Carbon-based nanomaterial: Properties and Applications

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Abstract:
One of the key pillars of nanotechnology is the study of materials wherein nanoscale properties enable the creation of new technologies in a broad spectrum of fields. The nanoparticles that are composed of carbon are known as carbon based NPs. These NPs come in a variety of morphologies, including tube-shaped, horn-shaped, spherical, and ellipsoidal. Fullerenes, carbon nanotubes (CNTs), graphene, nano fibers, carbon black, and carbon-based quantum dots are the major families of carbon-based NPs. These carbon containing materials have induced in a variety of fields and sparked great interest, including biological applications, energy storage and many other fields. Because of dimensions, their unusual physics and structural remarkable mechanical, electrical, thermal, optical, and chemical characteristics, they have piqued the interest of scientific researchers in an effort to enhance their properties through novel synthesis processes, assure macroscopic production, and discover fresh uses. “This book chapter” focuses on a thorough explanation of the different carbon allotropes (fullerenes, carbon nanotubes, and graphene) along with properties keeping main focus on application of CBN in various fields.

Keywords: Nanoparticles, Carbon based nanotubes, carbon based nanoparticle

Introduction

Carbon, which has six electrons, is made up of four exterior shell electron orbitals (2s, $2p_x$ $2p_y$, and 2p) and may therefore hybridize into sp^1, sp^2, and sp^3 due to owing these configuration Carbon is one of the universe's most plentiful and adaptable elements. It has an unusual ability to form bonds with almost every element, this property is called catenation. Carbon occur in a variety of allotropic forms. Common allotropes of carbon include diamond, graphite, and buckminsterfullerene. Carbon has two allotropes diamond and graphite which found naturally. With a bond length of 1.56, diamond displays sp^3 hybridization. In contrast, graphite has sp^2 hybridization with a hexagonal (honeycomb) lattice, a bond length of 1.42, and an inter-layer C-C spacing of 3.35 [1] New allotropes of carbon are categorized on the bases dimensions: zero-dimensional (0-D) in which all the dimensions are measured in nanoscale i.e fullerenes, one dimensional (1-D) in which one dimension is measured outside while rest two dimensions are measured inside nanoscale i.e carbon nanotubes (CNTs), and two dimensional (2-D) in which two dimension are measured on the exterior, whereas graphene nanomaterials (NMs) are measured inside. Graphene is a crucial structural ingredient for other carbon allotropes. As an example, CNTs are formed when graphene is rolled up, whereas fullerenes are formed when graphene is coiled up. Fullerenes (C_{60}), also known as molecular carbon, are an irregular thick sheet of graphite that curled up to create a sp here made up of multiple carbon molecules connected in an irregular manner. Carbon nanotubes (CNTs) are flawless cylindrical tubes with a diameter range of 1-100nm and are categorized generally into two groups: Single-walled CNTs (SWCNTs) and multi-walled CNTs (MWCNTs) [2, 3]. Carbon nanostructures are among the most promising in nanotechnology because of their versatility. They may be employed in a variety of sectors, including electronics, where the combination of a molecular-sized diameter (on the order of 1 nm) and a microscopic-scale length allows carbon nanostructures to be used in the production of novel devices due to their opto-electrical characteristics [4, 7]. Their vast surface area, strong electrical conductivity, and linear form make their surface very accessible to the electrolyte. Carbon-based nanomaterials also exhibit high anisotropic heat conductivity, allowing them to be employed in sophisticated computational devices where uncooled chips can reach temperatures of above 100°C [8]. Because they are made of pure carbon, they have excellent stability, high conductivity, minimal toxicity, and are environmentally friendly. They have wide applications in biomedical field this is due to the fact that human body is majorly consist of carbon so it thought as a biocompatible material. Ideally, the enormous potential of these materials continues to draw scientific interest, and their deployment in new technologies is predicted to transform human existence.

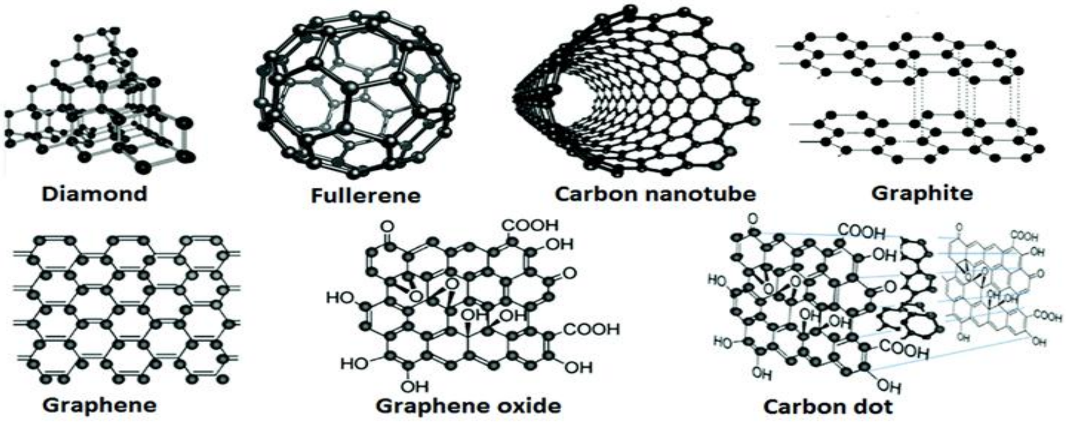

Fig.1: Various carbon based nanoparticle

1.Fullerenes :

Osawa first predicted fullerene in 1970 [9] but it was experimentally discovered in 1985 by Kroto et al. [10] who in 1996 was awarded the Nobel prize in chemistry [11 ,12] . It is considered the third allotropic type of carbon after graphite and diamond [13, 14]. Fullerene has an icosahedral asymmetric closed-cage structure comprised of 20 hexagons and 12 pentagons, each of which is bonded to three other carbon atoms via sp^2 hybridization [15]. Fullerene is known as buckminsterfullerene because to its resemblance to a skyscraper formulated by American architect “Richard Buckminster Fuller”. It was created using the laser vapourization process, which indicated that it is a compound having 60 carbon atoms (C_{60}) grouped in the form of a social ball with a diameter of 7. Fullerene is additionally referred to as buckyball due to its form. It is a carbon structure with no dimensions (0D)

Properties of fullerenes:

These have even numbers of carbon atoms (fullerene discovered till today), having general formula C20+2H, where H represents total number of hexagonal faces [16]. Fullerenes possessing "double bonds" in the 6:6 ring have two bond lengths that are greater than the 6:5 bonds in the icosahedral asymmetrical closed-cage structure. The C is not regarded as aromatic due to reduced electron delocalization due to the absence of double bonds within its pentagonal rings. As a result of C_{60} 's behave as an electron-deficient alkene that is reactive with electron-donor species, fullerenes can undergo a variety of reactions such as reduction, oxidation, hydrogenation, halogenation, nucleophilic reactions, radical reactions, transition metal complex reaction, regioselective reaction, and so on [17]. Fullerenes C_{60} derivatives show level of solubility [18], the geodesic-shaped structure and electronic bonding contribute to its molecular stability. In general, an endless number of fullerenes can exist as long as their structure is an icosahedron with hexagonal and pentagonal rings. Fullerene can have larger structures, such as C_{70}, C_{76}, and C_{78}, as well as smaller structures, such as C_{28} and C_{36} , in addition to the C_{60} molecule. C_{60} and other fullerenes began to be synthesized in considerable numbers in the 1990s by the condensation of soot formed during graphite vaporization [19]. Fullerenes being stable at temperatures above 1,000°C, and because of their high temperature stability, fullerenes may be found in high-energy events like lightning, meteorites, and geological materials [13, 14].Fullerenes can be chemically changed to display a variety of advantageous features that are critical in their applications. Superconductivity may be achieved by incorporating an alkali metal into fullerene, for example.

Four kinds are distinguished depending on how these changes are created, notably
1.Alkali-doped:Fullerenes doped with alkali metal, resulting in the formation of high electronegativity which leads to the formation of compounds in which atoms have general tendency of donationg electron,e.g K_3C_{60} and Rb_3C_{60} having critical temperature(Tc) 8k and 28k respectively.[20]

2. Endohedral: These are formed by Yetterium, lanthanum and noble metals, when atom get trapped inside hollow fullerene results in the formation of metallofullerenes which is endohedral. [21]
3. Exohedral: these are formed when fullerene containing conjugated pi system of electrons reacts with other chemical groups, two chemical reaction expected to occur on the fullurene surface leading to formation of exohedral adduct[22].
4. Heterofullerenes: When one or more than one carbon atoms in the cage are replaced with a compound that includes nitrogen or boron [23].

Applications of fullerene

1. Antiviral activity. Fullerene C_{60} and its derivatives have significant antiviral capabilities, and the Human Immunodeficiency Virus (HIV) may be monitored using antiviral drugs that are effective in both preventing and delaying the onset of AIDS. The anti-viral effectiveness of fullerene derivatives is based on a variety of biological features, including their unique chemical makeup and antioxidant activity. Wudl et al. proposed that because the C_{60} molecule has almost the same radius as the cylinder characterizing the HIV-P active site, there is a strong hydrophobic contact between the C_{60} derivative and the active site surface. C_{60}'s inhibitory action on HIV-P was validated by molecular modeling studies and experimental findings.
2. Hydrogen Storage: The ability of C-C bonds to be hydrogenated and so produce C-H bonds is the key feature that distinguishes fullerenes as the best hydrogen storage system. It is worth noting that the C-H bonds have lower bond energies and are bound to break when heated, returning to their unique fullerene form. Carbon and boron fullerenes have been investigated as prospective hydrogen storage media using density functional theory (DFT) ab initio approximations [24-26]. For instance, Yoon et al. [24] have conducted DFT studies in charged carbon fullerenes *Cn* ð20 ≤ *n* ≤ 82Þ systems. The molecular hydrogen binding strength was dramatically increased to 0.18-0.32 eV, which is theoretically acceptable for room temperature-ambient applications, with experiments revealing that the charged fullerene may reach up to 8.00 wt.% storage capacity. Similarly, covering C_{60} fullerene with mild alkaline-earth metals revealed that Ca and Sr will securely bind to the surface of the C_{60}. The binding is important because it is connected to charge transfer routes involving empty Ca and Sr metal levels. Charge redistribution provides electric fields that function as excellent hydrogen attractors, and studies revealed that $Ca_{32}C_{60}$ had a higher hydrogen uptake ratio of more than 8:4 wt.% [25].
3. Fullerenes used in Drug delivery and Gene Therapy: Drug delivery is delivery of drug at specific site where as replacement of broken or defected gene with new copies is considered gene therapy. Fullerenes are a type of inorganic nanoparticle with a tiny size (1 nm). Because metastasis is hampered by at least three membrane barriers: the cell membrane, the inner membrane, and the nuclear membrane, any material that reaches the nucleus of intact cells is a big concern. The core of fullerene is extremely hydrophobic, and the functional groups connected to it add to the molecule's behavioral complexity. Fullerenes become water-soluble by adding hydrophilic moieties and can transport medicines and DNA for cellular delivery. [27]

4. Energy material: The introduction of fullerene technology in energy-related materials and applications has considerably improved material properties and operations.They are employed in the following situations:

- Capacitor:

Hybrid NMs can give good materials, according to research [28]. The fullerene-graphene hybrid (C60/graphene) exhibits a capacitance of around 1:35 102 F g-1 with a current density of 1.00Ag-1, which is high when compared to 101.88 F g-1 for pure graphene. Furthermore, during the 1:00 × 103 charge/discharge cycle, the composite had an astounding retention rate of 92.35% [29]. There has also been mention of a whisker (FW)/polyaniline emeraldine base (PANI-EB), combination to have a high specific capacitance of 8:13 × 102 Fg-1 at a current density of 1.00Ag-1. The composite had low electrical resistance, and for 1:50 × 103 cycles, a rendition of 85.20% was observed, confirming the impact of fullerene C60 in capacitors [30].

- **Lithium-ion cathode and anode**: Fullerenes give comparative safety and a longer life cycle when utilized in lithium-ion batteries. According to research, using hydrogenated fullerenes as a high-performance anode improves reversible capacity but decreasing irreversible capacity [31]. Fluorine encapsulated B12N12- Fullerene as an anode for a lithium-ion battery demonstrated a low electrochemical cell voltage, but on encapsulation with fluorine its electrochemical cell voltage increases from 1.09V to 3.07V [32]. Fullerene can also be used as cathode due to their high electon affinity. DFT (Density Functional Theory) on electrochemical properties shows that when boron doped with fullerene the value of redox potential shifts from 2.46V to 3.71[33].

- **Super-conductivity:** Fullerene can be easily doped with alkali metals which results in the formation of highly electronegative compounds. At temperatures below 20-40K, these alkali-doped fullerenes function as superconductors. Doping with cesium (CS), rubidium (Rb), and potassium (K), for example, led in superconductors with Tc of 33 K, 29 K, and 18 K, respectively [34, 35].

5. Antioxidant-activity: The antioxidant property of fullerene is due to the fact that it has large double bond conjugation and a low lying LUMO, in which electrons can be transferred easily. Report shows incorporation of 34 methyl radical into a single C_{60} fullerene molecule. Thus fullerene can reacts with many superoxides without being consumed and because of these reason fullerene are called most efficient scavangers of radicals [36]. The capacity of fullerenes to constrain themselves inside the cell to mitochondria and other cell compartment locations where free radicals are produced during disease is the fundamental advantage of using them as a therapeutic antioxidant.

2. Carbon nanotubes (CNTs):

CNTs have a long history, dating back to 1952, when Radushkevich and Lukyanovich discovered and theoretically defined them [37] while Iijima attributed the current CNT finding. CNTs are versatile allotrope of carbon. These are 1D structure with sp^2-hybridized carbon atoms having an interatomic distance of 1.4A.These are hollow tubes having diameter in nano-range. The fundamental structural element (graphene) when rolled-up forms carbon nanotubes. CNTs are classified into two varieties based on the number of layers contained in the structure.

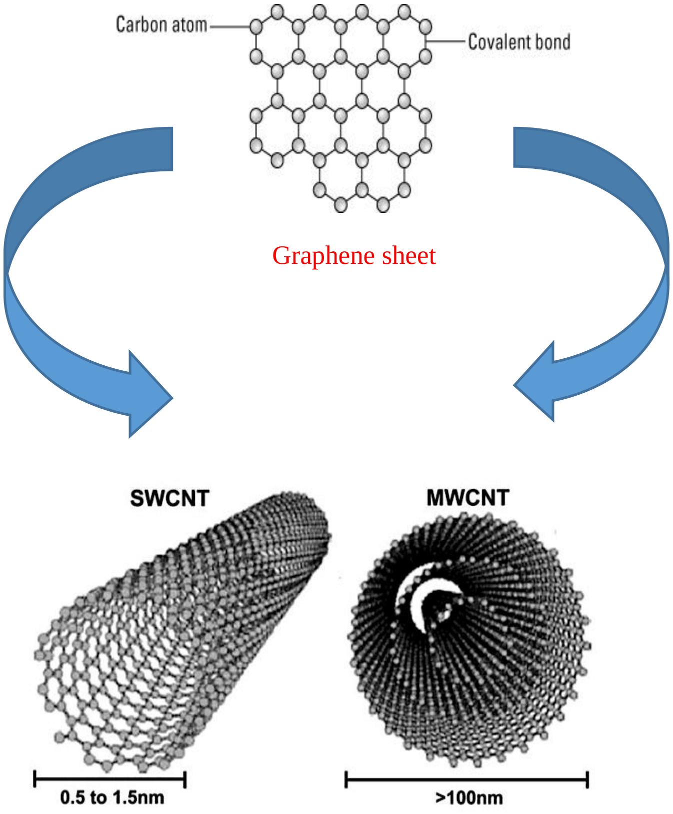

Fig. 2: graphene sheet conversion to single and multi-walled carbon nanotubes [38]

Table 1: Comparision between types of carbon nanotubes [38]

SWCNTs	MWCNTs
It is Single-walled carbon nanotube	It is Multi-walled carbon nanotubes
Formed by single layer of graphene	Formed by multilayers
Expensive	Economical
Diameter range 0.4-2 nm	Outer diameter: 2-100nm , Inner diameter: 1-3nm.
Due to single layer can be easily twisted	Difficulty in twisting
Less pure	High in purity
Catalyst is needed for its synthesis	Synthesized without catalyst
Thermal conductivity is 6000 W/mK.	Thermal conductivity is 3000W/m.K
Used in sensors	Utilized in the field of composite material
Easy to characterize and analyse	Diffucult to characterize and analyse

Properties of carbon nanotubes:

1. Electrical properties: Iijima's helical structure hypothesis underpins CNTs' electrical properties. [39] Carbon nanotubes' semi-conductor or metallic potentials are affected by the diameter and helicity of graphene. CNTs are formed by rolling a graphene sheet in such a way that the corresponding lattice sections of the two hexagons coincide [40, 41].The roll-up vector Ch= na1 + ma2= (n, m) may be used to adjust the diameter and helicity of SWCNTs, wherein n and m are integers and a1 and a2 represent graphene lattice vectors. [42].The two numbers (n and 0) represent the number of unit vectors along the grid's direction [43]. These two (n, 0) exponents predict the electronic structures of SWCNT, the chiral angle in the zigzag direction of the hexagonal honeycomb grating unit vector (a1, a2) is θ = 0, and the arm-chair tube corresponds to θ = 30 [44]. If (n, n), the nanotube is called "armchair," and when (n, 0), it is called a "zig-zag" (arm-chair symbolizes conductor characteristics, while zig-zag indicates semi-conductor features). Metal SWCNTs in rope form were calculated and found a resistance of 104 W cm at temperature 300 K. The calculated value is greater than the conductive carbon fiber currently available [45, 46].

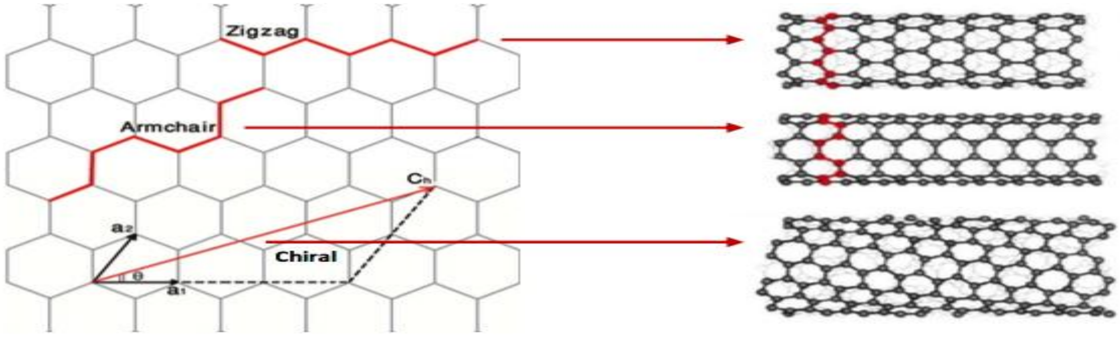

Figure 1. Schematic diagram showing zigzag, armchair and chiral carbon nanotubes.

Fig. 3

2. Thermal properties: Temperature, phonon mean free path, and functionalization all influence the thermal conductivity of carbon nanotubes [47]. Due to presence of sp^2 hybridisated covalent bonds in CNTs, these show higher conductivity then diamond. SWCNTs were found with a thermal conductivity of 1800-6000W/m.K, whereas MWCNTs have a thermal conductivity of 3000W/m.K [48, 49]. The thermal conductivity of polymers may be easily changed by including CNTs into their matrix, and the kind of CNTs has a significant influence on this potential [50, 51, 52].

3. Mechanical properties: Because of their strong covalent bonding (sp^2), carbon nanotubes have a great mechanical strength. These change their shape when force is applied without damaging original structure and when force is removed they came back to their or33iginal position. Mechanical strength is governed by number and size of nanoparticles. Because of high strength these can be used as additive material and also as a reinforcer.

Application of carbon nanotubes (CNTs):

1.Agriculture applications: In earlier times, various alternative approaches regarding increasing the crop production has been deployed such as chemical inputs, crop rotation ,genetic modification, precesion farming ,urban farming etc .however these technology has several drawbacks, low success rate, time consuming process limited availability of a specific gene. Nanotechnology is a prospective contender for viable agriculture in order to overcome these difficulties. Because of their tiny size (less than 100nm), NMs are an excellent alternative for spearheading the agri-nanotech revolution because they can pass through biological barriers and infiltrate plant tissue, offering a new and efficient method for nutrition and pesticide delivery [53, 54].

- **Plant growth regulators:** CNTs (because of small size) may penetrate the thick seed coat and initiate the water absorption mechanism, which may account for fast seed germination and early development [55, 56]. Root growth has been reported to increase in response to carbon nanotubes in onion, cucumber, and other plants [56]. Brassica juncea (mustard) seed germination rate, T50 (time for 50% germination), increased significantly in the presence of a low concentration of oxidized MWCNTs compared to the control. The amount of moisture of oxidized MWCNTs-treated seeds was much greater than that of untreated seeds, indicating that oxidized MWCNTs improved the seeds' capacity to absorb water and regenerate quickly. The elevated water content in oxidized MWCNTs-treated seeds was caused by the functionalized CNTs' facile penetration. It was shown that CNM concentrations of 50-100 mg/L are adequate to permeate the seeds and allow for rapid germination and development rates. [57, 58]. The availability of functional groups, as well as size, shape, surface structure, solubility, and concentrations, all contribute significantly to the toxicity and disease induced by CNTs during seed germination [59, 60]. Carbon nano-materials (CNMs) such as MWCNTs, fullerenes, and carbon nano-horns have been found on a range of plants including tomato, rice, cucumber, onion, radish, corn, soybean, switchgrass, and broccoli.

- **Bio-sensors:** A bio-sensor is a device that detects the reactions of particles in a solution comprising analytes to be investigated with a specific chemical. CNMs' high physicochemical potentials make them an attractive material for pathogen detection sensing applications [61, 62]. CNT-based biosensors have significant advantages over commercially available sensors such as metal oxides, silicon, and others, including high sensitivity (large surface area ratio), remarkable luminous properties, quick reaction time, and high stability [63]. Biosensors based on carbon nanotubes detect soil humidity, toxic materials, and pesticide residue for pest identification. These biosensors operate on the idea of detecting the activities of beneficial and unfavorable bacteria based on differences in oxygen consumption in comparison to respiration. CNTs' 1D feature allows for ultrasensitive analyte detection since all atoms are surface atoms and even little environmental perturbations can modify the electrical and optical properties [64] SWCNTs were identified to be promising bio-sensing instruments on the basis of chirality-dependent fluorescence in the near-infrared region (NIR) [65-67]. Chemical functionalization of peptides, lipids, nucleic-acids, and proteins can affect the surface chemistry of SWCNTs [68, 69].

- **CNTs as antimicrobial agents against pathogens:** CNTs can serve as an option for pathogen control because they have high antibacterial properties and trigger the activation of the immune system. Plants have an antioxidant defense mechanism. The anti-bacterial property of CNTs is due to extrinsic parameters like its dispersion ability, culture medium, type of bacteria, dosage of CNT, means of action between bacteria and CNT [70-72]. CNT harms bacterial physically as well as chemically, causing damage to cell membrane, changes the shape of the cell which leads leakage of cytoplasm thus enzyme and electrolyte release causing death of cell of the micro-organism.

2. Energy and environment application: Much research has been done on CNTs because to their specifically high surface area. As an adsorbent, carbon nanotubes (CNTs) aid in the elimination of various pollutants such as Zn+2 and Pb+2. In this section, we shall look at some of its environmental and energy-related applications.

• CNTs in waste water treatment: Nanotechnology play crucial role in water purification. CNTs offers great advantage to it due to its higher reactivity, high surface area, strong adsorption making it suitable for treatment of waste water [73]. The key strategy to remove contamination is by adsorption or by degradation/detoxification.The efficiency of CNTs for contaminants can be improved by functionalization of material. CNTs properties can further be modified in order to remove specific type of contamination like separation of nanoparticle can be facilitated by incorporation of magnetic component into CNTs [74]. Yang et al. improved the efficiency of electrochemical waste water treatment by a seepage carbon nanotubes electrode (SCNE). The reactor was built in such a way that contaminant migration via the porous carbon nanotube electrode considerably increased total mass transfer, resulting in a greater current efficiency (340-519) than a typical reactor (16.5-22.3). This so formed reactor also has application in waste water treatment. The CNTs-based electrode had 1.15 times the permeation flow of the electrode without CNTs [75].For wastewater treatment, electrochemically activated CNTs filters were created [76].

• Microbial fuel cells (MFCs): Microbial fuel cell (MFC) technology generates hydrogen or electrons from substances such as wastewater using a bacterial oxidizing process. Because of its superior and programmable physio-chemical potential, carbon nanotubes (CNTs) have received a lot of interest for cathodic applications. This is the fundamental idea of producing energy using an anode-cathode arrangementFor better electrochemical performance several modification is required to done in CNTs [77-79]. When CNT was doped with nitrogen (N-doped CNTs) it showed higher power density than the platinum as a catalyst for cathodic application. It has been noted that for better reaction process surface area along with durability of the material must be high. CNTs coating on anode showed higher voltage potential then untreated anode, which pen the path for anodic modification for improving its performance. Graphene-oxide (GO)/CNTs and melamine sponge composite 3D structure. These findings give light on the development of active anode-cathode systems for MFC applications.

•Minimising the cost of fuel cell: Because of the CNT's huge surface area, strong Pt support, and high platinum dispersion, it has a reduced particle size [80].As a result, it may diminish lowering the cost of manufacturing by minimizing the usage of platinum.

3. Biomedical application of CNTs: There are numerous application of CNTs in biomedical field:

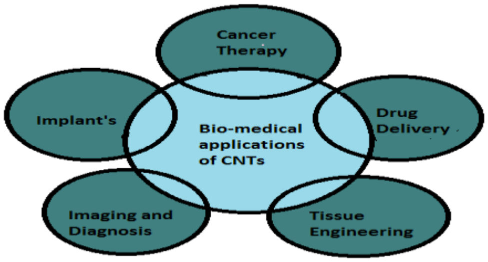

Fig. 4: Biological applications of CNTs

- **Cancer therapy:** Cancer is a type of disease in which uncontrolled growth of body cell occur and spread to other body parts, suppressing their function. These cells become cancerous as a result of ionizing radiation exposure, numerous genetic changes, or consumption of carcinogenic chemicals [81]. Previously known methods such as radiotherapy, chemotherapy, immunotherapy, surgical intervention, which have many side effect related to them. area, conjugation and encapsulation capabilities, target-specific action, improved drug Nanomaterial-based systems are thought to be a viable option for increasing the rate of success of cancer therapy. Nanoparticles when exposed to light becomes hot enough to destroy cancerous cells. CNT features include enormous surface loading capacity, and strong near-infrared (NIR) radiation absorption. Because of their absorbance, they can be used as a mediator in chemotherapy and photothermal treatment [82]. Functionalization enhances biocompatibility, dispensability, solubility, and aids in minimizing CNT clumping. It also aids in fast growth and endocytosis. Smart pills are pharmaceutical releases that contain ingestible sensors that can be electronically managed and altered to regulate a medication dosage based on data collected throughout the body. Biotin and a spacer coupled to CNTs act as a tumor-recognition unit with high efficacy including cytotoxicity towards particular tumors and cancer cell types [83].

All of these traits improve cancer therapy and diagnostics' effectiveness, rapidity, and selectivity [84].

- **Tissue engineering:** It involve replacement of diseased or damaged tissue with substitute for restoring normal functioning of patient. In tissue engineering in order to maintain mechanical integrity, bio-chemical cell-specific environment and elasticity a 3D scaffold is used. These scaffolds offer nutrients to the cell and aid in cell proliferation .Extra-cellular matrix (ECM) is a 3D arrangement of macromolecules and additional necessary building blocks of life that mostly consists of collagen, glycoprotein, mineral, and enzyme for optimal cell mass expansion. The main function of ECM is cell adhesion, intercellular communication and in nourishment of cell. Generally ECM should be balanced otherwise it trigger the function of other cellular response around the cell, Which become quite challenging due to its composition and very complex architech. To overcome this CNTs-based scaffold having which also show similarity with ECM are widely used in tissue engineering [85]. CNTS has good mechanical qualities as a 3D scaffold, with usually high tensile strength and elastic moduli, making them ideal for usage as a 3D scaffold [86]. Amiryaghoubi et al. combined CNTs and graphene oxide (GO) using natural and synthetic polymers that have the required qualities, making them excellent for use as multifunctional materials for bone and cartilage tissue engineering, controlling stem cell osteogenic and cartilaginous capabilities [87].

- **Drug delivery:** Now a days CNTs are considered as most suitable for the delivery of drug, this is because CNTs are biodegradable and do not require surgical excision for its removal. CNTs due to its small size can easily penetrate into the cytoplasm, CNTs' features enable the introduction of many entities on the tubes at the same time, such as targeting molecules, medications, and so on. The electrical characteristics and processes of Efavirenz (EFV) interaction with CNTs were studied by Xu et al. using density functional theory (DFT). The EFV adsorption on CNTs, Because of the pi-pi interactions, is more favorable. The CNTs-EFV pair has strong non-covalent interactions [88] Small compounds, such as cancer chemotherapy medicines, can be deposited onto carbon nanotubes for cancer therapy by non-covalent as well as covalent functionalization, potentially paving the way for personalized drug delivery.

Conclusion

CBN generally include nanotubes, fullerene, graphene-oxide. Research has proved its potential applicability in a variety of industries, including electronics, agriculture, and medicine. The unique properties of CBN i.e its structure dimension, optoelectronic property, large surface to volume ratio tunable surface chemistry, are well suited for its applications. Moreover, the surface of carbon based nanomaterial can be functionalized further to modify their property in order to achieve certain specific applications. The property such as catalytic activity and capacitance are generally enhanced through modification of property of CBN. The study's goal is to give a detailed examination of these materials, which will be vital for the anticipated expansion of carbon-based nanomaterials and will be beneficial in a variety of applications.

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