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Carbon Nanotubes: A Systematic Review

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ABSTRACT
As an advanced nano carrier drug delivery system carbon nanotubes were found in 1991 by SumioIijima and his hypothesis of CNT, which are made up coal isotope and have splendid electrical, mechanical, optical, and so forth properties. Their utilization in an assortment of fields has aroused individuals' curiosity. CNT are a major effect since innovative wonders, for example, electronic paramagnetic reverberation empower them to perceive sound cells from destructive ones, which is the Holy Grail in disease care. CNT has been the subject of broad examination in the course of the most recent twenty years as a prescription transporter structure. Worries about explicit issues, like biocompatibility and toxicity, created and are advocated further examination around here. various techniques (Arc release, CVD and so on) are utilized to plan both carbon nanotubes. Pollutions in CNT are taken out utilizing corrosive treatment, attractive purging, and size avoidance chromatography. As a result of the CNT have a hydrophobic person. surface change is accomplished utilizing both the functionalization. CNT are cytotoxic, which helps in malignancy care. Different energizers, for example, electro-attractive field , and pH shifts, were utilized to deliver drug from carbon nanotubes.
Keywords: *Carbon nanotubes, SWCNT, MWCNT, Synthesis Functionalization, Cytotoxicity, Application*

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INTRODUCTION

In recent years, nanotechnology and nanocomposites have gotten a lot of coverage. Researchers choose a specific filler and inject it into a specific polymer to create a specific composite with altered properties. The composite is called a nanocomposite if the filler is a nanomaterial [1]. These systems indicate a range of benefits in drug delivery, primarily focusing on improved drug safety and performance, such as targeted drug delivery, improved bioavailability, expanding medication or gene outcome of medication in tissue & improving therapeutic agent stability in the face of chemical/enzymatic degradation [2,3,4]. Nanotechnology is an increasingly growing field of study that has created breakthroughs in molecular diagnostics, imaging, bioengineering, and nanomedicines, among other fields. Because of their particular electrical, spectroscopic, metallic, semiconducting, different properties. They have a hollow core made of structurally hollow graphite sheets (Fig. 1) that rolled into tube & closed at the ends by a semi-fullerene-like structure.Their ability to cross cellular membranes and produce elastic or young's modulus of any known material makes them suitable for storing guest molecules. These carbon-based nanomaterials are used in a number of applications. Buckytubes are the common name for CNT [6,7]. Its common tool over other nanocarriers because of their biocompatibility, non-immunogenicity, ease of size modification, greater stability, and high drug loading potential [8]. They have a number of functional groups formed on their surface to aid further conjugation with targeting ligands and drug molecules.basic concept involved in this is to attach the antigen to CNT while preserving its conformation, resulting in a specific antibody response. With the growing interest in this area among the nanotechnology research community, it's predicted that many more applications of carbon nanotubes will be explored in the future for medical and other purposes.[9]

STRUCTURE

Fullerene structural family members include spherical buckyballs and nanotubes. They are extremely thin tubes that have a diameter of a few nanometres, or about 1/50,000th of the width of a human hair. Cones, rods, regular circles, and other odd and complicated shapes are among the many exotic fullerene structures.

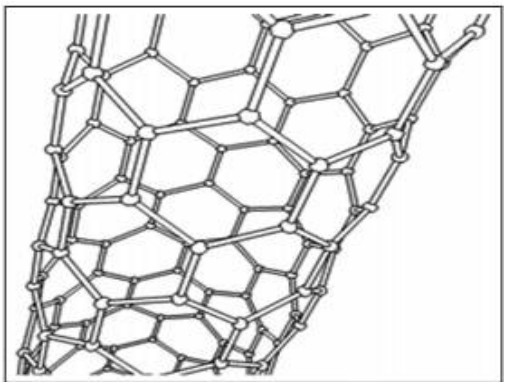

Fig 1: Structure of Carbon Nanotubes

Cylinder

One of the structures that make up a SWCNT is a cylinder.These cylinders appear when a grapheme sheet of a specific size is wrapped in a specific direction. We can only roll the sheet in a few different directions to form a closed cylinder. Two grapheme sheets are used to choose the middle& sheet is then rolled until the two atoms are perfectly aligned. chiral vector is that points from one atom to the next and has a length equal to the diameter of the nanotube. The nanotube axis & chiral vectors are parallel to each other.

Tubes

Long wrapped grapheme sheets are what these are. They are classified as one-dimensional (1D) structures because their length to diameter ratio is usually about 1000. The side wall and the tube's end cap are two distinct regions of different properties that make up SWCNT. Carbon atom hexagons and pentagons make up the end cap structure. A closed cag structure made entirely of both the carbon atom requires 12 pentagons, according to Euler's theorem. Five hexagons and a pentagon surrounding it produce the best surface curvature for enclosing a volume. Increasing gap between pentagons on a fullerene structure reduces ground stress and local curvature, making the structure more stable, according to the isolated pentagon law. optical behaviour, mechanical power, and electrical conductivity of SWCNTs with different chiral vectors varies. [9,10,11]

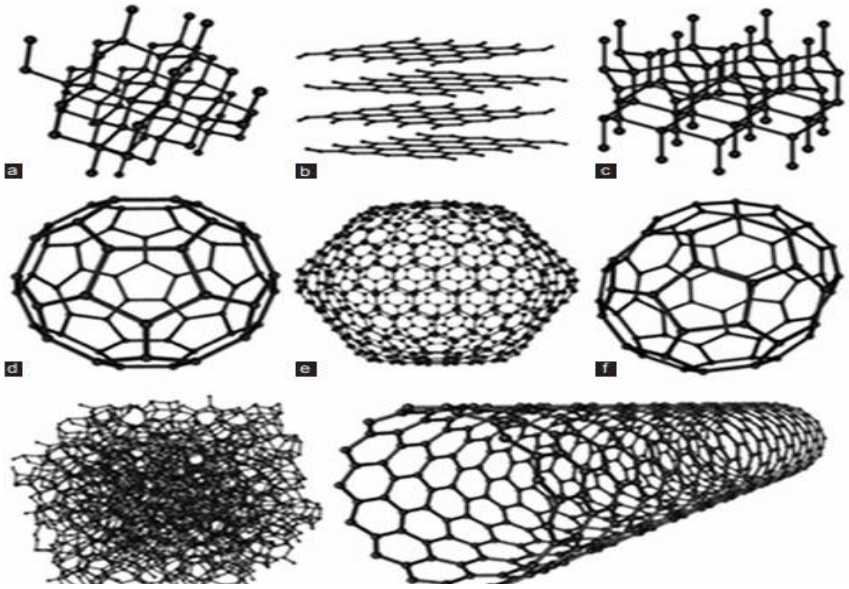

Fig2:(a)Diamond,(b)Graphite,(c)Lonsdaleite,(d,f)Fullerences(C60,C540,C70),

(g)Amorphous carbon and (h) Carbon nanotube

TYPES OF CNTs: [10,12]

CNTs with a single wall

SWCNTs are made from a single rolled-on graphene sheet 1–2 nanometers in diameter.The time required depending on the form of planning, it varies.

CNTs with two walls

In these nanotubes, which are made up of two concentric CNT, inner tube is enclosed by the outer tube.

CNTs with many walls (MWNTs)

MWNTs with diameters ranging from 2 to 50 nm are generated by rolling multiple layers of graphene on top of each other, depending on the number of graphene tubes used. These tubes have an inter-layer distance of around 0.34 nm.

On the basis of chirality

The chirality of CNTs is a difficult factor in deciding their electrical properties. There are three forms of CNTs based on chirality: chiral, armchair, and zigzag.

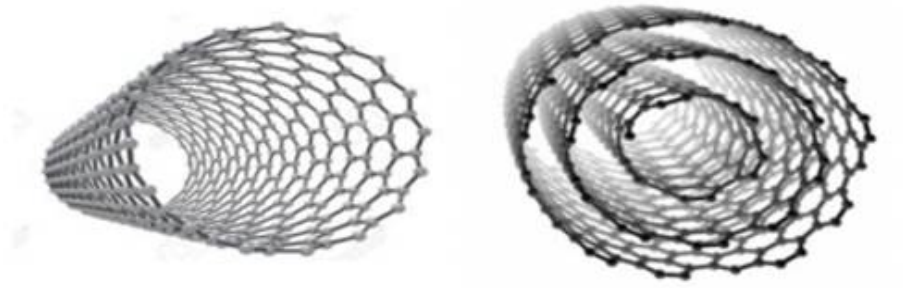

Fig 3: SWCNT & MWCNT

CARBON NANOTUBES PROPERTIES

CNT based field-effect transistors are predicted to supplant their silicon-based analogue equivalents in the near future. CNT are excellent integration agents as a product of their various characteristics.[13]

ELECTRICAL PROPERTIES

CNTs' chiral shapes have electrical properties, which is well-known for their electronic nature. According to the researchers, CNT have incredible conductive properties. These findings to demonstrate that defects, chirality, diameters, and crystallinity of tubular framework affect this property. P-type semiconductors are semiconducting SWNT. MWNTs are unlikely to be one-dimensional conductors they because are composed of tubes of SWNTs. A pseudo-gap was discovered in I–V measurements, suggesting that it is conductive. properties of both type of nanotube extensively investigated, as we can see from the preceding discussion. It was discovered to have a diffuse or quasi-ballistic dimension used in transistors & different advanced electronics switching applications because of their electronic structure. CNT emitters have the benefit of being able to emit at lower threshold voltages than other emitters.[9]

MECHANICAL PROPERTIES

CNTs are considered to be the planet's toughest material. according to studies, CNT is blurry in the radial direction. Vander Waal forces can cause two adjacent nanotubes to bend. Later, an AFM was used to quantitatively measure the radial elasticity of MWNTs, and a tapping/contact mode AFM was used to investigate SWNTs recently. When a load is applied to a composite structure, the radial direction elasticity of carbon nanotubes is crucial, particularly for the formation of CNT nanocomposites and their mechanical properties, which involve large transverse deformation of embedded tubes. Graphite has enormous potential because its carbon bonds are close to those found in CNTs, the stiffest and strongest structure ever synthesized by scientists. CNTs were discovered to be flexible and do not break when bent when tested under a TEM.[15]

Carbon nanotube thermodynamic properties

CNTs are important and useful as rolled graphitic structures. Because of their small scale, quantum effects are important, and 1-D quantization of phonon band structure can be seen in low temperature specific heat and thermal conductivity. Nanotube composite materials can double thermal conductivity in a variety of materials with only a 1% loading, indicating that tubes materials could be useful in industry for thermal control.[16]

FUNCTIONALIZATION ON CARBON NANOTUBES [16,17,18]

Traditional carbon nanotubes have some disadvantages due to their hydrophobic existence, such as low water solubility, but this property improved by surface functionalization. The functionalized CNT have improved properties that make it easier to make new nanomaterials and nanodevices. different factors affect the functionalization process, in addition to water solubility, include drug carrying capacity, cellular uptake, absorption profile, and excretion from the biological system[16]. Strong acid CNTs have carboxyl groups attached to their surfaces, which improves theirin aqueous solutions dispersibility.CNT could be used as medication delivery pathways or 'Nano carriers' allowing for prolonged medication release without damaging healthy tissue. The first property CNTs must have is that they are easily soluble in the gastrointestinal environment, which necessitates aqueous solubility as well as simple and uniform

dispersion. Since graphene side walls have p-p interactions, the solubility of CNTs in an aqueous medium is a significant stumbling block in the road to improved drug delivery. In this process which improves the wetting of the hydrophobic tube's surfaces and reduces the formation of CTN bundles.[16]

The subcategories of functionalization are as follows:

Functionalizationcan be accomplished in two ways, namely covalent and non-covalent functionalization. CNT functionalization takes place on the CNT's lateral wall. The limit of carbon nanotubes has been reached.

Covalent Functionalization:

By integrating functional molecules in a more stable way, covalent functionalization is achieved. Two of the most common methods of covalent functionalization of CNTs are cycloddition and oxidation.To covalently functionalize graphene, nucleophilic substitution, electrophilic addition, and addition and condensation reactions can all be used. The unsaturated carbon p-bond and other functional groups form a covalent bond during covalent functionalization. Strong acids like HNO3, H2 SO4 / HNO3, or KMnO4 / HNO3 can be used to oxidise CNTs. As CNTs are oxidised, they obtain the functional group COOH & functionalization creates a connection between the CNTs and other molecules, allowing for the development of any desired effects. Without affecting the electronic properties of CNTs, such linkages can be worked out further using amidation or esterification reactions suitable for molecular attachment. Two disadvantages are the shortening of CNTs and the production of defects on open ends.COOH functionalization allows other molecules to be ligated to the CNTs, allowing for any desired effects. Without affecting the electronic properties of CNTs, these linkages can be worked out further using amidation or esterification reactions suitable for molecular attachment. Two drawbacks of CNTs are their shortening and the development of defects on open ends.Functional groups on oxidised CNTs can react further with SOC land carbodiimide to create functional materials with a high propensity to react with other compounds in order to solve these problems. Cyclo addition is often a more efficient way of addressing the problems described above. Since aldehydes and amino acids condense during the 1.3-Dipolar cycloaddition reaction, an azomethine ylide adduct is formed, which interacts with CNTs on the side wall. As a result of this reaction, a pyrrolidine ring is formed. This creates a pyrrolidine ring, which promotes the conjugation of medication molecules.[18]

CNTs of non-covalent functionalization

It is fully reliant on the interaction of p p, vanderwal forces, and/or hydrogen bonding, with no effect on their chemical properties. Covalent functionalization has proven to be much more user-friendly than this method. Non-covalent functionalization is accomplished by p-p interaction in a number of ways, including protein functionalization, single-stranded DNA, and even fluorescence-attached PEG.[17]

SYNTHESIS OF NANOTUBES

Method of arc discharge:

In this method uses two vertical graphite rods, one of cathode and the other as an evaporated carbon anode molecule, copper, cobalt, and/or iron as metal catalysts (fig. 4) The chamber is flooded with direct current in an arcing operation. chamber is also pressurised & heated to around 4000 degrees. During the operation, half of the carbon that has evaporated has solidified on the tip of the negative electrode at a pace of one millimetre per minute, while positive electrode is consumed[16]. There are two primary synthesis methods with different precursor catalysts and synthesis with arc discharge. are made from a variety of catalyst precursors& complex anode made of graphite and metal composition for arc discharge expansion[17]. MWCNTs are usually made without the use of a catalyst precursor.[19]

Advantages

Technique producing a lot of nanotubes.

Consequences

High temperatures are required for the process, which is then analysed to see if there are any structural flaws.

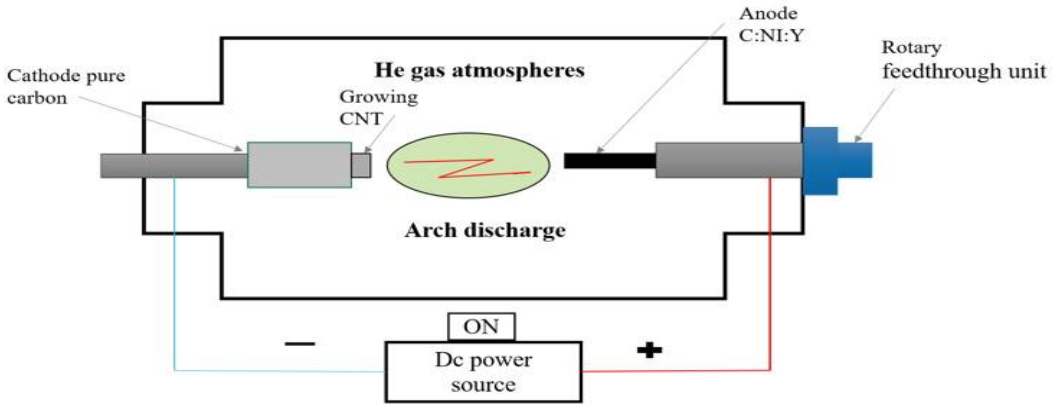

Fig4:Arc Discharge Method

Laser ablation method

In this process, a laser vaporises a graphite target at high temperatures in a sterile setting, producing carbon species that are transported from the high temperature zone by flowing inert gas to a conical, copper collector cooled by water[18] (fig. 5). Several metals, including Ni, Co, and Fe is added to a carbon target in a small volume, SWCNTs are formed. CTNs have a very high yield temperature-dependent using this approach. The laser, the growth temperature, and the catalyst are all being tweaked. average nanotube diameter and size distribution would be affected by the presence of gases and gas pressure[19].

Advantage: High yield and metal impurities are kept to a minimum.

Disadvantage. CNTs prepared for laser ablation are not uniformly straight.

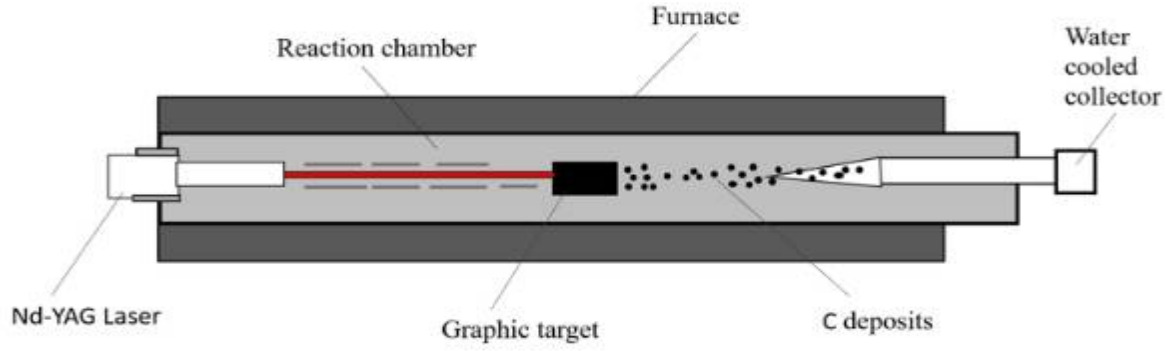

Fig 5: Laser abliation Method

Chemical Vapor Deposition:

CVD is the mechanism behind large-scale CTN expansion. On the surface of catalyst particles, this process is used to decompose the carbon precursor and CNTs.(fig. 6). two most valuable CVD methods are: Thermochemical & Plasma enhanced CVD. In this process, a carbon source, such as methane, carbon monoxide, acetylene, and others, is primarily used as an energy source in the gas phase. CNT synthesis with plasma enhanced CVD is essentially a two-step process. Physical vapour deposition, sputtering, dip coating, and other methods are used to prepare the catalyst. In a fuel gaseous atmosphere, the layer is then heated to 500-1000°. 19,20

Advantage: Cost-effective process that leads to large-scale production of pure CTNs.

Disadvantages: Large-scale synthesis routes are used.

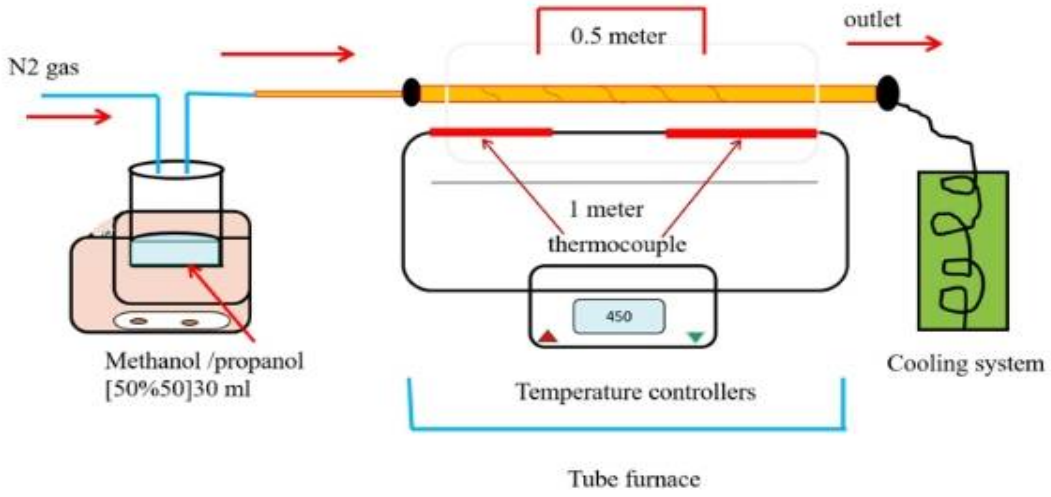

Fig 6: Chemical Vapor Deposition

Method of Flame Synthesis

Catalytic precursors are usually injected into the flame system during the flame synthesis process, where they nucleate and eventually condense into stable spherical metallic nanoparticles. For CNT growth and inception, parameters were used to decide the best catalyst particle size. The heat and carbon source can affect the activation and deactivation of catalyst particles, the creation of catalysts, and the morphology of the final synthesised products, as well as the activation and deactivation of catalyst particles, the creation of catalysts, and the morphology of the final synthesised products. As a result, a variety of flame patterns, including premixed, partly premixed, and unmixed, have been used.[19]

Using a Saline Solution

This method produces CNTs by immersing a stainless-steel mesh or carbon paper in a metal catalyst in a saline solution, ideally Co:Ni (1:1) & passing a carbon containing a gas Via it, a source such as ethylene can be accessed. material warmed by an electric current. The reaction between the gas and the catalyst produces CNTs that are supported on the conductive substrate.[21]

Spray Pyrolysis method

This is a more advanced type of CVD (or injection CVD) that produces high purity. Various aromatic and aliphatic hydrocarbons, as well as ferrocene as a catalystare used in this technique to keep the system sealed and avoid leakage. The solution is developed using a thermolyne single zone split tube furnace with a quartz tube vacuum-tight assembly. On a quartz or stainless steel boat, the samples are suspended nine inches from the tube furnace's core. Pure argon used to fill the quartz tube reactor. When argon flows through the furnace, it is turned on (50 sccm). When the injector head reaches 170°C, the argon flow rate is increased to 100 sccm, and a mixture of ferrocene dissolved in xylene is rapidly injected until the solution reaches the injector head. Black carbon nanotube powder is formed and collected as a result. remove the amorphous carbon and catalyst particles, the stock is washed with HNO3 (40 wt%).[22]

DRUG ADMINISTRATION

CNTs are a form of TDDS that delivers medication to the exact location where it is needed. So, loading the medication entails injecting the active form of the drug into the drug delivery system, which is paired with the other carriers in the form of CNTs. CNTs have a wide surface area and volume, allowing them to hold large amounts of narcotics. The functionalization of CNTs will strengthen its hydrophilic properties even further. The SW/MWCNTs (3 mg) is re-dispersed in 15 mL distilled water using probe sonification. The medication was added to 1 ml of solvent and vigorously stirred into the SW/MWCNTs solution. After that, the mixture was left to sit nightly at room temperature, stirring once in a while to extract the free medication, the drug-loaded SW/MWCNTs was homogenised at 10,000 revolutions per minute for 15 minutes. Calculating the absorbance at 440 nm in order to measure its concentration from the dose absorption curve, the amount of free medication was measured in the supernatant, allowing the drug loading efficiency to be estimated. The drug loading efficiency (DLE, w) can be calculated using the formula below:[23]

DLE percent = CUR weight added-free CUR weight in supernatant/MWCNTs

CNTS CYTOTOXICITY

The toxicity of nanotubes is a hot subject in nanotechnology research. Other toxicological studies pale in contrast to the findings of the CNT cytotoxicity study. In terms of their life and behaviour, they are well-understood. It demonstrated to be cytotoxic to mammalian cells in some studies, although others have explained their biocompatibility and tested it using a particular technique. Biomarkers that measure gene expression changes (due to the initiation of inflammation, apoptosis, or immune response) have been used in nanomaterial exposure studies. Carbon nanotubes' surface area, dispersal properties, functionalization, and biocompatibility may all cause cytotoxicity in mammals. In comparison to non-functionalized CNTs, according to some reports, that functionalization can improve CNT biocompatibility while lowering toxicity. Various experiments carried out to reduce immunotoxicity, including shrinking CTNs to reduce immunotoxicity. The recommended dosage allowance has been reduced, and biocompatible polymers used to protect the surface. cytotoxicity produced by polyurethane, polycarbonate, and other material. Some impurities, such as Fe, have been discovered to inhibit the formation of CTNs, which can be extracted using a variety of techniques, including nanotube oxidation followed by sulphurisation.[24,25]

MECHANISM OF DRUG RELEASE

After they've been packaged and functionalized, medications are loaded into CNTs. Understanding the mechanism of medication release from encapsulated CNTs is critical for demonstrating their therapeutic response. To induce opioid release from CNTs, various stimulants are used, including electric fields, magnetic fields etc . In another analysis, MWCNT hyaluronic acid loaded with gemcitabine was combined with PEGylated using a various pH as a result medication release stimulant, and the sample was analysed using the HPLC protocol. CNTs' unique properties are particularly important for practical applications. Before the useful potential of nanotubes is recognised, a number of problems remain unresolved, including creating more delicate representation methods, discovering better and less costly combination and filtration approaches, and improving our ability to monitor them at the nanoscale. we are certain that the nanotube promise will be fulfilled soon. innovation for malignant growth treatment, there are many conflicting reports showing both positive and negative results, so concerns about CNT toxicity remain unanswered. regardless of that many medications have been transmitted using CNT, the concerns surrounding CNT toxicity in the area of CNT innovation for malignant growth treatment remain unresolved. Several conflicting reports exist, indicating both poisonous and non-harmful activity. This seems to be due in part to the concept of "leading the discovery." To put it another way, there are no true performance benchmarks.[26]

PURIFICATION [10,27,28]

Impurities are bound in SWNT soot during the manufacturing process. These impurities can obstruct many of the SWNTs' desired properties. In fundamental science, it is often preferable to receive SWNTs or impurities that are as pure as possible. The tube structure is affected by industrial techniques such as heavy oxidation and acid refluxing. Main important streams of these techniques. first removes the SWNTs from the impurities, while the second results in a more consistent diameter or size distribution. The techniques will be briefly explained in this chapter, and selectivity will be discussed if possible.Some nanotube purification techniques are given below :

oxidation

The oxidative treatment of SWNTs may be used to clean the metal surface or remove carbonaceous impurities. disadvantages of oxidation that it oxidises all impurities and SWNTs. Fortunately, SWNTs do less harm than impurities. These impurities have a more open structure or have a higher number of defects than the others. Another explanation for the preference for impurity oxidation is that impurities are frequently bound to the metal catalyst, which is frequently used as an oxidising catalyst.Metal content, oxidation time, environment, oxidising agent, and temperature are all factors that affect the procedure's efficiency and yield.

The Acid Treatment

In most cases, the acid treatment will dissolve the metal catalyst. To begin, oxidation or sonication must be used to reveal the metal's surface. After that, the metal catalyst is dispersed in acid. For the time being, the SWNTs have been put on hold. Using an HNO_3 treatment, the acid has no effect on the metal catalyst. Like SWNTs, it has no impact on carbon particles. The acid has a small effect on the SWNTs and other carbon particles when used as a medicine. The mild acid treatment (4 M HCl reflux) is similar to the HNO_3 reflux in that the metal must be fully submerged in the acid to dissolve.

Annealing

The nanotubes will be rearranged and defects will be eaten at high temperatures (873–1873 K). Graphitic carbon and short fullerenes pyrolyze at high temperatures. The metal can melt and be removed using a high-temperature vacuum treatment (1873 K).

Ultrasonication

In this process, ultrasonic pulses are used to separate particles. Different aggregations of nanoparticles will be forced to vibrate, enabling them to spread out even further. The surfactant, solvent, and reagent used all have an effect on particle separation. The stability of the device's dispersed tubes is influenced by the solvent.If the SWNTs are still bound to the metal, they are more soluble in weak solvents. In comparison, monodispersed particles are soluble in a wide variety of solvents, including alcohols. The purity of the SWNTs is determined by the exposure period when an acid is used.

Magnetism purification

During this step, the ferromagnetic (catalytic) particles are mechanically separated from their graphitic shells. The SWNT suspension is mixed with inorganic nanoparticles (mostly ZrO2 or CaCO3) in an ultrasonic bath to dissolve the ferromagnetic particles.Permanent magnetic poles are then used to trap the particles. After a chemical treatment, a high degree of purity is achieved. After a chemical treatment, a high purity SWNT material is obtained.

Filtration down to the micron scale

Micro filtration classifies particles based on their size. A filter captures SWNTs and a small amount of carbon nanoparticles. Other nanoparticles (catalyst metal, fullerenes, and carbon nanoparticles) can pass through the filter. Micro filtration can be used to separate fullerenes from SWNTs by soaking them in a CS2 solution first. After that, the CS2insolubles are stuck in a filter. The filter can pass fullerenes that have been solvated in the CS2.

Chopping

Chemical, mechanical, of these methods may be used to cut the SWNTs. SWNTs can be cut chemically by partially functionalizing the channels, for example with fluor. The fluorated carbon will then be pyrolyzed and ejected as CF4 or COF2 from the sidewall. The nanotubes that had been chemically cut would be left behind. mechanical cutting caused by ball-milling. Owing to the high friction, the bonds between the nanoparticles will break, and the nanotubes will become disordered.As a result of the ultrasonic vibration, the nanotubes will have enough energy to agree the compound to the outside. As acid is applied to nanotubes, they burst at fault sites.

Improvements in functionality

Functionalisation makes SWNTs more soluble than impurities by adding alternative to the networks in communities. Filtration now allows them to be separated from insoluble impurities such as metal. Thermal therapy, such as annealing, makes it simple to separate the functional groups, yielding filtered SWNTs.

The Filling of a Nanotube:

During the process, the shaped nanotube closes on both ends. Appropriate chemistry, alternatively, can fill in the blanks. An acid treatment that oxidises the ends while leaving the oxide-containing functionalities behind is one of the methods used. –COOH and –OH are two well-known functional classes [29].

Applications of CNT's

Treatment for diseases of the CNS

Nanotechnology has the potential to modernize the current state of affairs in this area. Nanomaterials reach the BBB through various targeting mechanisms due to small dimensions and accessible external or exterior modifications, and thus can serve as efficient delivery carriers for targeting the brain. CNT-coated electrodes are expected to improve current electrophysiological techniques and make long-lasting brain–machine interfacing systems possible. For example, doxorubicin in nanoparticle-based formulations has the potential to be more effective than free agents in systemic chemotherapy for brain tumours. [30,31]

CNT'S in delivery of bioactive

Chemicals or chemical compounds that have a biological effect on our bodies are known as bioactive. Hydroxyapatite, for example, is a calcium phosphate that has a chemical resemblance to the mineral portion of bones and teeth tissues. Tissue adhesion and bone growth are assisted, resulting in the development of a biologically active bone-like apatite sheet. Amphotericin B-loaded MWCNTs were used as an effective nano-carrier for antileishmanial therapy.[32,33]

CNT's in cancer therapies

CNTs are promising drug carriers in cancer therapy aim drug delivery systems. CNT in vivo biodistribution and highly effective tumour targeting in mice for cancer therapy .Covalent conjugation of a particular ligand to oxidised SWCNT may also be used to build a tumour-targeted drug delivery system. In

vitro studies revealed a rapid reduction in tumour size as compared to non-targeted SWCNT, ensuring optimum drug efficacy with minimal side effects. paclitaxel-CNTs, and dexamethasone mesylate-loaded MWCNTs are several examples of active moieties. [23,34,35]

Medical application

Another use of CNT in medicine is for detecting molecules or animals. Many research on CNT' electrochemical reactivity have shown that they can enhance biomolecules and facilitate electron transfer in proteins. CNT can access the heamcenter of biomolecules, which is normally not sensed by glass electrodes, in heam-containing proteins. CNTs can also be used as blood vessels to deliver drugs to their intended recipients. When medications are administered in this manner, the dose can be decreased. [36]

Non-Medical Applications[9]

1. Structural:

Textiles: Fabrics made of carbon nanotubes are waterproof and tear-resistant.

Body Armor: MIT used CNT fibres to stop bullets and monitor the wearer's condition.

Concrete: Concrete with CNT increases tensile strength and prevents crack propagation.

2. Electromagnetic:

Optical Ignition: A sheet of 29 percent iron-enriched single SWNT is placed on top of an explosive material like PETN and ignited with a standard camera flash.

Ultra Capacitors: MIT is exploring the use of nanotubes bounding with capacitor charge plates to significantly increase the area and energy storage capacity.

Antenna for Radios and Other Electromagnetic Devices: CNTs can be used as antennas for radios and other electromagnetic devices.

3. Chemical Desalination:

Water is forced through a network of carbon nanotubes to remove salt, which requires less pressure than the conventional reverse osmosis process.

Air Pollution Filter: CNTs are a form of filter that is used in industry to purify and plant carbon dioxide.

4. Electro-Acoustic:

The Tsinghua Foxconn Nanotechnology Research Centre declared in Beijing in 2008 that loudspeakers made of CNT create sound similar to that created by lightning.

Gene therapy

A gene is used to enable cells to generate their own therapeutic proteins in this process. CNTs and CNHs are used in bioimaging, genetics, proteomics, and tissue engineering to manipulate genomes and atoms. used as vectors in gene therapy because of their tubular shape. SWNTs are swirled by unbound DNA because it binds individual nucleotides, altering their electrostatic properties and paving the way for potential diagnostic and therapeutic applications.[7,37]

Implants

Graft rejection is more common with implants that have pain after they've been placed. Nanotubes and nanohorns are small nanotubes and nanohorns attached to other proteins and amino acids in order to prevent rejection. used as implants in the form of artificial joints that will not be rejected by the host. CNTs filled with calcium and arranged in the structure of bone can serve as a bone substrate due to their high tensile strength.[7]

Carrier for drug delivery

Carbon nanohorns are spherical carbon nanotube aggregates with an irregular horn-like shape. CNTs and CNHs have been proposed as possible carriers for drug delivery systems in studies.

- Amphotericin B delivery through functionalized CNT has been demonstrated to be successful.
- Intracellular penetration is increased when Doxorubicin, an antibiotic, is given with nanotubes.
- Because of their controlled lipophilicity, the anticancer drug polyphosphazene platinum has enhanced permeability, distribution, and retention in the brain when given in nanotubes.[7,38]

CNTs have antibacterial properties

MWCNTs have been discovered to have a high antibacterial potential, according to researchers. MWCNTs was greatly influenced by their aspect ratio, as short tubes allow for more contact with microorganisms than long tube MWCNTs. Since shorter tubes interfere more with the cell membrane, the osmolarity of the membrane varies. Short tube aggregates in liquid medium have a smaller number of cells than long tube aggregates. Long tube aggregates can contain a greater number of cells during the aggregation process. Diameter also plays a role, with a smaller diameter resulting in closer contact with microbes and a larger diameter resulting in less interaction.[39,40]

A CNTs have antifungal properties.

In nano-composites, the polymer chitosan inhibited spore germination, germ tube elongation, and radial growth in nano-composites Chitosan induces cell wall morphogenesis, which inhibits fungi development.

Since Chitosan is so thin, it combines with DNA after entering the cell wall, as revealed by microscopic analysis. The transcription & translation processes are also inhibited after conjugation with DNA, which impact on the development of enzymes and proteins required for fungal hyphae growth. The polymer derivative with MWCNT had a different antifungal effect than the parent chitosan. . MWCNTs and chitosan derivatives were discovered to be more selective against C. Trobicalis as opposed to C. A. neoformans most potent is the niger. Candida strains have been shown to be resistant to CNT that has been functionalized.[41,42]

FUTURE PERSPECTIVES

Given the fact that CNSs have only been around for about three decades, they have made considerable strides during that period. The majority of antibacterial carbon nanomaterials are still in production. Despite the fact that many carbon-allotrope-based products are now commercially available, CNS are unable to replace or compete with commonly used antibacterial materials (e.g., polymers, Ag-NPs) for a variety of reasons, including their toxicity profile for human cells, the fact that they are slow and costly to manufacture, and the difficulty of large-scale fabrication. As a result, future experiments should primarily focus on manufacturing non-toxic CNS in large quantities at low cost. CNS functionalization appears to be a promising way to improve their performance in biological applications, potentially paving the way for biomaterial integration. While safety issues must be addressed thoroughly, designing novel vectors for nano medicinal applications may have practical advantages. alternatively, advancements in carbon nanotube technology could lead to a better understanding of biological and physical chemistry processes.

CONCLUSION

In this review, an endeavour has been made to study the carbon nanotubes and their advances in order to develop completely new types of CNTs and their conjugates with high efficacy and safety for potential health applications, a lot of creativity and innovation is needed. The carbon nanotubes will surely be an advanced tool in novel drug delivery systems.

CONFLICT OF INTEREST

No Conflict of Interest

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