Mechanical Properties of Carbon Nanotubes (CNTs): A Review

Mohammed Najat Rashko[1] & Samir Mustafa Hamad[1,2] & Azeez Abdullah Barzinjy[3,4] & Abubaker Hassan Hamad[5]

[1]Nanotechnology Department, Scientific Research Centre, Soran University, Erbil, Iraq
[2]Computer Department, Cihan University-Erbil, Erbil, Iraq
[3]Department of Physics, College of Education, Salahaddin University-Erbil, Iraq
[4]Physics Education Department, Faculty of Education, Tishk International University, Erbil, Iraq
[5]Department of General Science, Faculty of Education, Soran University, Erbil, Iraq
Correspondence: Azeez Abdullah Barzinjy, Salahaddin University-Erbil, Iraq.
Email: azeez.azeez@su.edu.krd

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Abstract: In this review, the main approaches were utilized for fabrication nanostructure materials namely arc discharge, laser ablation, chemical vapor deposition, and green synthesis. Also, the advantages and disadvantages for each approach are discussed intensively. In addition, the structure and morphology of Carbon Nanotubes (CNTs), according to the number of layers CNTs classified single-wall carbon tubes (SWCTs), double wall carbon tubes (DWCTs), and multi-wall carbon tubes (MWCTs) are demonstrated in detail. SWCTs can be divided into chiral (m≠n), zigzag (m=0), and armchair (m=n) based on the geometrical arrangement of atoms or molecules. Moreover, some of the mechanical features of CNTs such as Young's modules, strength and tensile strength, compressibility and deformability and fracture performance will be described. Throughout this review, it can be concluded that CNTs possess better mechanical features comparing with the analogous bulk or micro-scale tubes. For instance, Young's module of CNTs increases by decreasing radius of CNTs. Furthermore, the strength and tensile strength of CNTs becomes stronger due to this covalent bond between carbon-carbon. On the other hand, compressibility and deformability will also improve due to the anisotropic feature of CNTs shape. It can be concluded that, CNTs possess a wide range of possible uses, and they can be used in nanoscale devices, electronic applications, optical operation, materials science, architecture and many more. Also, CNTs have been utilized in numerous novel applications owing to their unusual electrical features, unique strength, and heat transfer performance.

Keywords: CNTs, Structure and Morphology, Young's Module, Strength and Tensile Strength, Compressibility and Deformability

1. Introduction

There are numerous applications of nanotechnology in different area of applications, for instance optical devices, food packaging, biomedicine treatment, pharmaceutics, catalyst, surgery, water purification, and many others area (Khan, Saeed, & Khan, 2019). The national nanotechnology initiative describes nanotechnology as the understanding and control of matter at dimensions between approximately 1 and 100 nm (NNI, 2020). The basic element of nanotechnology is nanoparticles, which have various employments in diverse fields, such as biosensors and nanoelectronic devices (Kong, Ding, Yang, & Wang, 2004; Yin et al., 2004).

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According to their structure or compositions, nanomaterials (NMs) can be divided into three classes (Figure 1). Fullerenes, carbon nanotubes such as (single-wall, double wall, and multi-wall), graphene, graphite, and nanofibers are examples of carbon based in nanomaterials. The second class is inorganic nanomaterials, such as Al_2O_3, ZnO, CuO, Fe_2O_3, and TiO_2 all of them are oxide-based nanomaterials. Another category of inorganic nanomaterials is quantum dot, and known as metalloid nanomaterials for example ZnO, ZnS, PbSe, and CdSe. The third category among these classification nanomaterials is hybrid nanomaterials, which are mixture of organic-organic, inorganic-inorganic, and organic-inorganic nanomaterials (Tebaldi, Belardi, & Montoro, 2016).

Diamond and graphite elements are the most common allotropes of carbon. Carbon atoms in diamond have sp^3 hybridization, which means that four bonds are directly connect the corners of a uniform tetrahedron. The obvious reason for its hardness is the rigidity of the resulting three-dimensional network (diamond). Carbon atoms in graphite have sp^2 hybridization which means that three bonds connect to three carbons by angle (120°), and weak bond π exist between carbons. The large number of sp^2creates the hexagonal structure like honeycomb form (Hennrich, Chan, Moore, Rolandi, & O'Connell, 2006). In1985, a team supervised by Korto and coworkers discovered Buckminsterfullerene (C_{60}), a new shape of carbon (Kroto, 1987).

The first report about CNTs was on multi-wall carbon nanotubes (MWCNTs) produced by arc-discharge approach, it was published by Iijima in 1991 (Iijima, 1991). CNTs possess cylindrical form, it may be containing one cylinder or more with an outer diameter ranging from 3 nm to 30 nm. At the beginning MWCNTs was discovered (Iijima & Ichihashi, 1993), approximately at the same time, Dresselhaus *et al.* fabricated single-wall carbon tubes (SWCNTs) using the same method as MWCNTs, but with the addition of transition metal particles like (Cu, Fe, Ni, etc.) to the carbon electrodes (M.S. Dresselhaus, Smalley, Dresselhaus, & Avouris, 2001).

The discovery of Nanotubes, in general, have encouraged researchers' attention from both a basic and advanced standpoint. The process of the graphene sheets is twisted around has a strong effect on certain performances of nanotubes. Carbon nanotubes are the best candidates for desired applications such as hydrogen storage due to their tuber geometry and ultrafine size (Dillon et al., 1997; Murata et al., 2000; Odom, Huang, Kim, & Lieber, 1998; Wilder, Venema, Rinzler, Smalley, & Dekker, 1998). As opposed to conventional micro-size graphitic, the small diameter of a carbon nanotubes has a significant impact on mechanical properties (Mildred S Dresselhaus, Dresselhaus, Sugihara, Spain, & Goldberg, 1988). There are a variety of techniques for synthesizing SWNTs, DWCNTs, and SWNTs. CNTs can be manufactured using a various way such as electrical arc discharge, laser vaporization or laser ablation, and chemical vapor deposition.

Carbon nanotubes are one of the strongest materials according to their mechanical properties, such as Young's module, stress and strain, strength and tensile strength, stiffness, wettability, compressibility and deformability fracture. CNTs are the stiffness and hardness structures ever created in expression of elastic modulus and tensile-strength (red, 2020). The ability to identify large strength, large stiffness, and large flexibility is always desirable which cannot be found in graphite fibers. CNTs' characteristics pave the way for a new generate of large features compound materials. Because of the technical difficulties inherent in the manufacture of nanotubes and the manipulation of nanoscale-size specimens, theory research on the mechanical properties of CNTs are more frequent and advance compared with experimental determination (Salvetat et al., 1999). This review article is an overview on mechanical properties of CNTs.

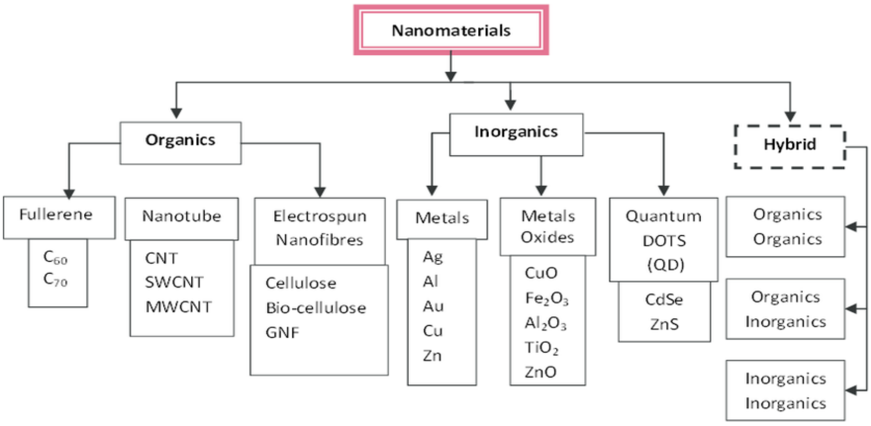

Figure 1: Classification of Nanomaterials according to organic, inorganic, and hybrid (Al-Kayiem, Lin, & Lukmon, 2013)

2. Synthesis of Carbon Nanotubes (CNTs)

Figure 2 shows that multi-walled carbon nanotubes (MWCNTs) are normally thicker than single-walled carbon nanotubes (SWCNTs). The dissimilar structural, chemical, electromechanical, and electrical properties of CNTs have been studied extensively over the last decade. Up to date, investigators concentrated on improving the quality of catalytic generated nanotubes (Ajayan, 1999; P. J. Harris & Harris, 2009).

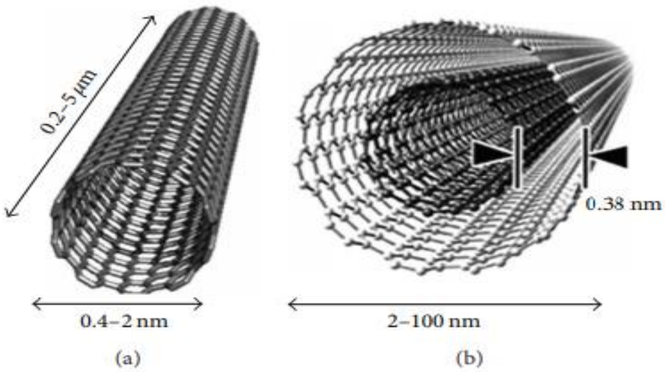

Figure 2: Virtual diagrams of (a) single-wall CNTs with diameter and length and (b) multi-wall CNTs with diameter and length (He et al., 2013)

The famous approaches for preparing carbon nanotubes are electrical arc discharge, laser vaporization, Chemical Vapor Deposition (CVD), and green synthesis. According to the comprehensive literature available on this topic, each of these methods has its own set of benefits and drawbacks, which are only briefly discussed below (Dupuis, 2005; Graham et al., 2005; Robertson, 2007; Seidel et al., 2004). Iijima was the first to synthesize carbon nanotubes (Iijima, 1991), using the electrical arc discharge system in 1991. Investigators have successfully used this method to produce high-quality CNTs for about the last two decades. In general, electrical arc-discharge is a process in which a graphite rod acts as anode (+) rod and cathode (-) rod, also a few millimeters apart between rods, and is evaporated utilizing a strong current to prepare Nano-carbon products. Some information about parameters of electrical arc discharge instruments: electric current (50 – 120) A, potential difference (20 – 25) V, diameter of each electrode approximately $(5-20)\mu m$, apart between electrodes 1 mm, and pressure of inert gas (100 – 500) torr unit. Also, noble gases are utilized to cool and condense of atoms to make a desired shape of CNTs. The structure of carbons to being carbon nanotubes is determined by noble gas such as helium, and which has a temperature range between 3000–3500°C (Jagadeesan, Thangavelu, & Dhananjeyan, 2020). In recent times, the best common way of manufacturing CNTs is the CVD. This technique is used a metal catalytic assistance in the thermal decompose of a hydrocarbon vapor. As a result, it is often called thermal chemical vapor deposition CVD or catalyst CVD. In fact, variety types of CVD were utilized for a variety of aims. Accordingly, CVD method is an easy and cost-effective process for synthesizing CNTs.

The first approach for producing fullerenes was by laser ablation technique. An objective graphite is evaporated by laser ray at large temperatures about 1200 °C while a noble gas is continuously moving through the system (Chou, 2005). Many carbon classes are generated by laser ablation and concentrated in a water-cool collector (Guo, Nikolaev, Thess, Colbert, & Smalley, 1995). When a goal is doping graphite with small quantities of transition metals including nickel and cobalt, SWNTs with a regular diameter can be made (Loos, 2014). Solid graphite materials are exposed by a laser source and vaporized to change carbon atoms. Graphite materials are the most famous carbon source. A nonstop laser source, such as a CO_2, and Nd:YAG lasers can be used for vaporization of target material. Further, the water-cooled copper collector is the stratum on which the vaporized carbon atoms deposited and develop. In addition, Argon gas is widely utilized as a noble gas that flows at a steady rate into the copper collector that is cooled by water (Jagadeesan et al., 2020).

Nowadays, green synthesis method is used to prepare of CNTs. A variety of complex methods have been established, including laser ablation (physical vapor deposition), electrical arc discharge, and pyrolysis process, and chemical vapor deposition which are basically toxic and expensive at the same time. Green synthesis method is ecological and suitable approach so-called one step water supported (quenching) production, in which graphite flakes extract is used from coconut shell wastes to fabricate CNTs (Hakim, Yulizar, Nurcahyo, & Surya, 2018). Table 1 highlights the properties of some process for preparing CNTs.

Table 1: Comparison of carbon nanotube production method (Bagotia, 2019)

Process/ Property	Arc Discharge	Laser Ablation	Chemical Vapor Deposition
Raw material availability	Difficult	Difficult	Easy
Energy requirement	High	High	Moderate
Process control	Difficult	Difficult	Easy, can be automated
Reactor design	Difficult	Difficult	Easy and can be designed as large-scale process
Production rate	Low	Low	High
Purity of Product	High	High	High
Yield of product	Moderate (70%)	High (80-85%)	High (95-99%)
Process nature	Batch type	Batch type	Continuous
Cost	High	High	Low

3. Structure and Morphology of CNTs

Carbon is one of the most significant utilized elements due to its versatility or ability. Its capability belongs to arrangement sp^3, sp^2, and sp hybrids, resultant in zero-Dimensional (0-D) (Fullerene), one-Dimensional (1-D) (carbon nanotubes), two-Dimensional (2-D) (graphene), and three-Dimensional (3-D) (diamond and graphite). These nano-allotropes of carbon materials have a broad range of physical and chemical features. Figure 3 shows nano-allotropes of carbon, such as fullerenes and graphene sheets, and in Figure 3 (c and d) shows single-walled carbon nanotubes and graphite sheets.

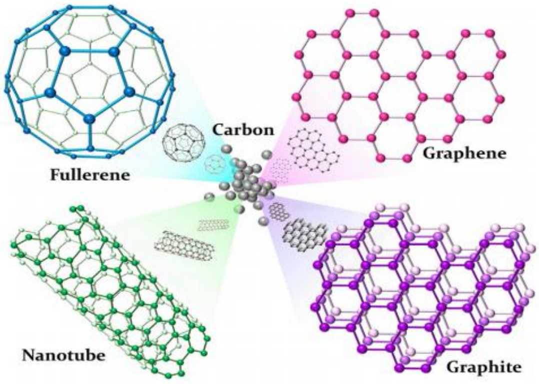

Figure 3: Manifestation various kinds of carbon allotropes like fullerene, graphene, nanotube, and graphite structure (Sengupta, 2018)

Carbon nanotubes are rolled-up graphite sheets that were formed as cylinders (Thostenson, Ren, & Chou, 2001). Graphene is a single graphite layer that can be helical in many directions to fabricate different form of CNTs as shown in Figure 4. CNTs are nearly one-dimensional form with a bucky-tube outline due to their high length-to-diameter ratio. SWCNTs and MWCNTs are the most vital forms. A SWCNT is a single helical graphene sheet cylinder, while multi-wall CNTs are a sequences of coexistences SWCNTs. These structures vary different in length and diameter from SWCNTs, and their properties are also very distinct. CNTs have sp^2 bonding, and this lattices and bonds like honeycomb, each atom is linked to three other atoms surrounding it, like graphite. As a consequence, the tubes resemble graphene sheets that have been rolled up (Aqel, Abou El-Nour, Ammar, & Al-Warthan, 2012). The chiral vector of a nanotube, which is defined by the chiral indices(n_1, n_2), can be utilized to determine its structure depending on the direction of the tube lattices (axis) in relation to the hexagonal network. Further, based on the geometric structure of the carbon atoms at the layers, CNTs can be classified into SWCNTs, DWCNTs, and MWCNTs.

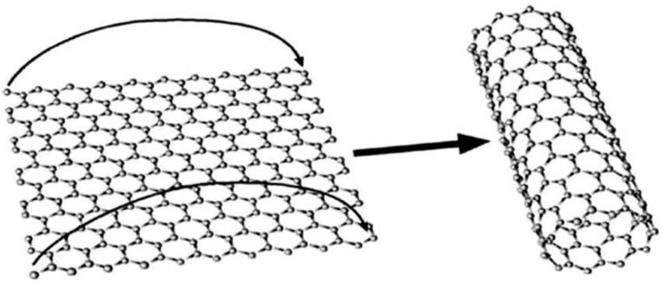

Figure 4: SWCNT is generated by helical a single layer of graphite sheet. (Chaudhury & Sinha, 2019)

Although the majority of SWNTs are chiral (n_1, n_2), a few have armchair (n_2 = n_1) or zigzag (n_2 = 0) configurations, as shown in Figure 5 (Tîlmaciu & Morris, 2015). A multi-walled CNT is made up of a numerous arrangement of many layers in its most basic form (Figure 5). Moreover, about CNTs structure, DWNTs (dual wall carbon nanotubes) are a type of MWNTs made up of just two tubes (Figure 5). DWNTs combine the features of together SWCNTs and MWCNTs, the diameter of DWNTs between the two main types of CNTs. As a result, the performance of both types of CNTs are combined. In terms of small diameter, weight, and capacity to shape bundles, DWNTs are similar to SWCNTs, but their mechanical permanence is much higher, particularly when covalent functionalization (S. B. Yang, Kong, Kim, & Jung, 2010). Furthermore, similar to MWCNTs, the outer-walled of DWCNTs can be functionalization minus compromising the electro-chemical or mechanical features of the inner channel (Pumera, 2007).

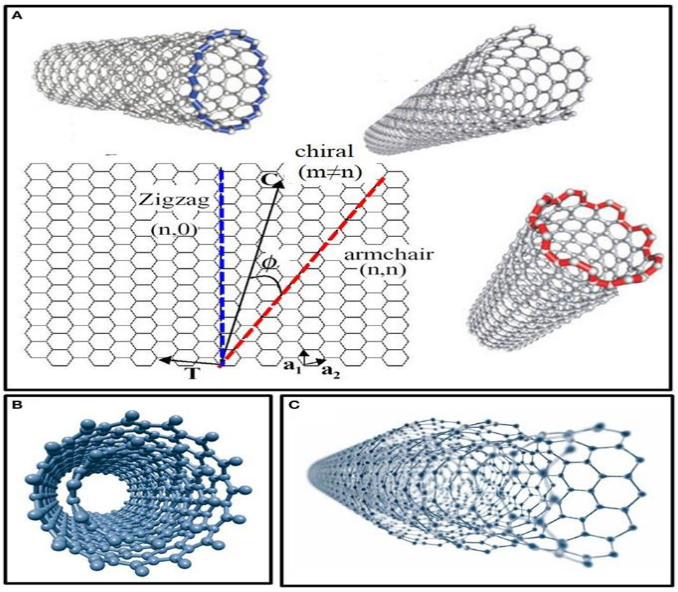

Figure 5: CNTs structure and models based on the number of layer or tuber (A) Structures of SWNTs as a result of chirality (zigzag, armchair, and chiral) (B) DWNTs model (C) MWNTs have a structure made up of several concentric cylinder (Tîlmaciu & Morris, 2015)

4. Mechanical Properties of CNTs

4.1 Young's Module of CNTs

Knowing Young modulus value of materials is a key factor in a variety of operations in different areas of applications. Simply, the fraction of stress state to strain state is the definition of Young's modulus feature, which is calculate of amount elastic-material's stiffness or rigidity (Ma, Sobernheim, & Garzon, 2016). In reality, structural engineers are commonly focused on elastic theory of materials, also architecture (design) focusing on stress under the elastic limitation, and harmless loads existence semi (moiety) compare with the elastic limitation, or fewer amount (B. Harris & Bunsell, 1977). The elasticity feature of solid materials are grain-boundaries, dislocation, defects like point, line, and plane. Solid's cohesion (same molecules) is directly proportional to Young's modulus, owing to the chemical-bonds between their atoms. Most accurately, in this situation, the covalent bonding of the solid, in the form of the potential energies $\mathrm{U(x)}$ should be determined through spacing between two atoms. Moreover, Taylor's series of the function of energy $\mathrm{U(x)}$ about r_0 (equilibrium position) provides Hooke's law for tiny strain, means that force is directly proportional to displace associated with the second order derivative of the energy potential energies $\mathrm{U(x)}$ at r_0 acts as the proportionality term. The

Young's modulus quantity of a narrow bar of isotropy solid materials, have cross section area (A_0) and dimension (l_0), and $Y_m = stress/strain = (F/A_0)/(\Delta l/l_0)$. Due to covalent bonds of solids like graphite, rock, silicon carbide, boron nitride has a strong modulus about larger than 100 GPa. Furthermore, experiments demonstration that elastic constants obey basic formula (law of inverse fourth power) collateral the lattice parameter in each class of solids (describe due to the existence of the bonds). Slight alternation in the lattice's parameter of a crystal can cause large change in its elastic-constant (Salvetat et al., 1999). For instance, cause inter layer thermal expansion, graphite type (C_{33}), which match the Young's modulus collateral with the C-axis of the hexagonal, is highly rely on temperature parameter (Kelly, 1981). Therefore, the Young's modulus feature of carbon nanotubes is associated with sp^2-bond strengths. Carbon-NTs are softer and more powerful than any other substance known on the world. Carbon-NTs have a Young's modulus about (TPa) unit, production them the strongest (great tensile strength feature) substance known, capable of withstanding great strains without rupture fracture (Sato, 2011). Table 2 demonstrate some information, important points in relation between Young's modulus of SWCNTs with different radius of tube (WenXing, ChangChun, & WanZhao, 2004).

Table 2: Young's modulus of SWCNTs for different tube radius (WenXing et al., 2004)

Type of CNTs	(n, n)	No. of atoms	Radius (nm)	Length (nm)	Y (GPs)
Armchair	(8,8)	1168	0.542	8.854	934.960
	(10,10)	1460	0.678	8.854	935.470
	(12,12)	1752	0.814	8.854	935.462
	(14,14)	2324	0.949	10.084	935.454
	Average				935.805 ± 0.618
Zigzag	(14,0)	840	0.548	6.230	939.032
	(17,0)	1360	0.665	8.362	938.553
	(21,0)	1890	0.822	9.428	936.936
	(24,0)	2400	0.939	10.500	934.201
	Average				935.287 ± 2.887
Chirality	(12,6)	1344	0.525	9.023	927.671
	(14,6)	1896	0.696	11.367	921.616
	(16,8)	2240	0.828	11.279	928.013
	(18,9)	2520	0.932	11.279	927.113
	Average				929.87 ± 11.5

Figure 6 shows the examined outcome of multi-wall CNTs aspect ratio (length /diameter) with young's modulus (GPa) unit (Ayatollahi, Shadlou, Shokrieh, & Chitsazzadeh, 2011).

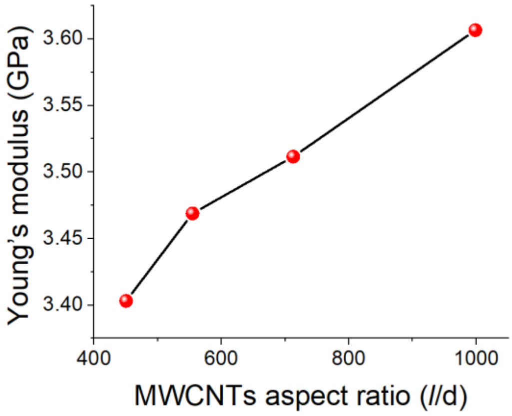

Figure 6: Examined outcome of multi-wall CNTs aspect ratio (length /diameter) with young's modulus (GPa) (Ayatollahi et al., 2011)

4.2 Strength and Tensile Strength of CNTs

The strength feature of a substance is less clearly known compare with the Young's modulus feature. It is relying on some main factors such as the atmosphere (temperature and pressure), and the measurement device (oscillations in cargo could change the amount of strength). It is confidently related to any imperfection and defect of the structure that may exist in the solid phase, and products with strengths reaching the theoretical edge are very rare (Salvetat et al., 1999). In general, the definition of strength of material is the information of the body concerned with the relationship between interior force, distortion, and outside cargo is known as metallurgy's strength of material. This strength can be accounted in two ways. The first one is the strength given through the interlinking covalent bonds between carbon-carbon. The second one is each carbon nanotube is a single great molecule.

Nanotubes have several important properties, one of them is that they are extremely strong. Carbon nanotubes (CNTs) have a tensile strength that is about one hundred times that of steel material of the similar thickness (UnderstandingNano, 2019). In theoretical situation carbon nanotubes (CNTs) have potential tensile strength that is unrivaled by virtually any other substances. The tensile strength property of carbon nanotubes is affected by several factors such as symmetries, diameters, temperatures, amount of strain, number of layers, and qualities. For instance, single-walled CNT with a zigzag pattern has tensile strength is approximately 200 GPa (L. Yang, Greenfeld, & Wagner, 2016). CNTs may be used to improve closely completely present production, enhancing these materials modify to stronger, more exactly manufactured, and compare with previous softer, this information about material has identical tensile strength (De Volder, Tawfick, Baughman, & Hart, 2013). Furthermore, previously unimaginable mass-produce materials and engineered systems will gradually become a possibility. Carbon nanotubes can be used to build superstructures, like space elevator, due to stronger and lighter features, as shown in Figure 7.

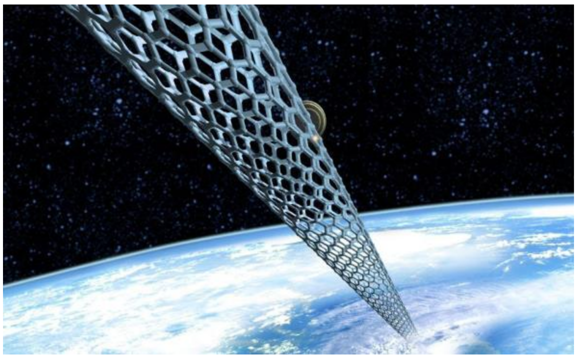

Figure 7: Virtual image obtain power of carbon nanotube used as space-elevator (Library, 2021)

Moreover, small atomic distortions introduced during the manufacturing process limit the tensile-strength of carbon-NTs more than any other element, resulting in a significant reduction in strength (Zhu, Wang, & Ding, 2016). To fully maximize the tensile strength performance of carbon-NTs, we must reduce defect or imperfection in the manufacturing process (Clair, 2016). As shown in Figure 8 by column chart, indicate tensile strength in gigapascals (Clair, 2016).

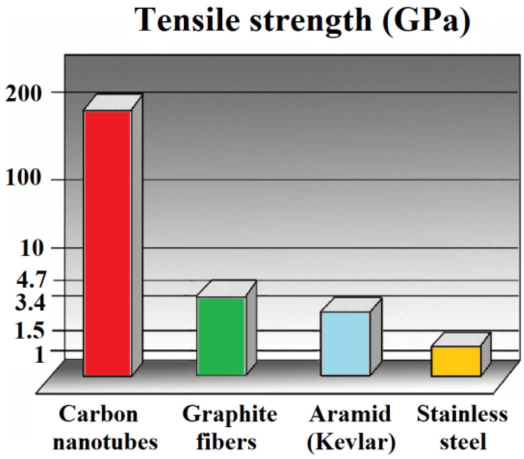

Figure 8: Tensile strength in gigapascals unit for some materials (Clair, 2016)

Table 3 shows the comparison tensile strength of some materials like SWCNT and MWCNT.

Table 3: Comparison tensile strength of some materials

Material	Tensile strength (GPa)
Epoxy	0.005
SWCNTs	150
MWCNTs	150
Steel	0.400
Wood	0.008

4.3 Compressibility and Deformability of CNTs

The mechanical properties of CNTs are predictable to be anisotropic due to the anisotropic feature of the CNTs structures. CNTs have high rigidity and strength in the direction of the axis, but it is comparatively compressible and deformable in the transverse path. One can define the compressibility as the change in volume caused by exterior pressure practical to an object's face. The change of volume divided to original volume approximately equal to $\Delta V/V_0 = -\varsigma\Delta P$ (Fanchi, 2002). Several assemblies have exhibited the formation of CNTs underneath compress, bend, and twist. The radial deformation model, which can be seen in transmission electron microscopy (TEM), highlights the role of van der Waals in mechanical properties of CNTs (Yu, 2004). Moreover, it can be shown that when single-walled carbon nanotubes with diameters of 2.5 nm or more are used to make a single-walled carbon nanotubes, van der Waals bonds between adjacent suspended carbon nanotubes can cause significant deformation resulting in a honeycomb structure (Tersoff & Ruoff, 1994).

CNTs deformation was simulated in the presence of a local connect. The tube radius and the number of layers were found to affect the elasticity and strength of the layers (Lordi & Yao, 1998). The results show that a strong force applied to CNTs caused to revers and elastic-deformation, implying that radial of mechanical forces wouldn't be talented of wounding a NTs. The growth of various buckling shapes in CNTs at the point of variabilities caused by increasing compression stress was demonstrated using molecular dynamics simulation (Yakobson, Brabec, & Bernholc, 1996).

The wavy shape was modeled along the inner curve structure of the curved carbon NTs. Their findings revealed that there is a critical diameter for the emergence of the ripple method at a given load and the duration of CNT formation (Liu, Zheng, & Jiang, 2003). In consequence, the overall energy absorbed of millimeter long CNTs arrays during compression or effect is goodly. As CNTs arrays are compressed, they appear to deform indefinitely, allowing for no energy dissipation when loaded. After maximum compression, an energy absorbing CNTs arrays can completely restore its original dimensions. To change the CNTs arrays inside the collection, a post-growth chemical vapor deposition treatment stage was introduced. This phase produced the required improvements in compressive power, deformation recovery (Figure 9) (Bradford, Wang, Zhao, & Zhu, 2011).

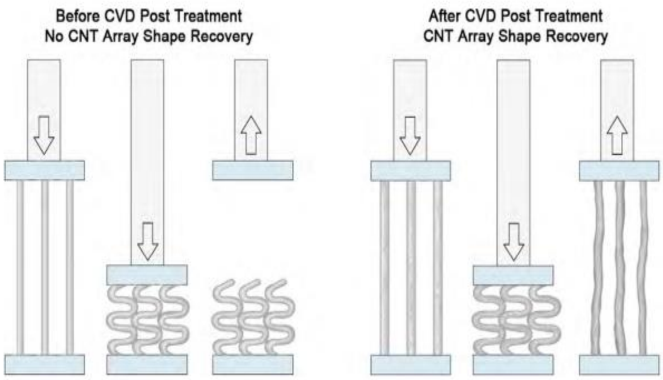

Figure 9: Compression of CNTs, before and after CVD post treatment (Bradford et al., 2011)

4.4 Fracture Behavior Test of MWCNTs

Figure 10 shows a nano-manipulator into the chamber's vacuum of a scanning electron microscopy (JEOL JSM6510), acting uniaxial tensile checks on specific MWCNTs (Yamamoto et al., 2010). The constant force was obtained in situ tensile tests using the resonance technique established by atomic force microscopy cantilevers acting like force sensor components (Sader, Chon, & Mulvaney, 1999). Focused electron beam induce deposition of a carbonaceous chondrite material which was used to clamp an individual MWCNTs to the cantilever tips (Ding et al., 2005). Figure 10d shows how to measure the applied force:

$$F = k(\Delta x - \Delta L) \quad [1]$$

Where k refers to the constant's force (stiffness), Δx is the cantilever's displacement, and ΔL is the elongation of the CNT.

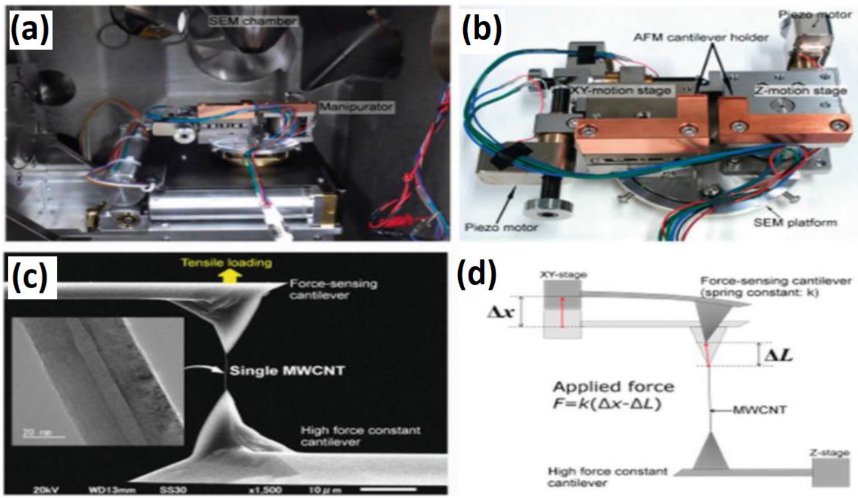

Figure 10: (a, b) Nano-manipulator system to test tensile on individual MWCNTs. (c) A SEM image of two AFM cantilever tips holding a MWCNT. (d) Schematic description of cantilever displacement during the tensile test of the MWCNTs (Shirasu, Yamamoto, Nelias, & Hashida, 2017)

By counting the number of pixels of the received scanning electron microscopy pictures, the NTs elongation was calculated. For the tensile measurements, the manipulator's XY motion-stage moved at velocity about 0.1 $\mu m/s$. Both cantilevers linked with multi-walled CNTs pieces were moved to a transmission electron microscopy study stage and tested by the TEM to determine their outside diameters afterward the multi-walled CNTs split. By use of TEM, the entire cross section area of the fractured multi-walled CNTs can be calculated including the internal pit, and used to measure values to quantify the tensile strength feature. The full fracture of CNTs layer and the "sword-in-sheath failure mode" are depending on the crystallinity and the presence of structural defects. Both types of fracture morphology can be found in multi-walled CNTs (Shirasu et al., 2017).

5. Applications of CNTs Based on Mechanical Properties

Carbon nanotubes (CNTs) are highly promised nanostructure because of their unique material performance. SWCNTs and MWCNTs are two types of allotropes of Nano-carbon. Some important nanoparticles utilized in Nano-composition such as polymers, metals, and ceramics metrics for support and modification of material properties. Because of their large stiffness features, and also large aspect ratios (Wong, Joselevich, Woolley, Cheung, & Lieber, 1998).

Carbon nanotubes may often be used as nanoscale Atomic Force Microscopy (AFM) probe and sensor. Nano-electromechanical system (NEMS) instruments, electronic transistor device, quantum-dots, Nanostructure bio-probe, biosensor, thin-film sensor, and multi-functional Nano composition are all examples of carbon nanotube built nanotechnology uses (V. Harik, 2018). Moreover, sensors and actuators made of carbon nanotubes can be utilized in a variety of applicator, equipment, and medical operations. For instance, SWCNTs are utilized by International Business Machines (IBM) in computer system be special as chips in transistor. Furthermore, CNTs base computer chips have present surpassed silicon (Si) base computer chips in terms of performance. In addition, CNTs have significant role in advancements in computer technology. Graphene form base transistor can be used to promote further advancements in carbon-based device technology and electronic devices. Thoughtful the features and mechanical properties of this materials is important for nanostructure proposal optimize and biomedical operation (Harik, 2018).

Most features have significant relationship between them. For instance, CNTs electrical conductivity permits for the formation of electro-magnetic actuator (EMA) by applied voltages to SWCNT cantilever beams (one side fixed) put off over a plate conductor, as seen in (Fig. 11). The tensile strength for SWCNT cantilever-beam rely on the flex rigidity of the SWCNT, which can be improved by selecting the suitable morphology SWCNT (V. M. Harik & Luo, 2004).

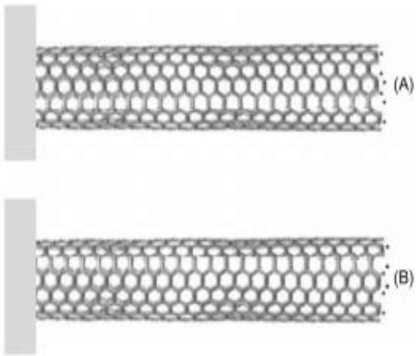

Figure 11: Virtual diagram demonstrated of CNTs resonators state utilized like sensor associated with the functionalization SWCNT of two different stiffness mechanical properties (Harik, 2018)

6. Conclusion

There are some methods to fabricate each kind of CNTs such as electrical arc-discharge, chemical vapor deposition (CVD), and laser vaporization. Based on geometry arrangement of atoms or molecules of SWCTs can be classified to chiral (m≠n), zigzag (m=0), and armchair (m=n). Moreover, the mechanical features of CNTs are important due to dedicate shock (unique) performances, CNTs light-weight but very strong features are not existed in other materials. In general, the range of Young's module of CNTs between 270-950 GPs, and also the range of tensile strength of CNTs between 11-150 GPs. According to their properties, they can be used in many applications such as the manufacture of car fuel tanks, tennis and golf bats, snow-ski poles, and coatings for military materials that cannot be detected by the radar, and technical electrostatic surface coating can be applied to various fields including touch screens and dual display screens.

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