



OVERVIEW OF THE NANO-CARBON TUBE FOR THE MEDICAL PURPOSES

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Abstract-

Carbon nanotubes (CNTs) are allotropes of carbon with a nanostructure that can have a length-to-diameter ratio greater than 1,000,000. Laser cutting, arc discharge, chemical vapor deposition are other options. Recent events have revealed a potentially transformative impact. Nanomaterials, especially for biomedical imaging, drug delivery, biosensors, and functional nanomaterials, are under development. As a method to accomplish these uses, efficient protein-material bonds will develop. High surface/volume ratio. The ratio of nanoparticles results in a much larger concentration of immobilized entities than is provided. Through the use of other materials, more and more people are interested in learning more about the influence of nanomaterials on protein structure and function. A variety of immobilization techniques have been proposed, with the attachment of specific enzymes to carbon nanotubes receiving particular attention. With an increasing focus on enzymatic flow reactions, multi-enzyme mobilization may become one of the next priorities in the future. In this study, we consider new techniques for enzyme immobilization on carbon nanotubes. To generate CNTs on a large scale for commercial applications, various modified synthesis processes have been devised. Because the cost is very low compared to other ways, the CVD approach is currently the most promising method for generating a significant number of CNT. However, commercial CNT applications are progressing slowly, owing to the expensive expense of producing high-quality nanotubes.

Index Terms -Nanotube, CNT, Nanomaterials, MWCNT, Graphene

INTRODUCTION-

Carbon nanotubes (CNTs) are long, hollow cylindrical structures made from sheets of graphite (also known as graphene), with diameters ranging from less than 1 nm to 10 nm. CNTs exhibit different electronic properties depending on how these graphene layers are rolled into a cylinder. Nanotubes can be single-walled structures, known as single-walled carbon nanotubes (SWCNTs), or multi-walled, known as multi-walled carbon nanotubes (MWCNTs). SWCNTs can be electrically classified into semiconductor and metallic SWCNTs (SWCNTs and SWCNTs), while MWCNTs mainly exhibit metallic behavior. New and

useful properties of CNTs, such as low cost, lightweight, high aspect ratio and area, distinct optical properties, high thermal and electrical conductivity, and Their mechanical strength make them suitable and attractive for a wide range of electronic, biomedical, and other industrial applications. For example, the NTC holds the promise for "beyond CMOS" electronics as active and interconnected devices in future integrated circuits [1] Fullerenes are molecules that are made up entirely of carbon in the shape of a hollow sphere, ellipsoid, or tube. Globular C₆₀ (Figure 1, A) consists of 60 carbon atoms arranged in a series of interlocking hexagons and pentagons (icosahedron truncated); however, fullerenes are less spherical profiles, such as C₂₀, C₃₆, C₇₀, and C₇₈, also available has been described. CNHs are horn-shaped sheaths consisting of single-walled, 2-3 nm. graphene sheets diameters, combined to form composite diameters about 80 nm. The individual CNHs have a graphite cone shape carbon structure, with their ends delimited by five-sided rings (Fig. 1, B). CNTs have a relatively well-defined diameter with a controllable length, while CNHs increase in diameter as their length increases because as the length increases, the base also increases anocone [2].

Diamond and graphite are considered two naturally occurring crystalline forms of pure carbon. In diamond, the carbon at exhibitbits a 3 hybridization, where the four bonds are oriented towards the corners of a regular tetrahedron. Result extremely hard three-dimensional (diamond) lattice, That's one of the reasons for its hardness. In graphite, 2 hybridization occurs, where each atom is connechomogenizesnwwith ith ize three carbons (120°) in the plane, and one The π bond is present in the z axis. The set of 2 forms typical hexagonal (honeycomb) lattice of a graphite sheet [3]

A new form of carbon, Buckminsterfullerene (C₆₀), has been was discovered in 1985 by a team led by Korto and his colleagues. Besides diamond, graphite, and fullerene (C₆₀), one-dimensional nanotubes are another form of the first carbon. reported by Ijima in 1991 when he discovered multi-wall carbon nanotubes (MWCNTs) in carbon soot are generated by an arc discharge method. Carbon nanotubes (CNTs) are carbon allotropes. CNTs are tubular, made up of lead. Tubes contain at least two layers, usually several longers and with an outer diameter of about 3 nm to 30nm. About two years later, he observed single-walled carbon nanotubes (SWCNTs). Around At the same time, Dresselhaus et al. one wall synthesis carbon nanotubes follow the same MWCNT. production route but add transition metal particles to carbon electrode [4]

Research Through Innovation

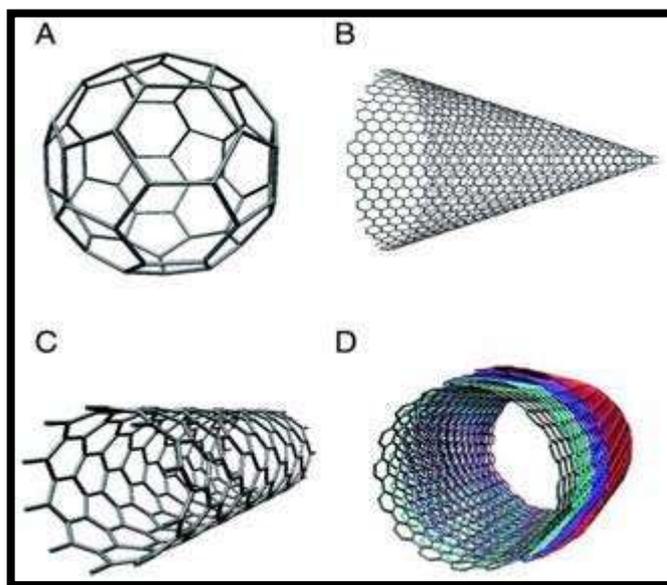


Figure 1: Fullerene molecules

HISTORY OF CARBON NANOTUBES-

Since their discovery in 1991 by Iijima and his associates⁴, Carbon nanotubes have been studied by many researchers around the world. Their great length (up to a few micrometers) and small diameter (several nanometers) for a great aspect ratio. They can be considered a quasi-one-dimensional form of fullerenes. So, These materials are expected to have additional properties interesting electronics, mechanics, and molecules Nature. Especially at the beginning, all the theory Carbon nanotube studies focus on the effect of nearly one-dimensional structure on the molecule and electronic properties.[5]

PROPERTIES-

The strength of the carbon bond gives carbon nanotubes excellent mechanical properties. No previous documents show superlative combination mechanical, thermal, and electronic properties attributed to surname. Their densities can be as low as 1.3 g/cm³ (one-sixth compared with stainless steel). Young's CNTs module (a measured hardness of the material) is superior to all carbon fiber has a value greater than 1 TPA, i.e. about 5 times higher than steel [7]. However, it's their strength that determines separate them. Carbon nanotubes are the strongest material never been discovered by mankind. Highest measured tensile strength The breaking strength or tensile strength of carbon nanotubes is up to 63 GPa, about 50 times higher than steel. Even the weakest carbon nanotubes have the force of some GPa. In addition, CNTs have Good chemical and environmental stability and high thermal conductivity (~3000 W/m/K, comparable to diamond) [8]. These properties, coupled with the lightness of carbon nanotubes, give them great potential in applications such as aerospace [9].

MORPHOLOGY AND STRUCTURE-

Comprised completely of carbon, the shape of natural SWCNT may be visualized as a rolled-up tubular shell of graphene sheet that's made from benzene kind hexagonal jewelry of carbon atoms (Figure 2(a)). Graphene sheets are seamless cylinders derived from a honeycomb lattice, representing an unmarried atomic layer of crystalline graphite. An MWCNT is a stack of graphene sheets rolled up into concentric cylinders. Each nanotube is an unmarried molecule composed of tens of thousands and thousands of atoms and the period of this molecule can be tens of micrometers lengthy with diameters as small as 0.7 nm [10]. The SWCNTs generally comprise the best 10 atoms across the circumference and the thickness of the tube is best one-atom thick. Nanotubes typically have a large period-to-diameter ratio (component ratio) of approximately 1000, so they may be taken into consideration as almost one-dimensional systems [11]. MWCNTs are large and encompass many unmarried-walled tubes stacked one within the other. The call MWCNT is confined to nanostructures with an outer diameter of less than 15 nm, above which the systems are known as carbon nanofibers. CNTs are awesome from carbon fibers, which are now no longer unmarried molecules however strands of layered-graphite sheets [12]

In addition to the two different basic structures, there are three different possible types of carbon nanotubes. The differences in the types of carbon nanotubes pro-depend ending on how the graphite is "rolled up" in the process creative process. These two integers correspond to the number un with along both directions in the have 'lattigrapheneapheme'. When m nanotubesCallaghanazag", when nn m mm nanotube is called "armchair", and all other configurations are called chiral. Figure 2 displays three different types of SWCNT: armchair, zigzag, and chiral. You can find more details about the structure considered by [13].

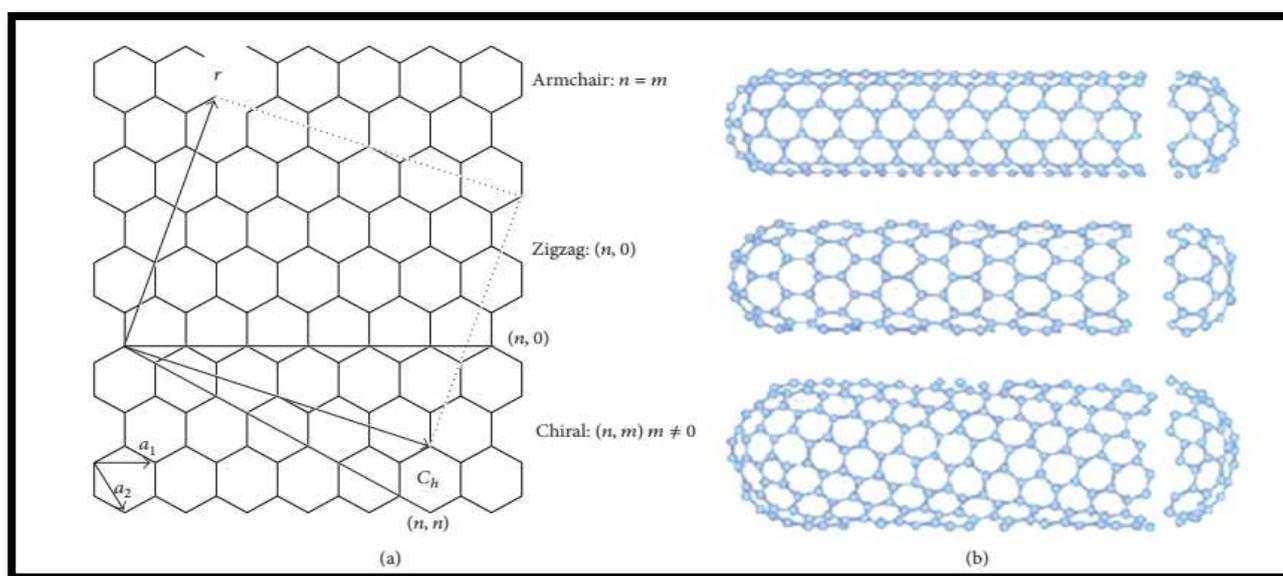


Figure- (A) Single-walled carbon nanotubes are formed by rolling a sheet of graphene along a lattice vector to generate chairs, zigzags, and chiral tubes, and (b) schematic representation of the three forms of carbon nanotubes. [14]

CARBON NANOTUBES METHOD OF PREPARATION -

High-quality nanotube materials are desired for basic and technological applications. High quality refers to the absence of structural and chemical defects on a significant length scale (e.g. 1 to 10 microns) along the pipe axis. The total number of patents and publications of carbon nanotubes is increasing rapidly [15]. However, their many challenges still need to be solved regarding Synthesize CNTs. Currently, there are four main challenges in the field of nanotube synthesis. (a) Mass production is the development of large-scale, low-cost processes to the synthesis of high-quality nanotubes, including SWCNT. b) Selective production, i.e. structural control and the electronic characteristics of the resulting nanotubes [16]. (compare to) Organizing, i.e. controlling the position and orientation of the nanotubes produced on a flat background. (D) The mechanism, i.e. the development of an in-depth understanding of nanotube growth processes. The growth mechanism is still a matter of controversy, and more a possible mechanism in the formation of NTC. Various techniques have been developed to produce CNTs and MWNTs have different structures and morphology with the number of laboratories [17]. There are three common methods used to synthesize CNTs: arc discharge, laser ablation, and chemical vapor deposition (CVD) [18]. the basic elements for forming nanotubes are catalysts, a source of carbon, and sufficient energy. Shared The feature of these methods is the addition of energy to a carbon source to generate fragments (groups or single C atoms) that can recombine to produce CNTs. The power supply can be the electricity of the arc discharge, the heat of the furnace ($\sim 900^{\circ}\text{C}$) for CVD, or intense light from a laser (laser removal) [19, 20].

A) Arc Discharge and Laser Vaporization-

Arc discharge and laser ablation were the first methods that allows the synthesis of SWCNT with a relatively large volume (g) Total. Both methods involve the condensation of gaseous carbon atoms are produced by the evaporation of solid carbon. For single-walled tube growth, metal catalysts are required in the arc discharge system [21]. The development of high-quality SWCNTs in the 1-10g scale has also been produced by laser ablation (laser furnace). Besides the laser furnace method, there are reports regarding the use of a typical industrial continuous wave CO₂ laser SWCNT production system. However, material requirements and large amounts of energy consumption by these methods make them less favorable for nanotube production. With arc and laser methods, only powder samples with entangled nanotubes in bundles can be produced. General characteristics of arcing and laser ablation is required a large amount of energy to produce rearrangement of carbon atoms into NTC. The temperature used is even higher than 3000°C , beneficial to the fine crystallization of CNTs, so the products are always made of good graphite connection. However, the basic requirements of these systems, including vacuum conditions and continuous graphite target alternative, make it difficult for large-scale production NTC [22].

B) Chemical Vapor Deposition (CVD)-

The CVD process involves gaseous or gaseous decomposition of Volatile carbon compounds catalyzed by metal nanoparticles that also act as nucleation sites for initiation Of the growth of carbon nanotubes. Unlike

the previous two, The method has proven that CVD is the preferred route. For large-scale production of carbon nanotubes [23]. Here, carbon is separated from hydrocarbons (or others). Carbonaceous source) In the presence of catalyst Temperatures below 1200 ° C. CNT structure like B. The number, diameter, length, and orientation of the walls were Well-controlled during the CVD process. So CVD This method has a gentle operation, low cost, Controllable process. Some in the last 12 years A method with the potential of Industrial production of nanotubes. They are all It is based on the CVD process. There are many of these methods The following approaches have proven promising [24,25].

CHEMICAL STABILITY-

The chemical stability of this nanocomposite needs to be evaluated for comparison with the HXLPE currently used in orthopedics. Various researchers have demonstrated the amazing radical scavenging capacity of MWCNTs in contact with reactive oxygen species, as well as other carbonaceous materials such as fullerenes and graphite. On the other hand, gamma rays affect CNTs by causing various structural changes such as the following. B. Decreased diameter, higher specific surface area and micropores, altered graphitization, and destruction of carbon nanostructures [26]. This forms a diamond-like structure and oxides. Therefore, it is clear that gamma irradiation may also have new effects on MWCNT / UHMWPE composites. A study by Martínez Morlanes examined these effects. The results showed that increasing the weight percent of MWCNTs resulted in a strong radical reduction, especially at allyl radicals, which increased oxidative stability after the accelerated degradation protocol. This removal effect of the composite was achieved by maintaining the crosslink density efficiency observed by the swelling measurement. The second article showed that all of these statements apply regardless of the type of CNT. This is a significant difference in the role played by other stabilizing processes, such as mixing vitamin E with polyethylene granules before heat compression. Recently, they analyzed the synergistic effect of both factors on the chemical stabilization of UHMWPE composites by immobilizing vitamin E on the outer surface of carbon nanotubes. Mixing UHMWPE powder with 1 wt% previously functionalized particles and then thermocompression bonding resulted in a composite with a 5-10 fold increase in decomposition induction time relative to the unfilled matrix [27].

Tribological behavior-

Another promising advantage of using a 2D graphene layer is that it can provide higher lubrication in applications involving frictional motion, as seen in some tribology studies on reduced graphene oxide layers on silicon substrates. is. In addition, the aforementioned increase in microhardness produced by GO / UHMWPE reduces the plastic effect on the bearing surface compared to its metal or ceramic counterparts. Both sides should contribute to the good coefficient of friction and wear resistance associated with any bearing material that wants to compete with today's highly crosslinked polyethylene [28]. However, despite the importance of knowing the wear behavior of these new composites, few studies have addressed this issue so far. The results of Tai's study showed that UHMWPE fortified with GO nanosheets increased the

coefficient of friction for all GO concentrations. The best results were obtained in terms of wear rate, with a significant reduction of almost 50% observed at 3% by weight of graphene oxide. Recently, found that UHMWPE reinforced with 0.1, 0.5, and 1 wt% graphene platelets more effectively reduced the coefficient of friction and wear resistance as the filler content increased. At a maximum normal load of 300 N on the Hysitron Triboindente 2D scratch node, the coefficient of friction was reduced by approximately 35% and the graphene nanoplate reinforcements increased wear resistance by more than a factor of four. This result is positive to consider that these composites may exhibit high wear resistance after gamma or electron beam irradiation due to the synergistic effect introduced by irradiation of the matrix through cross-linking. It can be a starting point [29, 30].

Table 1 - Noncovalent immobilization of protein and enzymes by indirect specific adsorption

Sr. No	Protein or Enzyme immobilized	Types of interaction	References
1	Glucose oxidase	(i) Surface of CNTs was positively charged by coating poly (sodium 4-styrene sulfonate) combined with ionic liquids. (ii) The enzyme was adsorbed onto nanotube composites through electrostatic interactions.	[31]
2	Alcohol dehydrogenase	(i) Chitosan-encapsulated CNTs have a positively charged surface; enzymes were immobilized through electrostatic interaction	[32]
3	Glucose oxidase and Alcohol dehydrogenase	(i) single-stranded DNA was wrapped on CNTs, and enzymes were immobilized onto DNA-wrapped CNTs. (ii) The binding of DNA onto CNTs appears to be primarily due to $\pi\pi$ - $\pi\pi$ stacking interaction, with the plane of the aromatic-nucleotide bases oriented parallel to the surface of the nanotube	[33]
4	DNA enzyme; Glucose oxidase	(i) Streptavidin and flavin adenine dinucleotide have also been used as the linking molecules between enzymes and CNTs. (ii) DNA enzyme immobilized onto CNTs attached with streptavidin via stable amide linkages. (iii) Glucose oxidase has been immobilized onto CNTs functionalized with the flavin adenine dinucleotide via amide linkages.	[34]

5	Horseradish peroxidase; Cytochrome	(i) Enzymes were adsorbed onto CNTs which were coated with surfactants such as Triton X-100, sodium dodecyl sulfate, and cetyltrimethylammonium bromide. (ii) Enzymes and surfactants are coassembled onto the CNTs. the CNTs are sonicated in the solution of a surfactant. When the enzyme is mixed with the suspension, it binds to the CNTs more strongly than the surfactant and displaces the surfactant to gain access to the CNT surface.	[35]
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Table 2- Structural studies of protein immobilized onto carbon nanotubes.

Sr. No	Protein	Nanomaterial	Spectroscopic techniques	Results	Reference
1	Albumin Lysozyme	SWCNTs	Circular dichroism Vis-Near IR	The protein is partially unfolded upon immobilization	[36]
2	Cytochrome c	MWCNT/poly (amidoamine)/chitosan	UV-Vis	No structural changes upon immobilization	[37]
3	Amyloglucosidase	SWCNTs, MWCNTs (in combination of coupling agents)	Circular dichroism	Enzyme retains its structure when physically adsorbed. However, covalent attachment leads to a significant loss of structure	[38]
4	Horseradish peroxidase	SWCNTs	Circular dichroism and fluorescence	Enzymes retain a high percentage of their native structure when immobilized	[39,40]

CONCLUSION-

Many customized synthesis techniques have been invented to manufacture CNTs on a large scale for commercial usage. Due to its low-cost relative to other technologies, CVD is currently the most promising technology for generating vast quantities of CNTs. Commercial applications of carbon nanotubes, on the other hand, have been slow to emerge due to the high expense of generating the finest quality nanotubes. Carbon nanotubes (CNTs) have a chemistry that has resulted in great progress and this subject will take the

lead applications of carbon nanotubes. The function of CNTs, and especially CNTs in terms of length, diameter, and chirality will lead to better control of CNT-based materials and devices at the molecular level. Present The article shows their great potential for biotechnology and biomedicine is only just beginning to become a reality. A lot of biomolecules (proteins, enzymes, or DNA/RNA) may interact and fixed on CNTs, resulting in a large amount of application.

CONFLICTS OF INTEREST

There are no conflicts of interest and disclosures regarding the manuscript.

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REFERENCE-

1. David R. Lide. CRC Handbook of Chemistry and Physics, 87th ed. American Chemical Society. 2007;2007:129–724.
2. Foldvari M, Bagonluri M. Carbon nanotubes as functional excipients for nanomedicines: I. pharmaceutical properties. Vol. 4, Nanomedicine: Nanotechnology, Biology, and Medicine. 2008. p. 173–82.
3. Saifuddin N, Raziah AZ, Junizah AR. Carbon nanotubes: A review on the structure and their interaction with proteins. Journal of Chemistry. 2013;
4. Lal C GTK. Studies On Carbon Nano-tubes- Polyaniline based Composites. Vol. 1. Nano Science and Technology Institute; 2008. 136–139.
5. Yamaguchi T, Bandow S, Iijima S. Synthesis of carbon nanohorn particles by simple pulsed arc discharge ignited between pre-heated carbon rods. Chemical Physics Letters. 2004 May 1;389(1–3):181–5.
6. Ruoff RS, Qian D, Liu WK. Mechanical properties of carbon nanotubes: Theoretical predictions and experimental measurements. Vol. 4, Comptes Rendus Physique. Elsevier Masson SAS; 2003. p. 993–1008.
7. Title: Functionalization of Carbon Nanotubes for Effective Biosensing and Potential Biomedical Applications. 2013.
8. T.W. Ebbesen. Large- Scale Synthesis of carbon nanotube. Letter to nature. 1992;358:220–2.
9. Zhang M, Li J. Carbon nanotube in different shapes. Vol. 12, Materials Today. 2009. p. 12–8.
10. Hirlekar R, Yamagar M, Garse H, Vij M, Vilasrao K. CARBON NANOTUBES AND ITS APPLICATIONS: A REVIEW. Asian Journal of Pharmaceutical and Clinical Research. 2(4).
11. Meyyappan M, Delzeit L, Cassell A, Hash D. Carbon nanotube growth by PECVD: a review. Vol. 12, Plasma Sources Sci. Technol. 2003.
12. Dresselhaus MS, Dresselhaus G, Jorio A. Unusual properties and structure of carbon nanotubes. Vol. 34, Annual Review of Materials Research. 2004. p. 247–78.
13. Zhu Z. An Overview of Carbon Nanotubes and Graphene for Biosensing Applications. Vol. 9, Nano-Micro Letters. SpringerOpen; 2017.

14. Terrones M. Science and Technology of the Twenty-First Century: Synthesis, Properties, and Applications of Carbon Nanotubes. Vol. 33, Annual Review of Materials Research. 2003. p. 419–501.
15. Journet C, Maser WK, Bernier P, Loiseau A, Lamy De La Chapelle M, Lefrant S, et al. Large-scale production of single-walled carbon nanotubes by the electric-arc technique. 1997.
16. J. A, Chandrakumar K, Wang Y, Irlé S, Morokum K. Mechanisms of Single-Walled Carbon Nanotube Nucleation, Growth and Chirality-Control: Insights from QM/MD Simulations. In: Electronic Properties of Carbon Nanotubes. InTech; 2011.
17. Kato T, Hatakeyama R. Growth of Single-Walled Carbon Nanotubes by Plasma CVD. Journal of Nanotechnology. 2010;2010:1–11.
18. Hiramatsu M, Hori M. Aligned Growth of Single-Walled and Double-Walled Carbon Nanotube Films by Control of Catalyst Preparation.
19. Su M, Zheng B, Liu J. A scalable CVD method for the synthesis of single-walled carbon nanotubes with high catalyst productivity [Internet]. Vol. 322, Chemical Physics Letters. 2000. Available from: www.Elsevier.nl/locate/cplett
20. Shokrieh MM, Rafiee R. A REVIEW OF THE MECHANICAL PROPERTIES OF ISOLATED CARBON NANOTUBES AND CARBON NANOTUBE COMPOSITES. 2010.
21. Kong J, Cassell AM, Dai H. Chemical vapor deposition of methane for single-walled carbon nanotubes. Vol. 292, Chemical Physics Letters. 1998.
22. Zhou Q, Meng F, Liu Z, Shi S. The thermal conductivity of carbon nanotubes with defects and intramolecular junctions. Journal of Nanomaterials. 2013;2013.
23. Sánchez FS, Ferrater C, Guerrero C, García-Cuenca M v, Varela M. High-quality epitaxial LaNiO₃ thin films on SrTiO₃ (100) and LaAlO₃ (100). Appl Phys A. 2000;71:59–64.
24. Awasthi K, Kumar R, Tiwari RS, Srivastava ON. Large scale synthesis of bundles of aligned carbon nanotubes using a natural precursor: Turpentine oil. Journal of Experimental Nanoscience. 2010 Dec;5(6):498–508.
25. Cassell AM, Raymakers JA, Kong J, Dai H. Large Scale CVD Synthesis of Single-Walled Carbon Nanotubes. Journal of Physical Chemistry B. 1999 Aug 5;103(31):6484–92.
26. Daud NA, Chieng BW, Ibrahim NA, Talib ZA, Muhamad EN, Abidin ZZ. Functionalizing graphene oxide with alkylamine by gamma-ray irradiation method. Nanomaterials. 2017 Jun 1;7(6).
27. Zoo Y-S, An J-W, Lim D-P, Lim D-S. Effect of carbon nanotube addition on tribological behavior of UHMWPE.
28. Zhao X, Liu R. Recent progress and perspectives on the toxicity of carbon nanotubes at organism, organ, cell, and biomacromolecule levels. Vol. 40, Environment International. Elsevier Ltd; 2012. p. 244–55.
29. Masud A, Zhou C, Aich N. Emerging investigator series: 3D printed graphene-biopolymer aerogels for water contaminant removal: a proof of concept. Environmental Science: Nano. 2021 Feb 1;8(2):399–414.
30. Puértolas JA, Kurtz SM. Evaluation of carbon nanotubes and graphene as reinforcements for UHMWPE-based composites in arthroplasty applications: A review. Vol. 39, Journal of the Mechanical Behavior of Biomedical Materials. Elsevier Ltd; 2014. p. 129–45.
31. Alpert Ş, Telefoncu A. Development of an alcohol dehydrogenase biosensor for ethanol determination with toluidine blue O covalently attached to a cellulose acetate modified electrode. Sensors. 2010 Jan;10(1):748–64.

32. Li S, He P, Dong J, Guo Z, Dai L. DNA-directed self-assembling of carbon nanotubes. *Journal of the American Chemical Society*. 2005 Jan 12;127(1):14–5.
33. Martin Nazario, Giacalone Francesco. Fullerene polymers : synthesis, properties, and applications. Wiley-VCH; 2009. 311.
34. Zheng M, Jagota A, Semke ED, Diner BA, McLean RS, Lustig SR, et al. DNA-assisted dispersion and separation of carbon nanotubes. *Nature Materials*. 2003 May;2(5):338–42.
35. Homaeigohar S, Elbahri M, Elbahri Nanochemistry M. A Buckypaper Like Adsorbent Based on Amphiphilic Graphite Nanofilaments for Removal of Enzyme Biomolecules from Water. 2018; Available from: <https://www.researchgate.net/publication/329037698>
36. Wu MS, Yang CH, Wang MJ. Morphological and structural studies of nanoporous nickel oxide films fabricated by anodic electrochemical deposition techniques. *Electrochimica Acta*. 2008 Dec 30;54(2):155–61.
37. Komori K, Terse-Thakoor T, Mulchandani A. Bioelectrochemistry of heme peptide at seamless three-dimensional carbon nanotubes/graphene hybrid films for highly sensitive electrochemical biosensing. *ACS Applied Materials and Interfaces*. 2015 Feb 18;7(6):3647–54.
38. Venkataraman A, Amadi EV, Chen Y, Papadopoulos C. Carbon Nanotube Assembly and Integration for Applications. Vol. 14, *Nanoscale Research Letters*. Springer New York LLC; 2019.
39. Alvarez-Paggi D, Hannibal L, Castro MA, Oviedo-Rouco S, Demicheli V, Tórtora V, et al. Multifunctional Cytochrome c: Learning New Tricks from an Old Dog. *Chemical Reviews*. 2017 Nov 8;117(21):13382–460.
40. Gay T, Kaufman J, Mcguigan M. Stronger than Steel: Stronger than Steel: Carbon Nanotubes. 2005.

