTs increases the antibacterial property. The orientation and aspect ratio of MWCNTs also greatly affects its antibacterial property.

- Genetic engineering:

The carbon nanotubes and the nanohorns played an important role in genetic engineering.In the development of bioimaging genomes , proteomics and tissue engineering , the carbon nanotubes and the Carbon nanohorns are used to maneuver genomes and atoms .The tubular nature of the CNTs and CNHs proved them as a vector nucleoside and cause change in its electrostatic properties .This creates its potential application in the diagnostic and therapeutics .

- Artificial implant:

Normally body shows rejection for implants with the post administration pain but miniature sized nanotubes and nanohorns get attached with other proteins and amibo acids avoiding rejection .Also they can be used as implant in the form of artificial joints without host rejection . Moreover, due to their high tensile strength, CNTs filled with calcium and arranged or grouped in the structure of bone can act as bone substitute.

XIII. LIMITATIONS OF CARBON NANOTUBES:

Despite of the exciting prospects of CNTs in drug delivery, there are some factors which limit the applications of CNTs. Presence of impurities, non-uniformity in morphology and structure, large surface area (leads to protein opsonization), hydrophobicity, insolubility and tendency of CNTs to bundle together are some obstacles for their nano-medical applications. Another key obstacle is the toxicity of CNTs. The observed toxicity has been largely attributed to the structural similarity between CNTs and asbestos fibers, therefore the toxicological evaluation of CNTs has received much attention in recent years. Since graphite and carbon materials have been associated with increased dermatitis and keratosis, therefore the exposure of cultured human epidermal keratinocytes (HaCaT) to SWNTs which caused oxidative stress and loss of cell viability, indicating that dermal exposure to CNTs may lead to these altered skin conditions. In another study, Monteiro-Riviere et al.[39] exposed Human epidermal keratinocytes (HEK) to MWCNTs and found that MWCNT induces the release of proinflammatory cytokine interlukin 8 from HEK which initiate an irritation response on target epithelial cells in time dependent manner.[39] Pulmonary toxicity was also investigated in a study in which very high concentrations of SWCNTs were directly instilled into the lungs of the animals; it was found that exposure to SWCNTs lead to the development of granulomas in rodents. Before the widespread utilization of CNTs in the medical science, it is important to note that the chronic toxicity of CNT must be experimentally studied and the appropriate safeguards must be taken against the possible interactions among the CNTs and biological systems. lack of solubility in most solvents compatible with the biological milieu (aqueous based). The production of structurally and chemically reproducible batches of CNTs with identical characteristics. At the time of production the carbon nanotubes contains lots of impurity and it is very much difficult to maintain supreme quality and purity of the carbon nanotubes.

XIV. CONCLUSION:

An overview of CNT synthesis, structure, characteristics, and applications is provided in the review. Many techniques were described briefly for the synthesis of SWNTs and MWNTs (CNTs). A common set of Nanotubes was used to review some of the CNTs' properties. Greater possibilities make it obvious that fresh technologies will develop in CNT in the future. The number and price of CNTs are a concern in technology. Additionally, it was explained that the functionalization of nanotubes uses less hazardous CNTs than do CNTs in their natural state. Several significant points have been put into this review to facilitate reader interaction and aid comprehension of the CNT. A carbon nanotube can be manufactured in both metallic and semi conductive forms, creating mixed junctions between metal and semiconductor.

It has been determined by citing numerous research papers that CNT has a wide range of possible uses, although more research is required. It is determined through the clarification of structure, synthesis, and functionalization that the findings from the aforementioned investigations have significantly contributed to the favourable development in a variety of fields.

However, the yield, purity, and structural quality of CNT produced by each technique are subpar. As a result, researchers need to revolutionise existing processes in order to produce CNT with cutting-edge features. The structure, diameter, purity, and other properties of the CNT are influenced by various working agents; for instance, the diameter of the CNT is influenced by the size of the catalyst. The most important thing to look after is the cost-effectiveness of the carbon source used in CVD techniques. The carbon source is used for the preparation of CNT so the price of the CNT is mainly based on carbon source price, so endeavours should be through to find out a novel carbon source.

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