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Synthesis and Physical Studies with Applications of Carbon Nanotubes by CVD Technique

A thesis
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the Degree of Doctor of Philosophy in Physics
By

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سُورَةُ الفَتْحِ

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِيْمِ

إِنَّا فَتَحْنَا لَكَ فَتْحًا مُّبِينًا ﴿١﴾

لِّيَغْفِرَ لَكَ اللّٰهُ مَا تَقَدَّمَ مِن ذَنۢبِكَ

وَمَا تَأَخَّرَ وَيُتِمَّ نِعْمَتَهُۥ عَلَيْكَ

وَيَهْدِيَكَ صِرَاطًا مُّسْتَقِيمًا ﴿٢﴾

وَيَنصُرَكَ اللّٰهُ نَصْرًا عَزِيزًا ﴿٣﴾

صَدَقَ اللّٰهُ العَظِيمُ

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Abstract

In this study, for the first time in the laboratories of the Department of Physics - College of Science - University of Diyala, the manufacture of multi-walled carbon nanotubes (MWCNT) was made using the chemical vapor deposition system (CVD), which was prepared and manufactured most of its parts manually. As different ratios were mixed Of methanol and butanol as a primary source of carbon and the use of both viruses as a catalyst and hydrogen peroxide for purification.

used were techniques Raman spectroscopy, Field Emission Scanning Electron Microscopes (FE-SEM), Transmission electron microscopy (TEM) (TEM), energy dispersion spectroscopy (EDS), and x-ray diffraction (x-ray).

The Raman spectrum showed that the composition contains two main beams and for all samples: the G-band within the range of (1570-1585) cm^{-1}, and the D-beam at the range (1300- 1340-) cm^{-1} which indicates the pattern of elongation (sp^2), and (sp^3) respectively.

Pictures of FE-SEM showed the formation of carbon tubes in various and various forms and for all samples, with a clear directional growth of the samples that were made from mixing alcohol ratios: (Methanol 75% + Butanol 25%, Methanol 50% + Butanol 50%), and the rate was obtained diameters are within (20-200) nm and lengths are within (1000-4200) µm.

As for images TEM, they demonstrated the formation of multi-walled carbon nanotubes with high clarity. EDS analyzes also showed the emergence of carbon, which is the main material for forming tubes and the appearance of both oxygen and iron.

The results of x-ray diffraction analyzes showed that all samples are polycrystalline and hexagonal type with a predominant direction (002).

After conducting the diagnostic process, the sample produced from (Methanol 50% + Butanol 50%) was used in the following applications due to growth in the straight direction of the carbon tubes as well as obtaining a good sample of (0.9 g) after the purification process as follows: -

First : the manufacture of an sensor for ethanol gas, and if the results show an increase in sensitivity when increasing the flow rate of the gas.

Second : the manufacture of a DSSC dye solar cell. The multi-walled nanotubes of both commercial and produced types were first loaded in 0.005, 0.01 ratios on titanium dioxide. This is precipitated as a paste on the base of the FTO glass by the method of the doctor blade, and then plasticized at 450° C for 30 minutes. The optical properties of these films were studied before and after the annealing process.

The highest efficiency of the DSSC4, which was 0.83%, was obtained.

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List of Symbols

Symbol	Meaning
Å	Angstroms
CNTs	Carbon nanotubes
HRTEM	High-Resolution Transmission Electron Microscope
MWCNT	Multi-Wall Carbon Nanotube
SWNTs	Single-Walled Carbon Nanotubes
nm	nanometer
CVD	Chemical Vapor Deposition
EDS	Energy dispersive
FE-SEM	filed emission scanning electron microscopy
0-D	Zero- dimension
1-D	One- dimension
2-D	Two- dimension
d	diameter
PVD	physical vapor deposition
ACNTs	Aligned Carbon Nanotubes
FC-CVD	Floating Catalyst Chemical Vapor Deposition
VACNTs	Vertically Aligned Carbon Nanotubes
APCVD	Atmospheric Pressure Chemical Vapor Deposition
BBCNT	Bamboo carbon nanotubes
CSCNT	Cup-stacked carbon nanotubes
RBM	Radial Breathing Mode
Dav	Average crystallite size
SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscope
TCVD	Thermal chemical vapor deposition
FWCNT	Few Wall Carbon Nanotube
XRD	X-ray diffraction
CNO	carbon Nano-onion
CDC	carbide derived carbon
CNF	carbon nanofibers
DWCNT	Double-walled carbon nanotubes
eV	Electron Volt
R_{gas}	Sensor Resistance
Sccm	Standard centimeter cubic per minute

Chapter One

Introduction and Basic Concept

1.1. Introduction

Nano-materials exhibit interesting physical properties distinct from both the molecular and broad scales, presenting new opportunities for physico-chemical as well as biomedical researches and applications in various areas of chemistry, biology and medicine. The unique chemical, physical and mechanical properties of carbon nanotubes have stimulated extensive investigation since their discovery in early 1990s by Iijima. Although there have been tremendous advances in the fabrication of Carbon Nanotube , the integration of these nanostructures into successful applications and large-scale production processes are yet not very smooth [1].

Nanotechnology and Nano-science are about controlling and under-standing matters on sub-micrometer and atomic scale. By definition they are exciting multidisciplinary fields which involve the design and engineering of objects or tools, characterization, production, and application of structures, devices, and systems by controlled manipulation of size and shape at nanometer scale. Nano-materials have sizes ranging from about 1nm up to several hundred nanometers, comparably to many biological macromolecules such as enzymes, antibodies, and DNA plasmids [2].

CNTs have unique nanostructures with remarkably mechanical, thermal and electrical properties, which made them highly attractive for the use as reinforcement in nanotube based composite materials [3]. Mostly these exceptional characteristics are predicted for a CNT which is ideal and far from CNTs currently being produced. CNTs are mostly taken more than micrometer in length and few nanometer less than 100 nm in diameters.

Several studies had concern with CNTs in many fields such as synthesized process, properties, and applications, all trying to reach the best conditions of the process of manufacturing, purification and diagnostics to obtain a perfect application.

CNTs have a large and varied chemical, optical, thermal, electronic and mechanical behaviors. Many manufacturing techniques such, the methods of chemical vapor deposition CVD, Arc discharge and laser ablation, but the CVD technique had been agreed to remain the best and better way to manufacture carbon nanotubes for many reasons. The important of CVDs can be related to inexpensive, uncomplicated, more adaptable and flexible to control manufacturing conditions[4].

Carbon has several allotropes including amorphous, graphite and diamond. Cyclacenes, nanotubes and fullerenes are accepted as the fourth form of solid carbon. The discovery of carbon nanotubes (CNTs) has sparked powerful research in the past decade. The CNTs unique chemical and physical properties suggest their promising applications in the creation of new nanomaterial. Many research groups have tried to synthesize new nanotubes using elements other than carbon, Kroto and Iijim [5-7] are considered to be establish carbon nanotubes science, either because of the precedence in find the initial imaging that made these names. Iijima the most prominent among them due to "his remarkable findings caused the scientific community focus on nanotube research".

In this study, the CVDs system was used to synthesize CNTs by mixing different ratios of alcohol (methanol and butanol) at 700 ^{o}C, with using Fe as a catalyst for precipitation. The products were characterized through filed emission scanning electron microscopy (FE-SEM), Raman spectroscopy, X-ray diffraction with transmission electron microscopy (TEM) and Energy dispersive (EDS).

1.2. Carbon atom

Carbon if the sixth element in the periodic table element, Carbon has six electrons that allows bonding with different atoms and hybridization. Many nanomaterials can be formed by carbon atoms only such as Graphene, planer, tubular and spherical graphite [8].

Another litterateurs reported that carbon nanomaterials can be include fullerenes, CNT, and monocrystalline graphite: graphene as shown in Figure (1-1) which is within (0-D, 1-D,2-D) respectively are the common and famous examples of sp^2 hybridization [9]. The new generation of carbon family behave the same hybridization but showed variant in physical and chemical properties as presented in Figure (1-2) [4, 10].

Moreover, the isolated atoms of carbon having four valance electrons in outer orbits 2p and 2s is shown in Figure (1-3) [11]. The graphene structure comprises unite hexagonal carbon atoms as presented in Figure (1-4a) and Figure (1-4b) which reported the four orbitals mixture forming with each ether new orientations paving for the new physiochemical properties [12].

The three σ bonds amongst carbon atoms are formed because of the hybridization of sp^2 while being positioned inside the plane, whereas the π bonds which are out the graphene sheet's plane are responsible for many physical properties. Hybridization sp^2 performs are crucial role in alternating chemical and physical carbon materials' properties in classic and advance classifications, because of the process of re-hybridization, surface curvature and containment of π and σ bonds [12, 13].

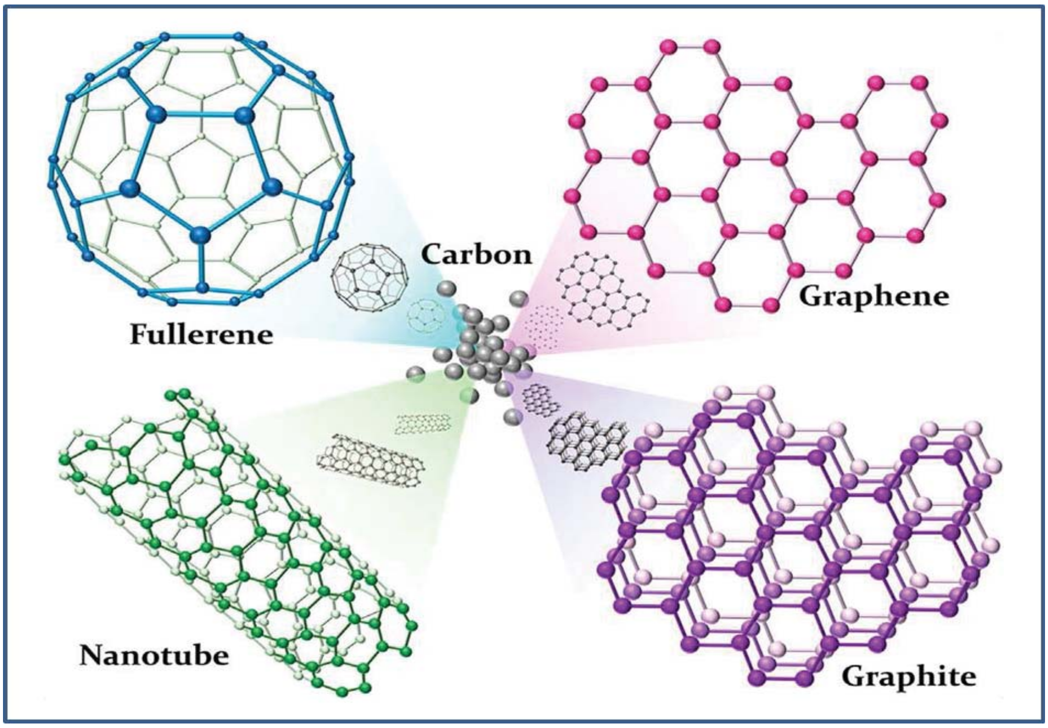

Fig.(1-1): Carbon allotropes in four different crystallographic structures [9].

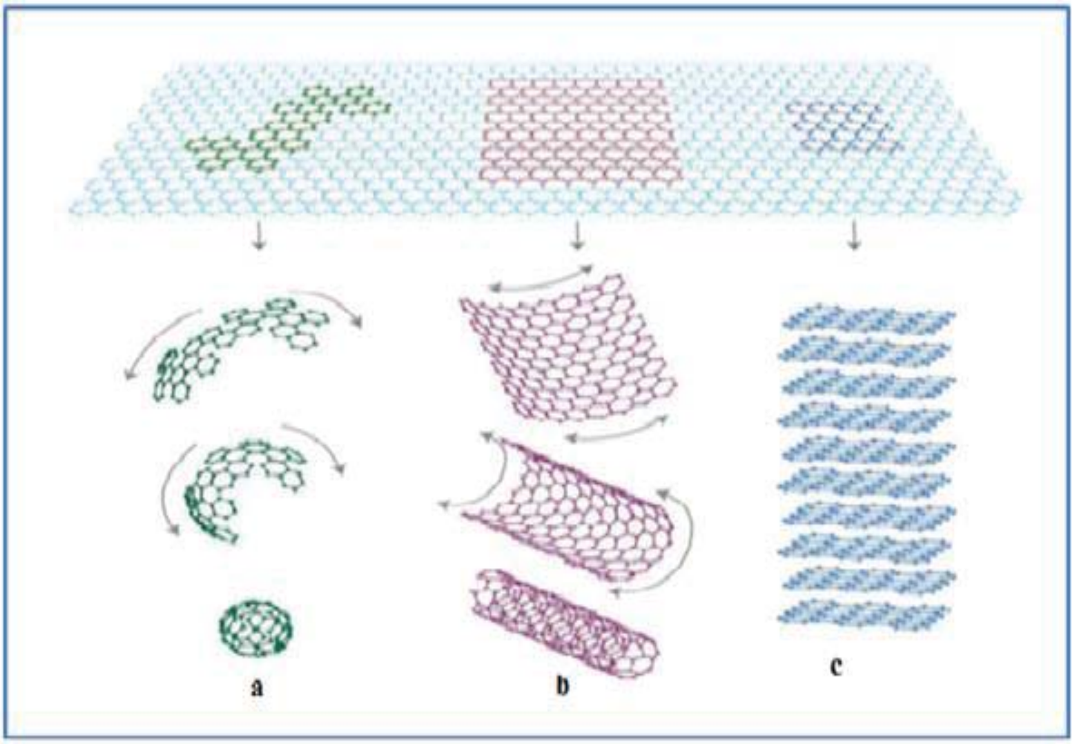

Fig.(1-2): a. a fullerene , b. a carbon nanotube, c. graphene [10].

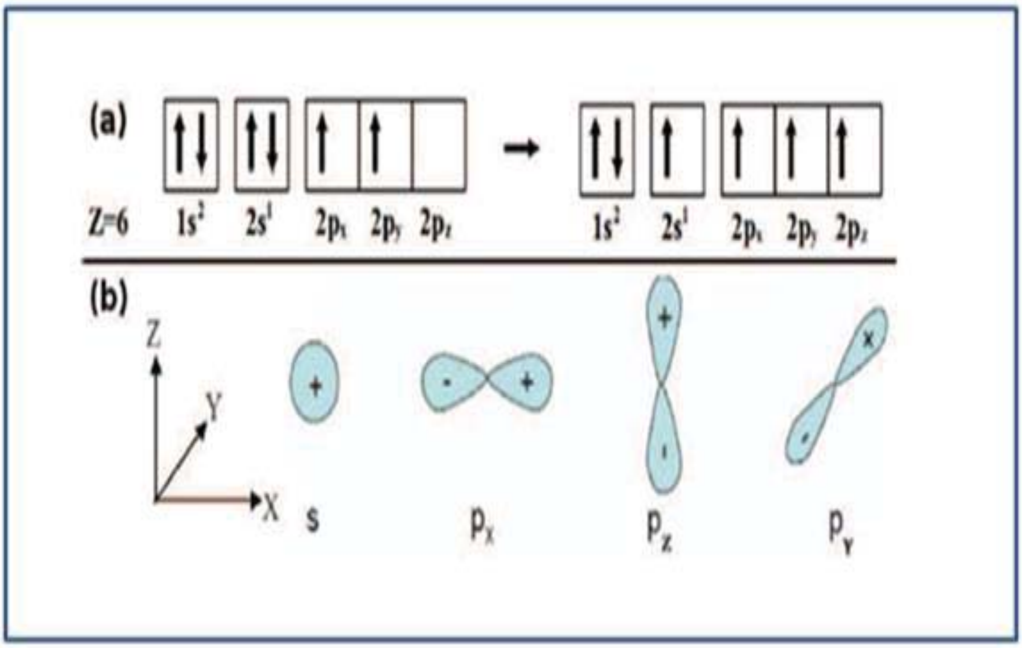

Fig.(1-3): a. Electronic configuration of a carbon atom ,
b. Representation of its atomic orbitals [11].

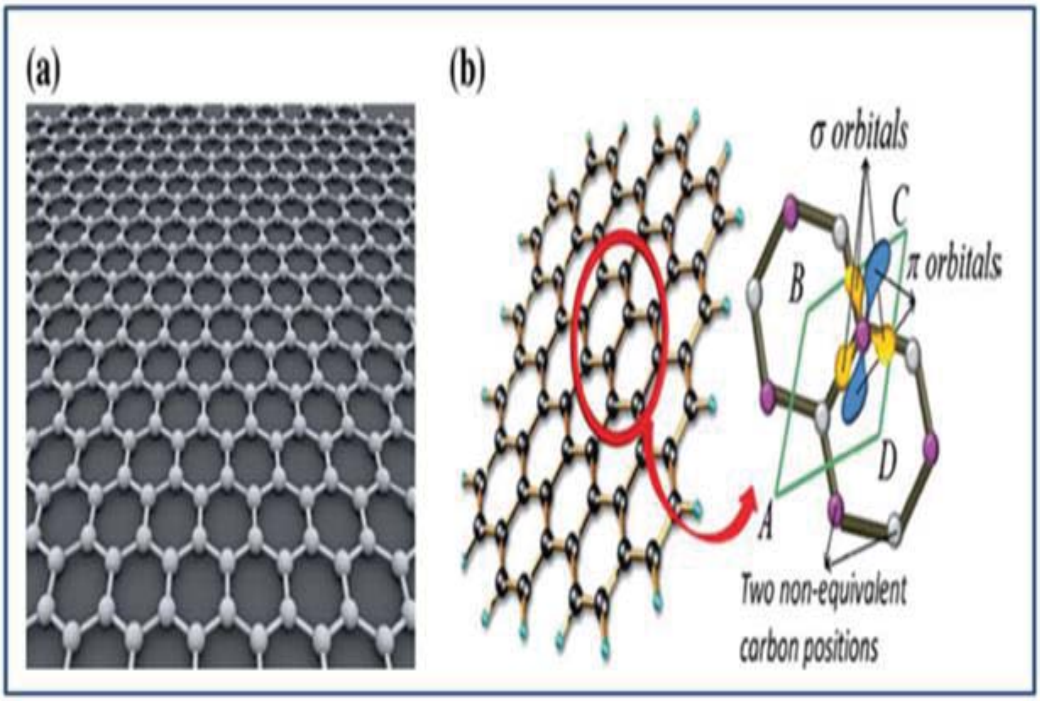

Fig.(1-4): Basic a hexagonal and orbital structure of graphene [12].

1.3. Strategy of synthesized Carbon Nanotubes

The methods of synthesis generally include, Laser Ablation, Arc-discharge and deposition of chemical vapors are utmost significant techniques utilized for the carbon nanotubes production. This section describes the elaborative carbon nanotubes' significance. Carbon nanotubes are not impurities of their size and type depending on the type of technique used to produce it. The techniques listed below produce carbon nanotubes in the form of powders containing small parts of the impurities, and other carbonaceous particles as well for example, amorphous carbon, nano-crystalline graphite, fullerenes & various metals normally, Ni, Co, Fe and Mo were presented in form of crystals throughout the synthesis process.

1.3.1. Arc-discharge method

To obtain CNTs with a few structural defects using the arc discharge method are produced by arc discharge using very high temperatures (above 1700°C). This method contains a reactor with high voltage، two graphite electrodes, a water cooled trap and a vacuum chamber of stainless steel. Moreover, the initial step is Arc discharge for recognition and production of CNTs Figure (1-5).

The principle of action is to evaporate carbon rod was separated by a distance of 1 mm, which is contained inside a container with inert gas at low pressure will lead to creating of a direct current at 50-100 A, causing the arc-discharge at high temperature between the poles. The use of hydrogen gas instead of inert gases such as (Ar ,He) is better to obtaining MWCNTs [14] .

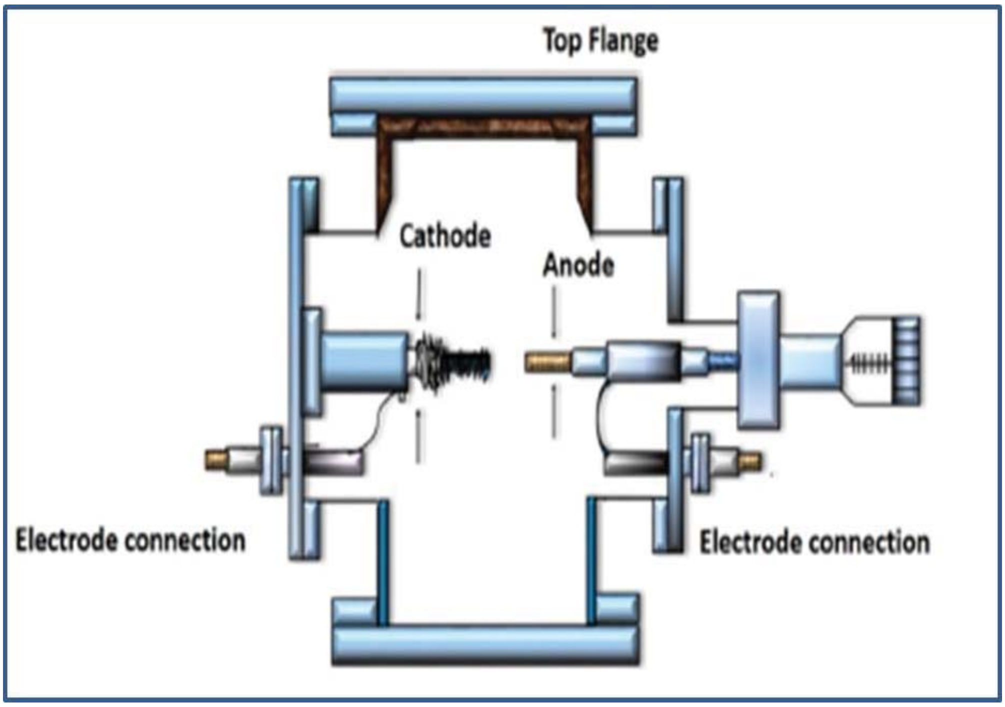

Fig.(1-5): Schematic diagram showing the arc discharge method [15].

1.3.2. Laser ablation method

The CNTs utilizing laser ablation was initially testified by Guo et al. (1995). Such method was an encouraging way for the MWCNT and SWCNT production. Figure (1-6) represents a schematic diagram of laser ablation. Further, this method's graphite target is vaporized by pulsed laser in a reactor of high temperature with an inflow of inert gas into the respective chamber. The inclusion of water cooled surface in the system assist in forming the nanotubes. Furthermore, Richard Smalley & co-workers utilized a graphite composite and particles of metal catalysts as well (the finest harvest was made from nickel mixture and cobalt) for the synthesis SWCNTs. Generally, this is more exclusive in comparison to the chemical vapor deposition and arc discharge[14].

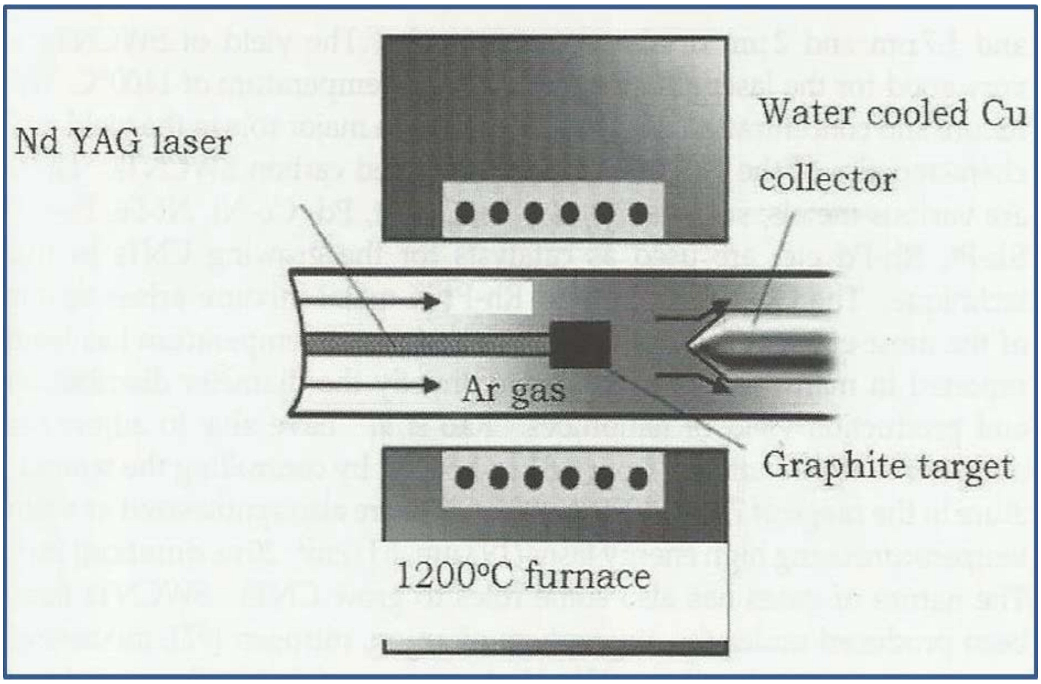

Fig.(1-6): Schematic of laser ablation [14].

1.3.3. Chemical vapor deposition CVD

This technique is able to control the direction of growth on substrate and huge quantity of nanotube production as well [16]. The above mentioned techniques presented two intricate problems for example, the understanding of both the ordered synthesis and large scale production [17]. The CVD is extensive and finest method used in the synthesis of CNTs . The CVD's method required tube furnace with tube quartz, sources of carbon such as: acetylene, methane or ethylene and gas flow to carry the steam particles into the chamber shown in Figure(1-7).

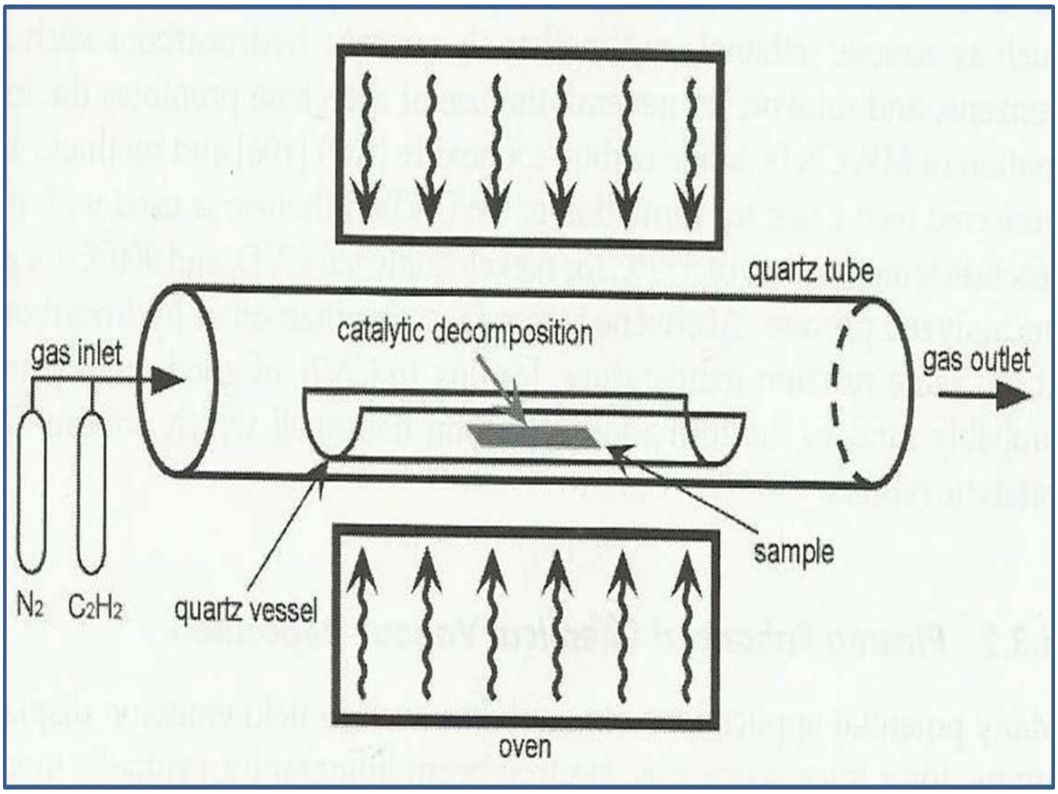

Fig.(1-7): Schematic of thermal CVD [14].

There are two basic steps: First, the catalyst، is a metal particle such as ferrocene and others, prepared in several ways such as (PVD: physical vapor deposition, sputtering and dip coating etc.). In the secondary step, the substance is heated up in a gaseous environment which is rich in carbon. Furthermore, the decayed carbons are immersed in catalyst through diffusion transformed for CNTs. Comparing with two methods, CVD is considered as a common economic technique for CNTs production at comparatively ambient pressure, low temperature but then at the crystallinity cost.

Being adaptable procedure, the hydrocarbon's in gas, solid and liquid state while enabling the usage of several substrates and allowing the growth of CNT in different forms .The forms may entangled or aligned, thick or thin films, coiled or straight or even an anticipated nanotube's construction at already defined sites on a patterned substrate. The two major advantages of this procedure, attainment of nanotubes is done at greatly less temperature though at lower quality. The catalyst can be placed over a substrate that permitted the CNTs for adoption of well-disciplined structures[14] .The carbon nanotube growth method is complex and still unclear and would be elaborated in the next section in detail.

1.3.4. Mechanism of Growth CNTs into CVD

The nature of CNTs surface influence the properties due to growth many groups such branches or outside the wall like distortion which causing change in hybridization of carbon groups from sp to sp^2. Some of changes or distortions were favored in some applications while another applications had to used specific types of CNTs [18]. As mentions before many attempts were done towards prepare a specific type by choose the method and the conditions of precipitation which mostly succeeded to make control for preparation.

The control may preparation done by many parameters such as flow rate of gas, temperature of precipitation and carrier gas. All the parameters influence in degradation of carbon source and the nature of building free radicals. This section includes an explanation of the supposed growth mechanism of carbon nanotubes to understand the ways of forming tubular structure.

Generally the mechanism depend on tow conditions temperature of dissociation and temperature of precipitation. The process include two reactions. The first decomposed of hydrocarbons than emits heat into the catalyst while the second, condensation or precipitation the carbon fragments which deposited process that emits heat [19]. The most reported literatures concerned with two properties for growth which are Tip and Base Growth, as represent in Figure(1-8). From Figure(1-8a) shows the tip probabilities, when the catalyst has a sharp contact angle or week interactions with the substrate, causing move the catalyst on the tubes and that limited from growth large filaments. When the catalyst is connected at obtuse angle having a substrate or communication amongst strongest support and catalyst, that causing note in this pattern the failure of the carbon nanotube in pushing the catalyst to the top as shown in Figure (1-8b) [20, 21].

Mostly, this type accrues when the lack of interaction of carbon with the substrate, which leads to the avoidance of it and take carbon nanotube for the catalyst as a base for the growth of roots with more length as compare with tip growth. The greatest suitable growth molecular model of CNTs depend on forming intermediates free radical fragment refers to the progress round a point of fixed center [22]. The conjugation with sp2 carbon atoms hybridization is accountable to increase a stabilized and building tubular structures for mono or poly sheets of free radicals which produced under the high temperature [23]. Mostly the nature of sp2 hybridization which characterized by π bonding responsible to forming dio trio or multi-layers of CNTs.

The decomposition or degradation for the sources of carbon such hydrocarbon materials CxHyOz produce carbon fragments of free radicals as shown below:

$$\text{Hh Cc Oo} + \text{heat} \rightarrow \text{c C}^* + \text{h H}^* + \text{o O}^* \text{ ----------------- (1-1)}$$

The primary fragments carbon free radicals C* which may mono or dio or more species of free radical [24].

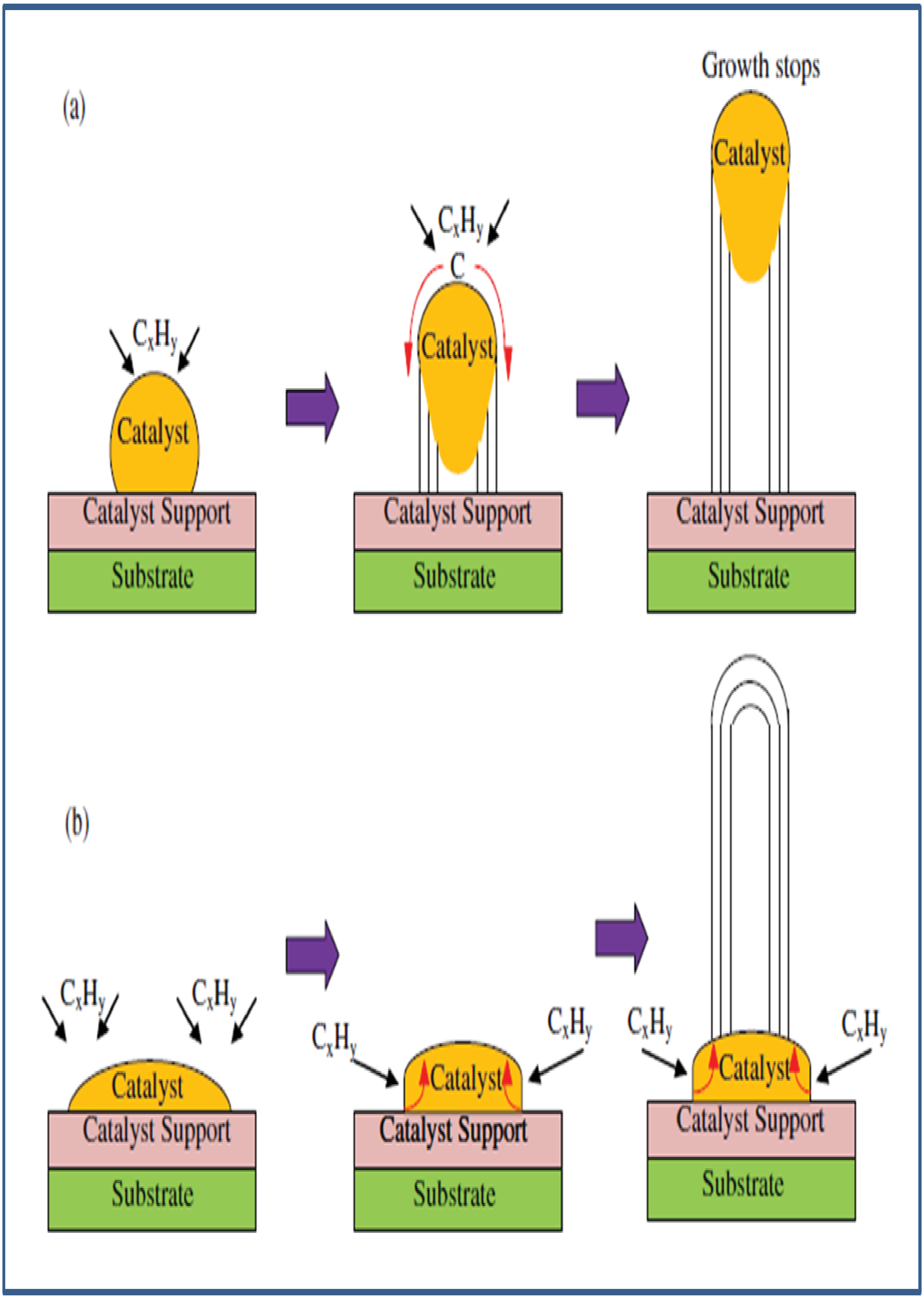

Fig.(1-8): Schematic representation of the two typical CNT growth modes, (a) tip growth mode and (b) base growth mode CNT [21].

1.4. Literature Review of CNT

In 2009, S. Esconjauregui et al., were synthesized CNTs and various other Nano morphologies of carbon while utilizing “atypical” (Pt, Pd, Al, Mg, In, Na, Cs, W, K, Ni3C, Ir, Mn, Ti and Mo) and “typical” (Fe, Co and Ni) catalysts by chemical vapor deposition. The metal’s catalytic activity intensely relies upon its electronic structure [25].

In 2009, M. Bystrzejewski et al., they studied in detail the synthesis of carbon nanotubes by CVD using eight aliphatic alcohols (methanol to decanol). it was found that the pyrolysis of alcohols comprised one to six carbon atoms in chain resulted in products containing single- and multi-walled nanotubes. Pyrolysis of C6–C10 alcohols yielded multi-walled nanotubes and carbon encapsulates filled with catalyst particles. The results show that CNTs can be synthesized in high yield from low-cost starting materials and by using simple CVD techniques [26].

In 2010, A. Szabó et al., they discussed the main three methods of synthesis are; the chemical vapor deposition (CVD), laser ablation and arc discharge. Thus, the outcomes of several methods indicated in this review appears the CVD method as finest one for the MWNTs’ production on larger scale [27].

In 2010, J. Sengupta et al., studied the influence of Ni and Fe catalyst’s synthesis on the CNTs at (APCVD) atmospheric pressure chemical vapor deposition. expermantly Fe as catalyst was show best graphitization degree for CNT structure. Moreover, the mechanism of tip growth mostly causes the growth of CNTs along with Ni and Fe catalysts. The Ni-CNT was observed to be bamboo like, however, Fe-CNT emerged as metal filled straight tubes [28].

In 2011, A. Firouzi et al., succeed to synthesized CNTs is carried out on quartz substrate through (FC-CVD) at the temperature of 950°C while utilizing the gas of methane at 150 (SCCM) flow rate and applied as gas sensors. After this, the measurement of CNT's electrical resistance is done by sensor exposure to the concentrations of CH_4 and CO_2 while functioning at the room temperature. Outcomes showed that sensors vastly responded to the molecules of gases [29].

In 2011, **Abu-Abdeen, Mohammad, and Abdu Aljaafari** , synthesized CNTs using the ACCVD method is per-formed as a function of growth temperature and at constant growth time, alcohol flow rate, catalyst concentration and carbon source. Mixture of multi-walled carbon nanotubes and carbon nanopowder is achieved at a growth temperature of 700°C. Bundles of single walled carbon nanotubes with a little multi-walled ones are grown at 800°C. A majority of multi-walled nanotubes and little bundles of single walled CNTs are grown at temperature of 900°C [30].

In 2012, A.Aqel et al., discussed Carbon nanotubes in terms of history, types, structure, synthesis and characterisation methods Carbon nanotubes have attracted the fancy of many scientists worldwide .Carbon nanotubes have attracted the fancy of many scientists worldwide [31].

In 2012, M. Lubej et al., discussed the CVD method for the synthesis of carbon nanotubes, and has reviewed some theories and simulations that have been put forward to model these processes. It seems that progress is being made in simulating the nucleation, growth and termination mechanisms involved. Although the simulations of carbon nanotube synthesis differ in several respects, it appears that the main elements applied in simulations are similar. For better and more accurate numerical simulations of carbon nanotubes synthesis based on the transport and kinetics in the chemical vapor deposition reactor, a simpler system [32].

In 2013, D. Lukowiec et al., prepared MWCNT's by CVD on the substrate of silicon while comprising a catalyst having two layers of buffers and a thin film at 750°C temperature utilizing (C_2H_4) as a source of carbon for 45 min. they have confirmed the homogeneity, high quality and purity of the manufactured carbon nanotubes [33].

In 2013, E. G. Ordoñez-Casanova et al., used technique of spray pyrolysis, ferrocene as catalyst whereas, aliphatic alcohols such as butanol, ethanol, propanol and methanol are used as a source of carbon. Thus, this research of synthesized carbon Nanotubes illustrated significant variances in Nanotubes forming layers' number, quality & quantity as well as length diameter as per function of carbon numbers used in alcohols [34].

In 2013, **Khorrami, S. A. and R. Lotfi**, reported that TCVD were grown CNTs on copper catalyst with using H_2 and N_2 mixture. The results with TCVD were shown different morphologies when using different value of flow rate for carrier gas. The amounts of deposited carbon and length were decrease with increasing flow rates [35].

In 2014, R. Purohita et al. , have successfully minimized the distribution diameter of SWCNTs up to an approximate degree. They developed suitable separation processes to separate the CNTs to the semiconducting or metallic nanotubes of precise chirality. The 3 to 6 walled thin FWCNTs production is an excellent choice in comparison with thick MWCNTs, using CVD, arc-discharge and ablation laser [14].

In 2015, Y. Li et al., have successfully synthesized VACNT arrays with a rapid growth rate by ethanol-assisted CVD method using a two zone growth strategy, separating carbon feedstock pyrolysis and CNT deposition. The use of ethanol as an additive in the reaction environment, the use of two temperature zones, and the uniformity of catalyst nanoparticles were important factors contributing to the sustained and efficient growth of VACNT arrays. Both 0.8-nm- and 3-nm-thick Fe catalyst films worked well for the production of VACNT and forests of 7 mm in height could be easily obtained within 45 min [36].

In 2015, R. Sharma1 et al., manufactured MWCNT by CVD decomposition and arc discharge. The synthesis of multi-walled CNTs is done on the thin nickel film popped on a substrate of silicon with the help of de-positioning of acetylene's thermal chemical vapors at 750℃ temperature. Moreover, the arc manufactured CNTs are categorized by scanning electron microscopy (SEM), X-ray diffraction (XRD) and transmission electron microscopy (TEM). The comparison of outcomes with grown nanotubes is carried out with the process of chemical vapor deposition [37].

In 2015, F. G. Granados-Martínez et al., produced the CNTs by CVD from hexane, butanol, ethyl acetate and diethyl ether. For the altered precursors, the temperature range for the synthesis of CNTs was observed to be of 680-850 °C. However, the diameter of CNTs from butanol was 55-230 nm, ethyl acetate was 100-300nm, diethyl ether's was 45-200 nm, while hexane range from50-130nm. The content of carbon for all samples was observed to be greater 93% and carbon nanotubes from butanol indicated 99% of carbon continent [38].

In 2016, Pandey, P. and Dahiya, M., presented several interesting properties, such as high aspect-ratio, ultra-light weight, strength, high thermal conductivity and electronic properties ranging from metallic to semiconducting. The production of carbon nanotubes can be done by plasma based synthesis method or arc discharge evaporation method, laser ablation method, thermal synthesis process, chemical vapor deposition and by plasma-enhanced chemical vapor deposition. The CNTs are valuable in the field of drug delivery, blood cancer, breast cancer, brain cancer, liver cancer, cervical cancer, gene therapy**.** This review leads to a useful knowledge related to general overview, types, preparation methods and applications of CNTs. [39].

In 2017, F. Abdulrazzak et al., synthesized FWCNTs using homemade movable tube furnace reactor through chemical vapor deposition at 450°C and 750°C . The mixture of propanol and methanol is used as a carbon source on the caver of silica surface. This process prospered to create FWNT 450°C that had greater surface area and larger active site as compared to the FWCNT 750°C in the properties of adsorption [40].

In 2017, N. Tripathi et al., used a plant derivative green catalyst which is an inexpensive synthesized for multi-walled carbon nanotubes' synthesis. The noteworthy points of this growth should be stated as: (1) all the grown CNTs are devoid of lethal metal catalysts (2) the essential lower temperature of growth (575°C) is prerequisite and manufactured high crop in relation to other catalysts utilized is being testified [41].

In 2017, Mirabootalebi, S. O. and Akbari, G. , Among of the main methods for synthesizing carbon nanotubes, CVD due to simplicity, controllable mechanism, high ability for synthesizing aligned CNT, variety modified types for producing different kind of CNT, high efficiency close to 100% and suitable for mass producing; is the most attractive way for synthesis of carbon nanotubes. Laser ablation and Arc discharge are common method for synthesis CNT that both of them are not suitable for mass production, besides that; quality of yields in arc discharge is low. The problem of mass production also exists for electrolysis, and this method used in laboratory scale. In mechanic thermal despite simplicity and large scale of production, not continuous and process is very slow [42].

In 2018, Y. M. Manawi et al., summarized the numerous CNTs synthesis through the method of (CVD). The carbon nanomaterials comprised of graphene, carbon Nano-onion (CNO), carbon nanotubes (CNTs), carbide derived carbon (CDC) and carbon nanofibers (CNF). Additionally, the recent challenges in the nanomaterial's application and synthesis are emphasized with recommended areas for forthcoming investigations [43].

1n 2018, Ameneh A. et al., they using CVD to grow CNTs at a large scale under different condition .The flow rates of 1500 sccm of Ar and 40-45 sccm of acetylene at 750°C were the optimal conditions for large scale production of nearly pure CNTs [44].

In 2019, S. Shukrullah et al., studied the production of multi-walled CNT bundles by Fe_2O_3 catalyst supported by alumina with the aid of FC-CVD technique which is floating catalyst chemical vapor deposition. The molecules of ethylene were decayed in a reactor of FC-CVD for various quantities of metal nanoparticles [45].

In 2020, **Liyu Dong et al.,** were synthesized Double-walled carbon nanotubes and continuously collected using FC-CVD method , they included de-ionized water in the catalyst system, which achieved a more uniform and controlled distribution for efficient DWCNT production. Using a water-assisted FC-CVD process with optimized conditions, a transition from multi- to double-walled CNTs was observed with a decrease in diameters from 19–23nm to 10–15nm [46].

1.5. Aim of the Research

The objectives of this work include the following items:

1- Synthesis and identification with physical studies for synthesis CNTs from alcohol mixture in CVD.
2- Find the best ratios of methanol/Butanol to prepare the best quantities and qualities of CNTs.
3- Using synthesized CNTs in two applications solar cell and gas sensor .
4- Trying to reach the best sensitivity for synthesis CNTs by changing the ratios of precursor Methanol and Butanol.
5- Starting the broad strategy to synthesis and enhance the physio-chemical properties of CNTs to use it in many applications with best results.