SYNTHESIS, CHARACTERIZATION OF CARBON NANOTUBES AND ITS PROPERTIESE

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IN

PHYSICAL CHEMISTRY

Department of chemistry

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Year 2014

CERTIFICATE

This is to certify that **MOHD.AMISH KHAN** a student of **M. Sc (Chemistry) Ro. No.- 140022480012** has worked towards him M.Sc. dissertation entitled **"** ***Synthesis , Characterization of carbon Nanotube and its properties*** **"** an authentic work carried out by him at Department of Chemistry Kisan Post Graduate College Bahraich, under my supervision **Dr. P. N. Tripathi** and this work is not submitted elsewhere for a degree.

Dated……………….

Place…………………..

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Mohd. Amish Khan

Date…………..
Place…………..

DECLARATION

I have declare that the submission of the M.Sc. (Chemistry) dissertation is my own work and that to be best of my knowledge and belief. This dissertation contain matters neither previously published/written by another person nor a substantial extent has been accepted for the award of other degree of the University/institute.

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I DEDICATE

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MY GRAND

MATERNAL FATHER

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ABSTRACT

In the present work, I have tried to understand the Nanoscience, nanoparticles, synthesis of Carban Nanotube, Characterization and main focus on Propertise and application of Carban Nanotube. I described three method of preparation of Carbon Nanotube. I tried to characterized by SEM, TEM, AFM & Raman spectroscopy. I tried to understand the properties of Carbon Nanotube with application. So this present work is devoted towards preparation and characterization of Carbon Nanotube and its application.

ABBREVIATION

Techniques;

- **SEM :** Scanning electron microscope
- **TEM :** Transmuted electron microscope
- **STM :** Scanning tunneling microscope
- **AFM :** Atomic force microscope
- **XRD :** X – Ray diffraction
- **UV- Visible :** Ultra violate – Visible spectrophotometer
- **NMR :** Nuclear magnetic resonance
- **FTIR :** Fourier transform infrared spectroscope
- **DLS :** Dynamic light scattering
- **OM:** Optical microscopy
- **TGA:** Thermogravimetric analysis
- **LTM :**Laser transmission measurement
- **MDSC:** Modulated differential scanning calorimetric analysis
- **MS :**Mass spectroscopy
- **MTGA:** Modulated thermo-gravimetric-analysis

Units;

- **nm :** Nanometer
- **ns :** Nanosecond
- **nl :** Nanoleter
- **ng :** Nanogram
- **µm :** Micrometer
- **µL :** Microleter
- **mV :** Mili volt
- **rpm :** Rotation per Minute
- **min :** Minutes
- **Hrs :** Hours
- **Å :** Angstrom

Roman letter symbols

- **Af :** Absorption fraction
- **C:** Speed of light (m s-1)
- **CpL :** Water's specific heat (J kg-1 K-1)
- **E:** Electron charge (C)
- **H :** Planck’s constant (J s-1)
- **hLG :** Water’s latent heat of vaporization (J kg-1)
- **K :** Wave vector
- **kB:** Boltzmann constant (J atom-1 K-1)
- **me :** Electron mass (kg)
- **P :** Power (W)
- **q :** Momentum (kg m s-1)
- **rnuc :** Nucleation radius (m)
- **Rf :** Reflection fraction
- **Tf :** Transmission fraction
- **V :** Volume (m3)
- **ve :** Electron velocity (m s-1)
- **X :** Thermal diffusivity (m2 s-1)

SWNT : Single walled carbon nanotube
CNT : Carbon nanotube
1D : One dimensional
DEP: Di-electrophoresis
CVD: Chemical vapour deposition
MR: Magneto-resistance
R-T : Resistance against Temperature
I-V : Current against Voltage
FL : Fermi Liquid
CB: Coulomb blockade
DMF: Dimethyl formamide
CB: Carbon black
CNF : Carbon nanofibres
SAXS: Small angle X-ray scattering
BCNT: Ball-milled multiwall carbon nanotubes
CVD : Chemical vapour deposition
DoE: Design of experiments
DoS ; Density of state
DWNT : Double-wall carbon nanotubes
FCA ; Free carrier absorption
HBCNT : Ball milled and then heat treated multiwall carbon nanotubes
HCNT : Heat treated carbon nanotubes
MFB : Minimum film boiling
MWCNTs : Multiwall carbon nanotubes
NIR : Near Infrared
SWNTs: Single wall carbon nanotubes

CONTENTS

This dissertation consists of the following contents:-

TABLE OFCONTENT

LIST OF FIGURE

LIST OF TABLES

CHAPTER 1

1.1INTRODUCTION OF NANOSCIENCE & TECHNOLOGY:-

One of the historically important observations on the size dependent properties of materials came from the great scientist of 19th century. Many decades later in (1926) the first laboratory test proof on the size dependency of electronics properties of semiconductor had been published. Although nanotechnology is a relatively recent development in scientific research ,the development of its central concepts happened over a longer period of time .The emergence of nanotechnology in the 1980s was caused by the convergence of experimental advances such as the invention of the scanning tunneling microscope in 1981 and the discovery of fullerenes in 1985,with the elucidation and popularization of a conceptual framework for the goals of nanotechnology begging with the 1986 publication of the book Engines of Creation. The field was subjected to growing public awareness and controversy in the early 2000s, with prominent debates about both its potential implication as well as feasibility of the applications envisioned by advocates of molecular nanotechnology. [1] In 1981 they were the first to see atoms and hence make nanotechnology a possibility .Scientist were soon able to pick up and move atom to build structures. Originally the term nanotechnology was restricted to these original experiments, which held no immediate practical use. However, as soon as the significance of the discovery was appreciated, interest increased, and the term has been more broadly used nanometer level. In recognition with this reality National Science and Technology Council (NSTC) of USA created an integration working group on Nanoscience, engineering and technology 1998th. Then in the year 2001 announced the National Nanotechnology Initiative (NNI) programme with a large amount of fund in the budgetary provision. [2]

Nanoscience understands of matter at atomic and molecular scale as well as the development of device that have a size of only few nanometers (~10^{-9}metre). The real move towards the use of Nanoparticles and the study of modern nanotechnology did not occur until the early 20th century with the production of carbon black and subsequently fumed silica in 1940s. Nanotechnology was first used to describe the extension of traditional silicon machining down into Taniguchi of Japan in 1974. [3] Richard Feynman discussed the possibility of manipulating and controlling things on a molecular scale in order to achieve electronic and mechanical system with atomic sized components.

"Nanoscience is an emerging area of science which concerns itself with the study of materials that have very small size dimensions, in the range of Nano scale. The word itself is a combination of Nano from the Greek "nanos "(or Latin"nanus") meaning "dwarf" and word "Science" meaning knowledge ".It is an interdisciplinary field that seeks to bring about mature nanotechnology, focusing on the nano scale intersection of fields such as Physics, Chemistry, Engineering computer science and more. [4] Nanoscience is interesting in part of lesson because it by definition is new. But a more profound and important reason is that it deals with objects which are only slightly larger than an atom. This means that the properties of Nanoscience the objects can be influenced by direct manifestation of quantum mechanics. It is also possible that Nanoscale objects do behave just like as expected from (semi) classical physics, but the downgrading in size opens up possible new applications. In order to understand the meaning of Nanoelectronics, it is useful to fracture the word into components. The first half of the word Nano refers to the size of something, in particular something very small. [5]

1.2 Micro to Nano range:-

A micrometer, also called a micron, is one thousand times smaller than millimeter. It is equal to 1/1,000,000th (or one millionth of meter). Things on this scale usually can't be seen with your eyes. The diameter of a hair, which is 40-50 microns wide, is very hard to discern without the use of a magnifying glass. A magnifying glass will help you see a dust mite. Dust mites are usually around 400 microns long.

A nanometer (nm) is 1,000 times smaller than a micrometer. It is equal to 1/1,000,000,000th or one-billionth of a meter. When things are this small, you can't see them with your eyes, or a light microscope. Small objects require a special tool called a scanning probe microscope. Things on the nanometer scale include: Virus (30-50 nm), DNA (2.5 nm), bucky balls (~1 nm in diameter), CNT (~1 nm in diameter).Here are some other everyday objects measured in nanometers: One inch equals 25.4 million nanometers.

A sheet of paper is about 100,000 nanometers thick. A human hair measures roughly 50,000 to 100,000 nanometers in diameter. In two dimensions we could stack about 250,000 components in the same space as a red blood cell. If we add the third dimension that could translate into 65,536,000,000,000,000 components. Intel will be manufacture devices by 2007 will feature size about 20 nm across. Your fingernails grow one nanometer every second.

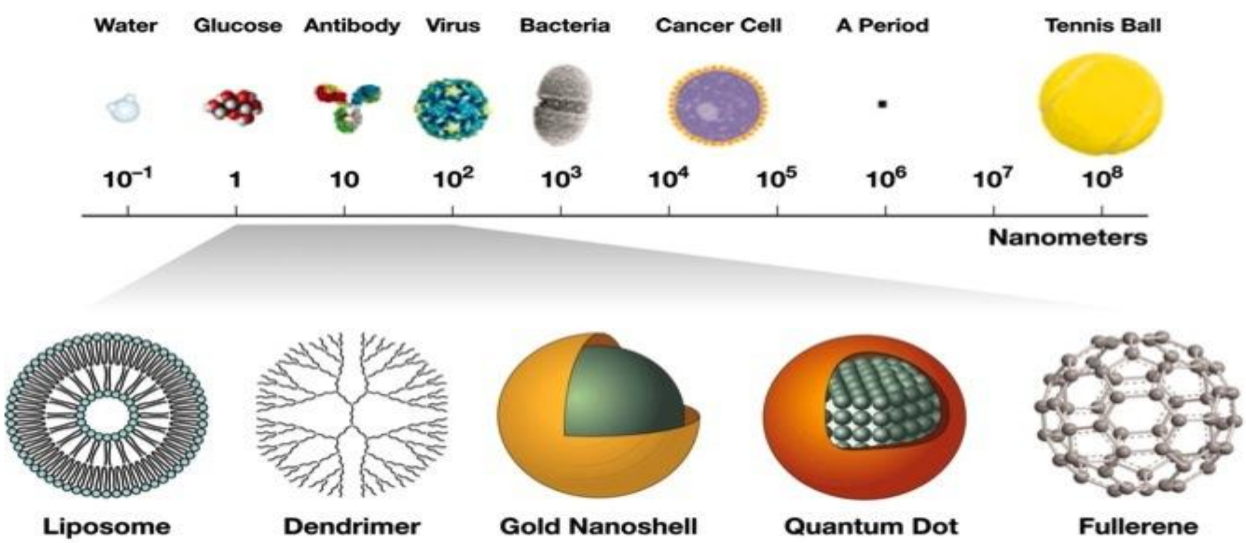


Figure 1.1: Nanoscale

A fascinating and powerful result of the quantum effects of the Nanoscale is the concept of "tunability" of properties. That is, by changing the size of the particle, a scientist can literally fine-tune a material property of interest (e.g., changing fluorescence color; in turn, the fluorescence color of a particle can be used to identify the particle, and various materials can be "labeled" with fluorescent markers for various purposes). Another potent quantum effect of the Nanoscale is known as “tunneling,” which is a phenomenon that enables the scanning tunneling microscope and flash memory for computing. [6]

1.3 Nanoscience & Nanotechnology:-

The most common working definition of Nanoscience & Nanotechnology is the following:-

"Nanoscience is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales where properties differ significantly from those at larger scales."Nanotechnology is the design characterization, production and application of structure devices and systems by controlling shape and size at nanometer scale” Nanoscience is the study of phenomenon on a nanometer scale. Atoms are a few tenths of a nanometer in diameters in size .Typically Nano means 10^{-9} .So a nanometer is one billionth of a meter and is the unit of length that is generally most appropriate for describing the size of molecule. Nanometer objects are too small to be not seen with naked eye. Anyhow the rough definition of Nanoscience could be anything which has at least one dimension less than 100nm.

The nanometer scale is conventionally defined as 1 to 100nm.One nanometer is one billionth of a meter (10^{-9}m).The size range is set normally to be minimum 1nm to void single atoms or very small group of atoms being designated as Nano-objects. Therefore Nanoscience and technology deal with at least clusters of atoms of 1nm size. The upper limit is normally 100nm, but this is a "fluid" limit, often objects with greater dimension (even 200nm) are defined as Nanomaterials. [7]

1.4 Nanoparticles& Nanomaterioals:-

1.4-1 Nanoparticles:-

A particle having one or more dimension of the order of 100nm or less. There is no strict dividing line between Nanoparticles. In fact the size at which material display amazingly different properties to the bulk material is the size of Nanoparticles. Nanoparticles are further classified according to their size. In terms of diameter ultrafine particles or Nanoparticles can be define as a chunk of matter whose physical dimension lie in the range of few nanometer to few hundred nanometer and which exhibit solid like properties. Nanoparticles are the simplest form of structures with sizes in the nm range. In principle any collection of atoms bonded together with a structural radius of <100 nm can be considered a Nanoparticle. These can include, e.g., fullerenes, metal clusters (agglomerates of metal atoms), large molecules, such as proteins, and even hydrogen-bonded assemblies of water molecules, which exist in water at Ambient temperatures. Nanoparticles have common in nature – for instance proteins exist in almost all biological systems, metal-oxide Nanoparticles are easily produced, etc. Nanotechnology is the science that deals with matter at the scale of 1 billionth of a meter (i.e., 10^{-9} m = 1 nm), and is also the study of manipulating matter at the atomic and molecular scale. Nanoparticle is the most fundamental component in the fabrication of a nanostructure, and is far smaller than the world of everyday objects that are described by Newton's laws of motion, but bigger than an atom or a simple molecule that are governed by quantum mechanics .In general, the size of a Nanoparticle spans the range between 1 and 100 nm. Metallic Nanoparticles have different physical and chemical properties from bulk metals (e.g., lower melting points, higher specific surface areas, specific optical properties, mechanical strengths, and specific magnetizations), properties that might prove attractive in various industrial applications. [8]

1.4-2 The different field of Nanoparticle:-

Quantumdots, Nanocluster, Liposomes, FunctionalizedNPs, IronoxideNPs, Ag, Fe, Al, Bi, Mo, Nanoparticle, Carbonnanotube, GoldNPs, PolymerNPs, Dendrimers, Micro and Nanobubbles, Upconverting NPs, Iron, platinum NPs, Nanodevices, Nanotransisters, Nanocell, Nanocapsules, Nanoforum, Nanosphere, Nanofibers, Nanoribbon, Nanopipette, Nanowires, Nanobds, Nanohorn, Nanospring, Nanoneedles, Nanoarray, Nanobelts, Nanopolymers, Nanobomb, Nanofluids, Nanocompopsits Nanocontilever, Nanoplates, Nanoceramics, Nanochannels, anosensors, Nancages , Nanobeam, Nanobots, Nanoshell, Nanosim etc.

1.4-3 Nanomaterials:-

A Nanomaterials is an object that has at least one dimension in the nanometer scale (approximately 1 to 100nm .Inorganic, Organic and Biological materials can be prepared in Nanorange. In other word **"Any material manipulated at the scale of nanometer is called Nanomaterials."** Nanomaterials can be inorganic, organic and biological as shown in fig.1.2.

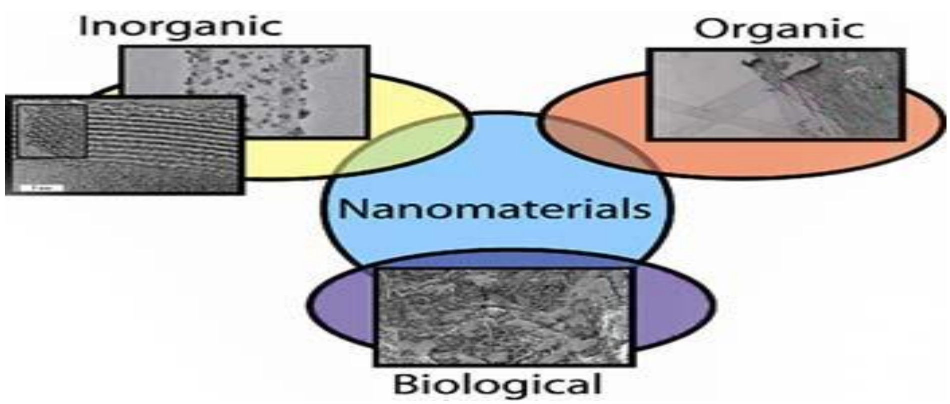


Figure 1.2: Nanomaterials

Nanomaterials can be from made carbon, ceramics, chemical precursors, ferrites, minerals, polymers, semiconductors and silica or silicate. Nanotechnology products are consolidated materials or devices that utilize nanostructure. [9]

1.5 Classification of Nanomaterials:-

Nanomaterials are classified on the bases of their size: Indicated in fig.1.3.

1.5-1) One dimensional Nanomaterials

1.5-2) Two dimensional Nanomaterials

1.5-3) Three or more dimensional Nanomaterials

1.5-1) One Dimension Nanomaterials:-

The ranges of 1D Nanomaterials are 1-100nm.For Example: Thin film, layers and coating etc.

1.5-2) Two Dimension Nanomaterials:-

The ranges of 2D Nanomaterials are 1-100nm.For Example: Nanotubes, Fibers, and Nanowire etc.

1.5-3) Three or more Dimension Nanomaterials:-

The ranges of 3D Nanomaterials are 1-100 nm. For Example: Nanoring, Nanoshell, Quantum dots, Nanoparticles etc. [10]

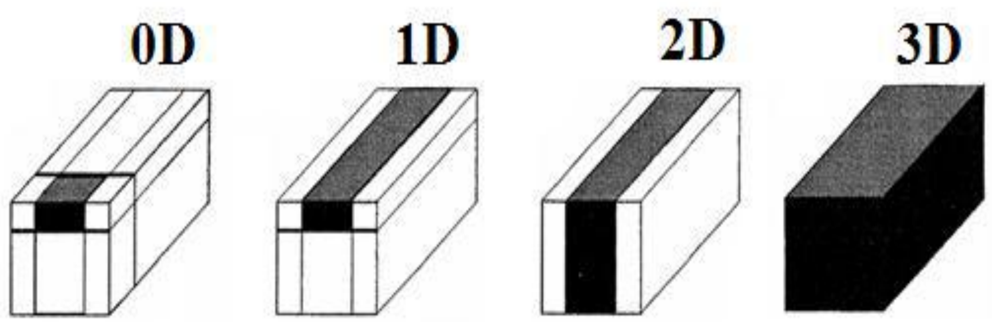


Figure 1.3: Classification of nanomaterial

Table 1.1: Classification of Nanomaterial

Dimension	Example of nanomaterials
0D	Colloids, Nanoparticles, Nanodots, nanoclusters
1D	Nanowires, Nanotubes, Nanobelts, Nanorods
2D	Quantum wells, super lattices, membranes
3D	Nanocomposites, filamentary composites, cellular materials, porous materials, hybrids, Nanocrystal arrays,

1.6 Characterization of Nanoparticles:-

Nanoparticles characterization is essential to establish understanding and control of Nanoparticles synthesis and applications. Characterization is done by using a variety of different techniques, mainly drawn from materials science. Common techniques are Electron microscopy, Transmission electron microscopy (TEM),Scanning electron microscopy (SEM),Atomic force microscopy (AFM),Dynamic light scattering (DLS),X-ray photoelectron spectroscopy (XPS),Powder X-ray diffraction (XRD),Fourier transform infrared spectroscopy (FTIR),Matrix-assisted LASER desorption/ionization, Ultraviolet visible spectroscopy, Dual polarization interferometer and nuclear magnetic resonance (NMR). The theory has been known for over a century, the technology for Nanoparticles tracking analysis (NTA) allows direct tracking of the Brownian motion and this method therefore allows the sizing of individual Nanoparticles in solution.

There is mainly two type's method:

1.6-1) Microscopy Method

(There is various type of microscope TEM, STM, AFM)

1.6-2) Spectroscopy Method(there are various type of spectroscopy X-ray photoelectron spectroscopy ,UV-visible Plasmon absorption and emission ,Plasmon resonance light scattering, Surface-enhanced Raman Scattering ,Non-radioactive and non electron characterization methods)

1.6-1Microscopy:-

An optical microscope uses visible light (i.e., an electromagnetic radiation) and a system of lenses to magnify images of small samples. For this reason it is also called a light microscope. Optical microscopes are the oldest and simplest of the microscope .The resolution limit of an optical microscope is imposed by the wavelength of the visible light. Visible light has wavelength between 400 and 700 nm .The resolving power of an optical microscope is around 0.2 micrometer or 200 micrometer .Thus for objects to be distinguishable; they need to be separated by at least 200nm.

In 1981, a totally new concept of imaging was introduced by Binning and his coworkers from IBM. When the two are placed very close together, but actually touching a bias between the two cannot allow electrons to tunnel through the vacuum between them. This creates a tunneling current which can be measured and which is a function of the electron density on the surface. Electron density is the probability of finding an electron in a particular place. There is high electron density around the atoms and bonds in molecules.

This type of microscope is called Scanning Tunneling Microscope (STM).Variation in current as the probe passes over the surface are translated into images. The STM can create details 3D images of a sample with atomic resolution. This means that the resolution is actually so high that it is possible to see and distinguish individual atoms (0.2 nm = $2*10^{-10}$) on the surface .The invention of the STM earned Binning and his CO-worker Heinrich Roher (at IBM Zurich) the Nobel prize in Physics in 1986.

1.6-2 Spectroscopy Methods:-

Spectroscopy is defined as the branch of science that is concerned with the investigation and measurement of spectra produced when matter interact with or emits electromagnetic (EM) radiation .Depending on the wavelength of the electromagnetic used and the type of interaction with matter that occurs (absorption, scattering, etc.) different spectra are measured from which a lot of information can be inferred.

CHAPTER 2

2.1 CARBON NANO TUBE:-

2.2-1 Discovery of Carbon Nanotube:-

The true identity of the discoverers of carbon Nanotubes is a subject of some controversy. For years, scientists assumed that Sumio Iijima of NEC had discovered carbon Nanotubes in 1991. He published a paper describing his discovery which initiated a flurry of excitement and could be credited by inspiring the many scientists now studying applications of carbon Nanotubes. Though Iijima has been given much of the credit for discovering carbon nanotubes, it turns out that the timeline of carbon Nanotubes goes back much further than 1991. In 1952 L. V. Radushkevich and V. M. Lukyanovich published clear images of 50 nanometer diameter tubes made of carbon in the Soviet Journal of Physical Chemistry. This discovery was largely unnoticed, as the article was published in Russian, and Western scientists' access to Soviet press was limited during the Cold War. Before they came to be known as carbon Nanotubes, in 1976, Morinobu Endo of CNRS observed hollow tubes of rolled up graphite sheets synthesised by a chemical vapour-growth technique. The first specimens observed would later come to be known as single-walled carbon Nanotubes (SWNTs).The three scientists have been the first ones to show images of a Nanotube with a solitary Graphene wall. [11]

In 1991, S. Iijima accidentally observed carbon Nanotubes under a transmission electron microscope. He was actually examining some sample of carbon cluster viz. 'fullerene ' synthesized using electric arc discharge method .Carbon Nanotubes were so less in this sample that as Iijima himself said somewhere that it was like observing 'a needle in a hay stack' .This was followed by some elegant theories predicting the nature of electron and phonon spectra of carbon Nanotubes. Discovery of Nanotubes was a breakthrough in that sense. Iijima's experimental suggested that even a sample set up as used in producing fullerenes should produce Nanotubes under certain conditions. It was quite clear as more and more scientists started reporting the observation of Nanotubes that the conditions flavored for fullerene were unsuitable for producing the Nanotubes.

The potential applications of Nanotubes created a wave of excitement amongst the scientists which lead to unfolding of many unique properties carbon Nanotubes possess. Their potential applications in electronic , optoelectronics and energy saving have been well realized .Just in one decade several groups all over the world have dedicated their research activities to synthesize and analyze the Nanotubes. Following the original deposition method, it was found that chemical vapor deposition, laser ablation and some other methods could be employed to produce carbon Nanotubes. Further it was found that not only carbon but many other materials like ZnO,TiO_2, MoS_2 etc. can have shape of Nanotubes .They have their own applications but carbon Nanotubes still remain the most important ones due to their technological potential.

S. Iijima reported the discovery of new shape for molecules of carbon known as carbon Nanotubes, a new form of carbon, configurationally equivalent to two dimensional grapheme sheet rolled into a cylindrical, just a few nanometer in diameter and several micron long with a length to diameter ratio greater than 1, 00,000.This intriguing structure has sparked much excitement in the recent years and a large amount of research has been dedicated to their understanding. These Nanotubes are about 100 times stronger than steel but just a sixth of the weight and they have unusual heat and conductive characteristic that guarantee that they will be important to high technology in the coming years.

Prior to S. Iijima's discovery of Nanotubes in 1991, carbon Nanotubes has been produced and observed under the various conditions .In 1976, Oberlin, Endo and Koyania showed hollow sphere carbon fibers with nanometer scale diameters. Carbon Nanotubes can be considered as cylinders made of graphite sheets mostly closed at the ends, with carbon atoms spread at the apexes of the hexagons, just like on a graphite sheet shown in figure2.1:

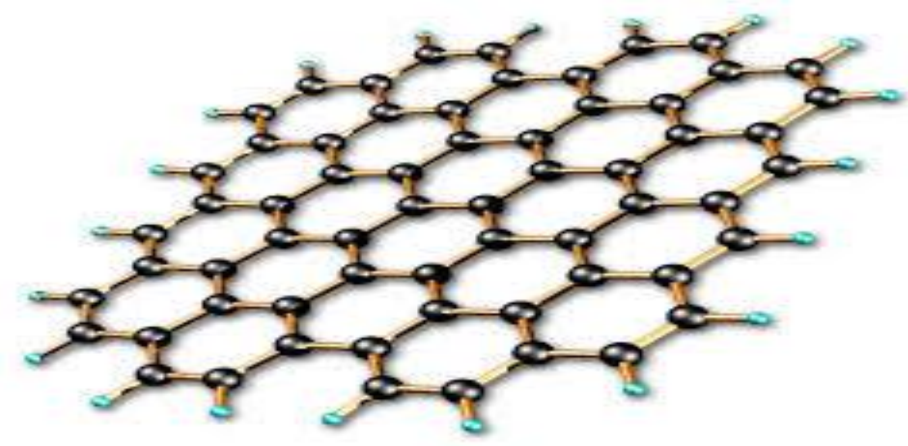


Figure 2.1: Graphene sheet (made of graphite)

Consider carbon Nanotubes as folding of a graphite sheet, just like one roll a piece of paper in to cylindrical form. The difference, however, is that a paper is two dimensional solid material.(area much larger ,few cm^2 , as compared to thickness of few micrometers) and in a graphite sheet we are talking about an area of few $micrometer^2$ and thickness just the atomic size of a carbon atom. If we consider the rolling of graphite sheet, we can imagine carbon atoms being spread in hexagonal arrangement with some lattice stain.

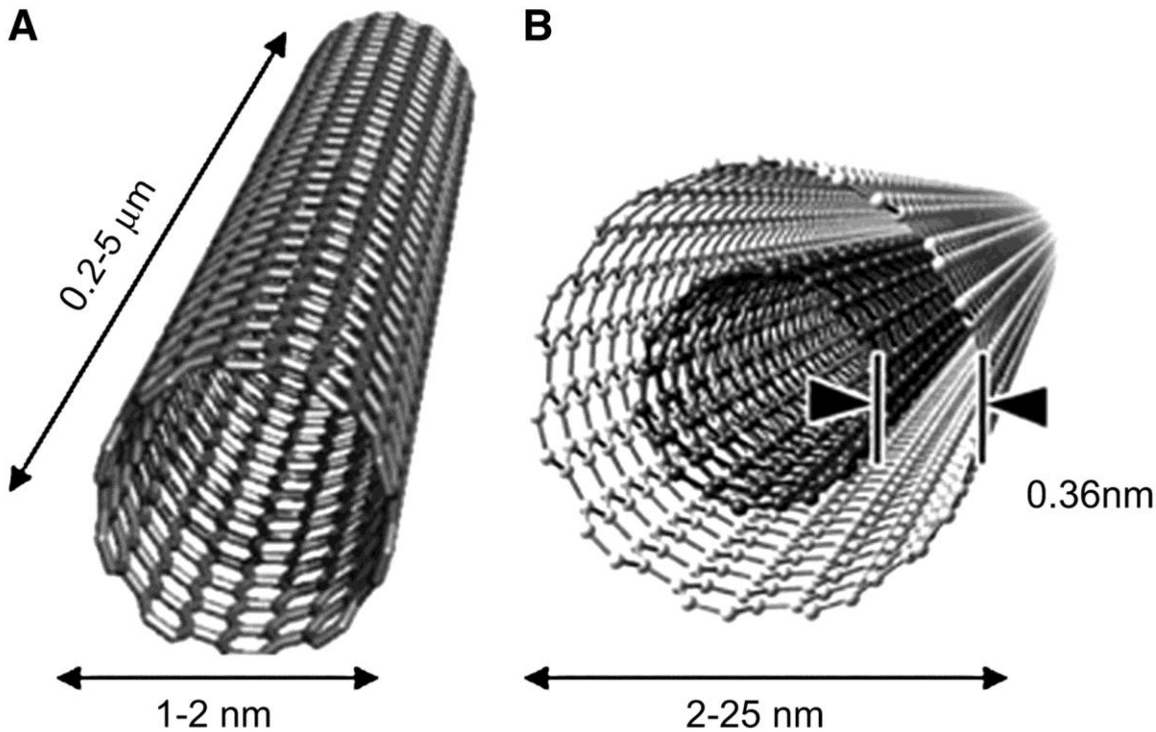


Figure 2.2: Carbon Nanotube

The lines connecting the filled sphere (carbon) are the bonds that exist between the atoms. Besides, during their formation, Nanotubes get tapped with hemisphere of fullerene. It is also possible that many concentric cylinders may be formed as a Nanotube. Such concentric Nanotubes are termed as Multiwall Carbon Nanotubes (MWCNT). The distance between their walls is ~0.334 nm. This is similar to what one gets between two graphite layers in a single crystal. MWCNT are most easily formed .However, under certain conditions it is possible to obtain even Single Wall Carbon Nanotubes (SWCNT). We illustrate the concept of both SWCNT and MWCNT shown in figure 2.2.

2.2Types of Carbon Nanotube:-

There are two types of carbon nanotube:

SWCNT and MWCNT depending on number of concentric Graphene cylinder that tube contains.

2.2-1) Single wall carbon Nanotube (SWCNT)

2.2-2) Multi wall carbon Nanotube (MWCNT)

2.2-1) Single Wall Carbon Nanotube:-

SWCNT is a cylindrical rolled up sheet of grapheme, which is a single layer of graphite atoms are arrange in exhibit pattern. SWCNT around 1.4 nm to 15 nm diameter exhibit quantum conductivity .Endo has referred the TEM image of a Nanotube as a single walled Nanotube. Furthermore, in 1979 John Abrahamson describes the CNT as the carbon fiber which was produced on carbon anode during arc discharge. Single wall carbon Nanotube is shown in figure 2.3:

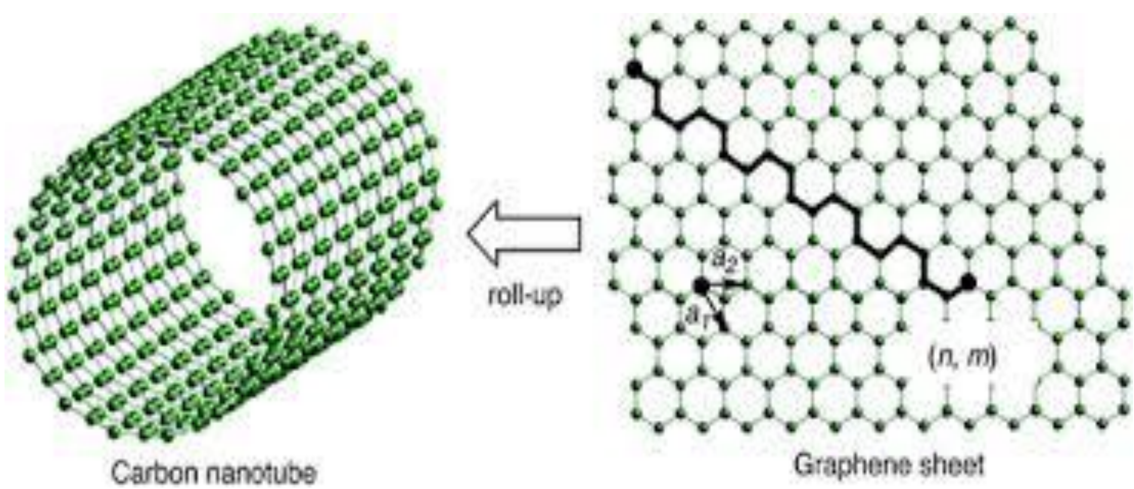
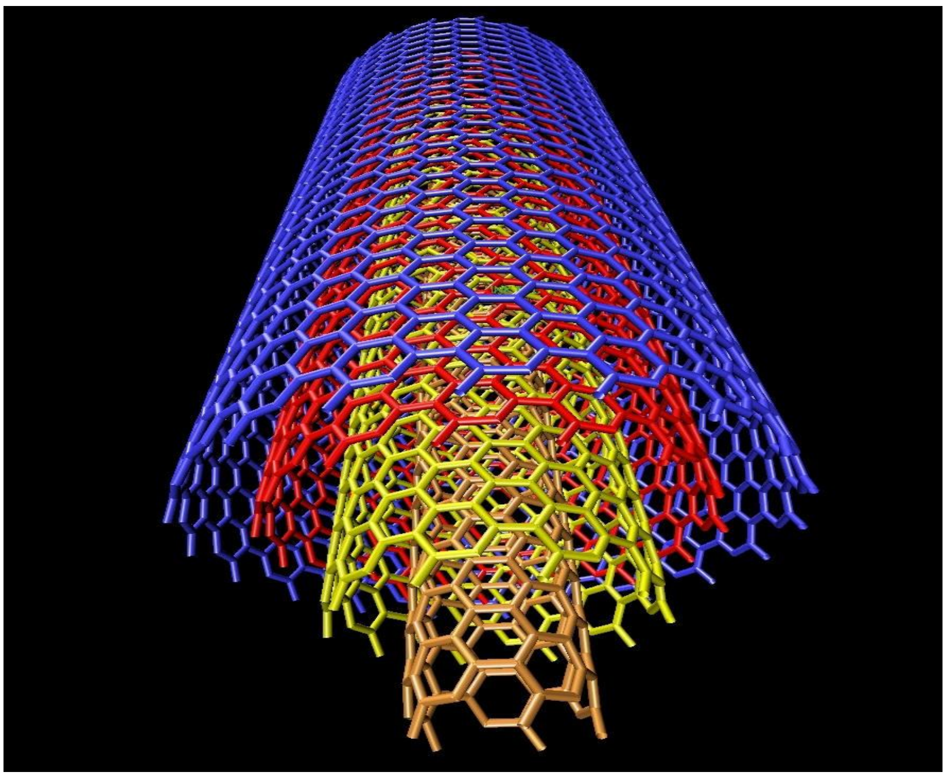


Figure2.3: Single wall Carbon Nanotube

2.2-2) Multi Wall Carbon Nanotubes:-

MWCNT is the cylindrical rolled up sheet of grapheme which is (multi) two or more layer of graphite atoms arranges in hexagon patterns .MWCNT 2.5 nm to 30 nm diameter. CNT can be semiconductor and conductor. The young's modulus of MWCNT is around 1.28 Tera Pascal .This high young's modulus makes the Nanotubes a very strong structure.



MWCNT consists of multiple concentric Nanotube cylinders as shown in Figure 2.4:

In other word"The second type consists of tubes made of more than one concentric Graphenecylinders coaxially arranged around a central hollow with a constant interlayer spacing which is nearly equal to 0.34 nm (Dresselhaus, et al. 2001), graphite layer spacing, and called multi-shell or multi-wall carbon Nanotubes (MWNT), MWNTs consist in 2 to 30 concentric Graphene, diameters of which range from 2.5 to 100 nm.

MWNTs are stronger than SWNTs, but they have more defects than SWNTs".

MWCNTs can be turned into SWCNTs using some etching methods. SWCNT have diameters ranging from ~1 to 2 nm. MWCNT have outer diameters ranging from 2 to 25 nm. The concentrically formed MWCNT are, however, rotationally disordered (turbo tactic).As the carbon Nanotubes can be imagined as folding of a graphite sheet, two things are obvious: (1) Carbon atoms on Nanotubes are sp^2 bonded like in graphite, although some strain would be expected due to curvature and (2) there should be more than one way of folding the graphite sheet.

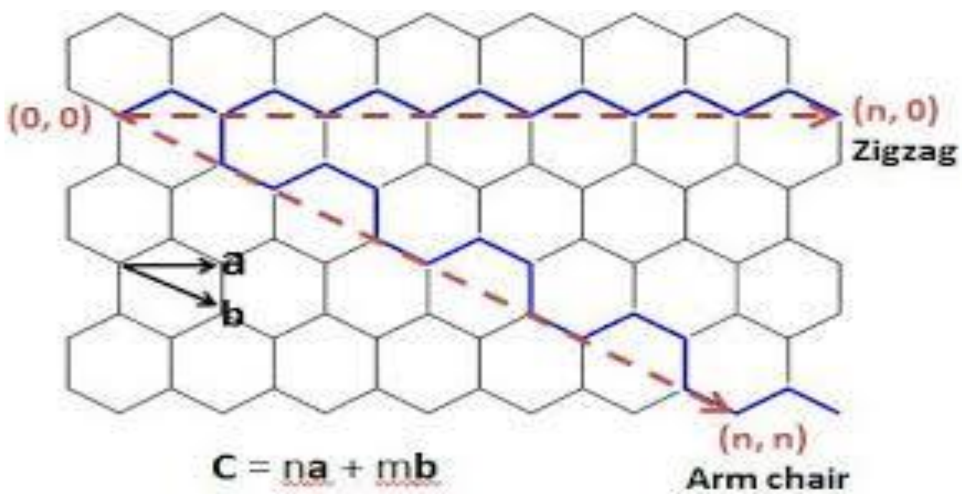


Figure2.5: Graphene sheet with various directions and cell

It is indeed possible to unique identify each hexagon (Fig.14) as (a, b) with a =0,1,2,3,…….and b=0,1,2,3….. Position of any hexagon would be given by a vector 1 as

R= ax +by ……………………………1

Consider now the length of primitive vector x and y , in terms of distance 'd' between two nearest carbon atoms .It is clear from the sample geometrical considerations that

$X = (3)^{1/2}d$ and $y = (3)^{1/2}d$ ………………………2

Vector R denoting the position of a hexagon is known as a 'chiral vector'. A tube obtained by folding the sheet along R (a, b) is called a chiral tube (a, b) .An angle between x-axis and vector R, also can be used to denote the folding. It is observed that all the angle between $0<\theta<\pi/6$ are sufficient to unique different types of tubes. The tubes whose mirror image is identical with its own image is known as 'achiral' tube and 'chiral' otherwise .The tubes are normally terminated with the with the hemisphere of fullerenes as was predicted by Smalley.

These are simply called as 'caps' or 'end caps' .Caps contain six pentagons (half the number in C_{60} fullerene) and different number of hexagon so that they can fit on the notation used here , for a Nanotube we need to have $a<b$ .Diameter of the Nanotube is obtained as follows

D = circumference of the tube/π ……………….3

Circumference of tube = $(3)^{1/2}\, d\, (a^2+ab+b^2)^{1/2}$ ……………….4

As $x.x = y.y$ and $x.y=3d^2$

$D= (3)^{1/2}d\, (a^2+ab+b^2)^{1/2}/\pi$ …………………5

Where D= diameter, d= distance between two nearest carbon atoms, a and b are the chiral length of vector R.

Angle θ in terms of chiral length a and b is obtained as

$\cos\theta = R.by/|R|.|by|$ ……………………..6

$\cos\theta = (ax + by)\, b.y/ (3)^{1/2}d\, (a^2+ab+b^2)(3)^{1/2}d.b$ ……………7

$\theta=\cos^{-1}\{(2b+a)/2(a^2+ab++b^2)\}$ ………………….8

For the angles $0< \theta<\pi/6$

A carbon Nanotube of a cylindrical rolled up sheet of Graphene which is simple layer of Graphene atoms arrange in hexagonal patterns there structure give them great tensile strength and elastic properties, the tubes are though and when bent squeezed they spring back to their original shape they also transfer heat very efficiently they can be made to exhibit either metallic and semiconductor characteristic depending on the way they get folded.

A form of carbon atoms are linked by a cylindrical framework with diameter of only a few nanometer is known as carbon Nanotubes ,it is also known as Bucky tube .CNT exhibit extraordinary mechanical and electrical properties and the young modulus is about 1 Tera Pascal .It is very stiff like diamond .Their estimated tensile strength is 200 Giga Pascal.

2.3 Nanobuds:-

Carbon Nanotube is a newly created material combining two previously discovered allotropes of carbon: carbon Nanotubes and fullerenes. In this new material, fullerene-like "buds" are covalently bonded to the outer sidewalls of the underlying carbon Nanotube. This hybrid material has useful properties of both fullerenes and carbon Nanotubes. In particular, they have been found to be exceptionally good field emitters. In composite materials, the attached fullerene molecules may function as molecular anchors preventing slipping of the Nanotubes, thus improving the composite's mechanical properties.

Figure 2.6: Nanobuds

2.4 Classification of Carbon Nanotube:-

Indeed three types of carbon Nanotubes (we will consider here only the SWCNT for the sake of simplicity) are possible viz. armchair, zigzag and helical, under appropriate conditions. Depending upon their chirality or the way of folding as discussed above for a SWCNT, basically three types arise figure .2.7

2.4-1) Zigzag CNT

2.4-2) Armchair CNT

2.4-3) Helical CN

2.4-1) Zigzag CNT:-

These are formed for θ =0 and chiral (a ,0) i.e., by folding parallel to axis .The name zigzag has given due to zigzag arrangement of carbon atoms that can be seen in figure 2.7

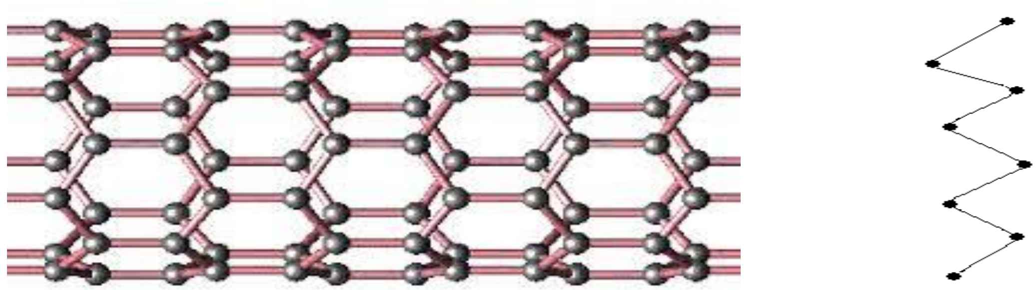


Figure2.7: Zigzag arrangement of carbon atoms

If cross-section of the tube as shown in figure (2.7) is taken .This type of tubes i.e., there mirror image are similar as the original structure.

2.4-2) Armchair CNT:-

These are formed for the angle theta = π/6 and chirality (a, a) .These are also 'achiral' in nature. Armchair structure with arrangement with carbon atoms can be seen in figure 2.8

Figure2.8: Armchair Arrangement of carbon atoms

2.4-3) Helical Carbon Nanotube:-

These are obtained when angle theta is anywhere between 0 and $\pi/6$ chirality is (a, b) .Helical structure of CNT is shown in figure 2.9.

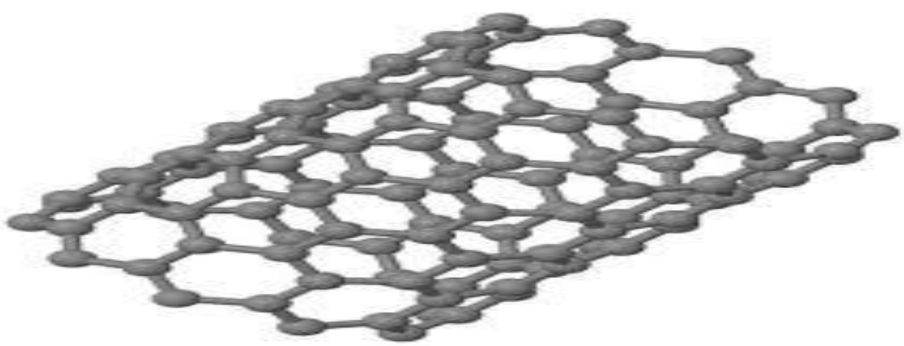


Figure2.9: Helical arrangement of CNT

Such tubes are chiral and there mirrors image appear to differ from their original structure.

Table (2.1) shows the comparison of three types of CNTs

Types Of CNT	R	θ	Cross-Section
Zigzag(achiral)	a ,0	0	Trans
Armchair (achiral)	a , a	30	Cis
Helical(chiral)	a , b	0<θ <30	Mixture of trans &cis

Beside these basic types, a variety of shapes like ropes, springs, stripes, bamboo structure, conical shapes and many others are observed to have been formed of CNTs under different experimental condition.

2.5 Preparation of Carbon Nanotube:-

Iijima had detected carbon Nanotube in an electric arc discharge set up for synthesizing fullerene. His Nanotube was multiwall type. The yield of Nanotubes was very low compared to the fullerene content. Due to tremendous interest the scientific community took in CNTs, soon arc discharge and other method like laser ablation and Chemical Vapour deposition were optimized to increase the yield and even to get SWCNT. It's now understood that electric arcoptimized to increase the yield and even to get SWCNT and also the electric arc discharge mostly can produce MWCNT. The laser ablation method can be used to produce SWCNT .There are also some attempts to use ion beams, etc. to obtain CNT. However, such methods are uncommon. In the following we briefly discuss the parameters and few points regarding CNT synthesis using electric arc discharge, chemical Vapour deposition and laser ablation techniques.

2.5-1) Arc Discharge Method

2.5-2) Chemical Vapour Depositions

2.5-3) Laser Ablation

2.5-1) Arc Discharge Method:-

First of all Nanotubes were observed in1991 in the carbon soot of graphite electrodes during an arc discharge by adding transition metal catalysts and by using a current of 100 amp. During this process, the carbon contained in the negative electrode sublimates due to the high temperature generated during the discharge .Because Nanotubes were initially discovered by this technique, it has been the most widely used method of Nanotube synthesis .With this process both single walled and multiwall Nanotubes with length up to 50 micrometers can be synthesized. The yield of this method is up to 30% by weight.

Carbon Nanotubes, in an electric arc discharge set up between two graphite rods as electrodes, are formed under certain condition as follows. Shown in figure 2.10

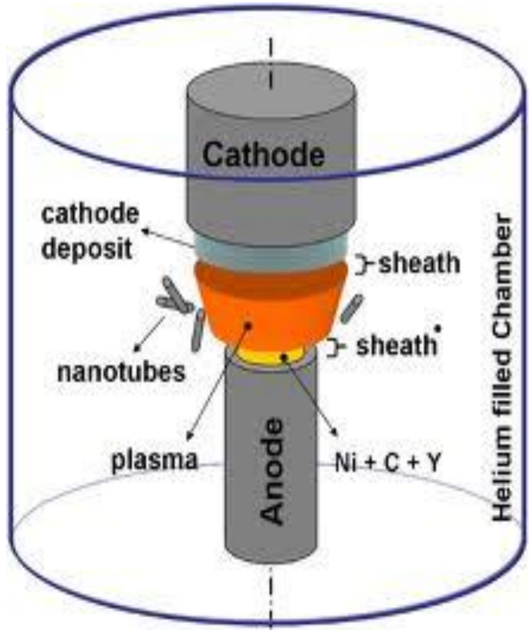


Figure2.10: Electric arc discharge set up

Electrodes- graphite

Diameter of electrodes-5 to 20 nm

Gap between the electrodes- ~1 nm

Current -50 to 120 amperes

Helium gas pressure- 100 to 500 torr (no CNT formed if P<100 torr)

Voltage- 20 to 25 volts

Cooling of the chamber is preferred.

Yield –of MWCNT~30 TO 50%

Nanotubes are found to be deposited in the central region of cathode. For MWCNT it is not necessary to use any catalyst. Central region of cathode reaches a temperature close to 3000°C and Nanotubes are aligned in the current direction between the two electrodes. The central region of cathode is surrounded by a region, in which Nanoparticles, fullerene and amorphous carbon are formed. It therefore becomes necessary to purify the MWCNT to get rid of these other particles. No tubes are found to be deposited on the walls of the experimental chamber as in the case with fullerenes. Diameters of nanotubes are in the range of 0.7 nm to 1.5 nm.

2.5-2) Chemical Vapour Depositions:-

In this Chemical Vapour Deposition (CVD) technique a substrate is prepared with a layer of metal catalyst particles (such as nickel, cobalt, iron, or a combination of these) .The substrate is heated to approximately 700°C.To initiate the growth of Nanotubes, two gases are blend into the reactor, a process gas (such as ammonia, nitrogen, hydrogen etc.) and a carbon containing gas (like ethylene, acetylene, ethanol, methane etc.).Nanotubes grow at the sites of the metal catalyst. The temperature is high enough to break the bond between the carbon atom is transported to the edge of the particle where it forms the Nanotubes. Chemical Vapour Deposition (CVD) is a common method, for the commercial production of Nanotubes .For this purpose, the metal Nanoparticles will be carefully mixed with a catalyst support (for example, MgO,Al_2O_3 etc.) to increase the specific surface area for higher yield of the catalytic reaction of the carbon feedstock with the metal particle. The CVD is the most promising industrial scale deposition technique in term of its piece/unit ratio. In 2007, a team from Meijo University has shown a high efficiency (CVD) Technique for growing carbon Nanotubes from camphor.

For the large scale production of the Nanotubes, this method is most useful. Here a hydrocarbon gas is cracked under certain conditions. Experimental set up is shown in the figure 2.11

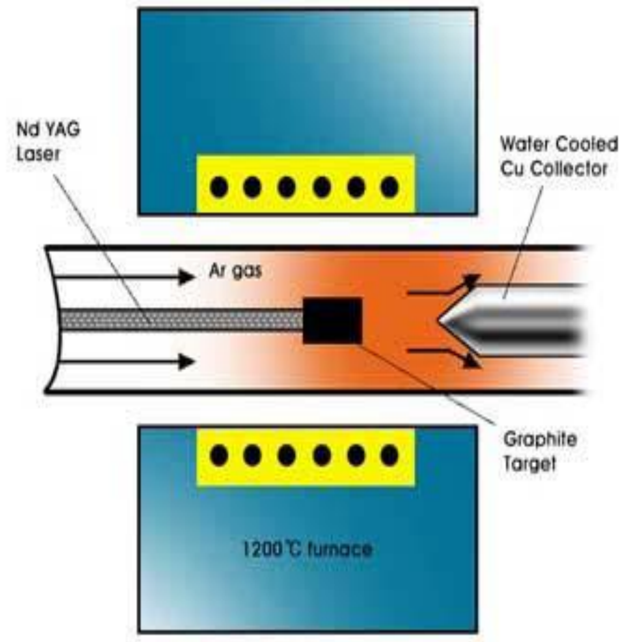


Figure2.11: Chemical Vapour Deposition

As there are no graphite hexagons present in some of the precursors used to deposit carbon Nanotubes, catalyst play an important role in carbon Nanotubes formation. Advantage of these aligned Nanotubes can be deposited on solid substrate so that they can be used for some electronics application. Both MWCNT and SWCNT are possible to obtain by this method .No Nanoparticles or amorphous carbon formation takes place, making high purity Nanotubes.

Gases -CH_4, C_6H_6 etc.

Pressure in the chamber

Furnace Temperature -~1000°C

Catalyst- Fe, Co, Ni, Pt etc.

2.5-3) Laser Ablation Method:-

In this technique a pulse laser vaporizes a graphite target in high temperature reactor while an inert gas is blend into the chamber. The Nanotubes develop as the vaporized carbon Nanotube condenses on the cooler surface of the reactor. A water cooled surface is provided in the system to collect the carbon Nanotubes. This method produces single walled carbon Nanotubes. Laser Ablation Method of production of SWCNT is more expansive than Arc Discharge or Chemical Vapour Deposition (CVD). Schematic sketch of the Laser Ablation set up is given in figure 2.12. Advantage of using Laser in the synthesis of carbon Nanotubes is that the Nanotubes are invariably SWCNT .Ropes of 10 to20 nm diameter and length ~100 micrometer also are observed. Narrow size distribution of diameters of SWCNTs is an attractive feature of this technique.

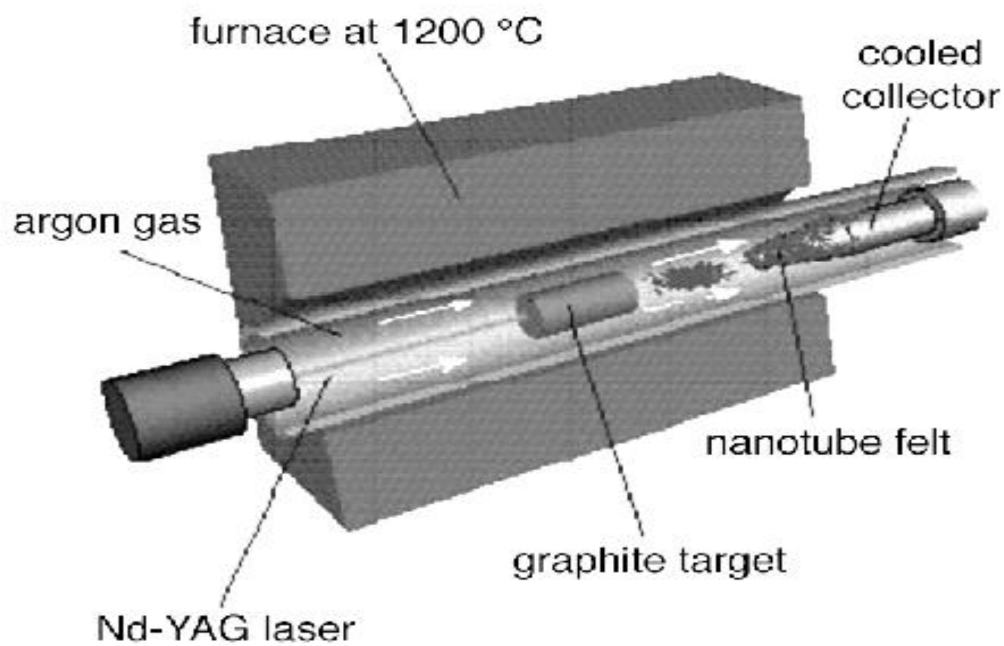


Figure2.12: Laser Ablation set up

CHAPTER 3

3.1 CHARACTERIZATION OF CARBON NANOTUBE:

Carbon Nanostructured materials have atleast one dimension smaller than 100nm, which makes their characterization complicated and require sophisticated instruments.

This study is a parametric study whose aim is to find optimal growth and pretreatment conditions for high quality and high yield, therefore, through characterization of obtained CNTs is essential. In this study the catalyst was characterized by X-ray diffraction (XRD), N_2adsorption(BET surface area) and scanning electron microscopy (SEM), and purified and unpurified CNT samples were analyzed with SEM, thermo-gravimetric analysis (TGA), Raman spectroscopy, and transmission electron microscopy (TEM).We describe three technique to characterize CNT in below. [12]

3.1-1) Scanning Electron Microscope

3.1-2) Transmission Electron Microscope

3.1-3) Raman Spectroscopy

3.1-1) Scanning Electron Microscopy:-

SEM (Scanning Electron Microscopy) images the sample morphology by scanning the surface with a high energy beam of electrons. Using SEM, morphology of CNTs, Diameters of CNTs also can be measured roughly with SEM. Sending an electron to the specimen surface, and several signals can be detected. The morphology of CNT, their dimensions and orientation can be easily revealed using SEM with high resolution. Aappropriate is use of an environment SEM (ESEM) which does not need prepration of sample using a conductive coating .A description of the ESEM and its use for our research are given below:

AFEIXL-30 ESEM FEG made by Philips has been employed to study the morphology of the CNT. A Shottky hot field emission tip is employed as an electron source and has an ultimate resolution of 1.2-1.5 nm. A large specimen chamber housing a motorized stage with an internal CCD camera allows observation of fairly large specimen. Pressure varies from 1 to 20 torr. Gaseous detection systems are used in imaging the samples. [13] Partial ionization of the chamber gas causes charge neutralization of the sample surface, with oppositely charged species being collected by the gaseous secondary detector through a cascade effect. The overall outcome is an improved image of samples regardless of the nature of the samples.

The CNT samples described below were grown at UC and are studied by ESEM. The first group represents bulk synthesis of CNT on powdered ceramic carriers, and the second include specimen synthesized on a flat Si substrate ESEM is a perfect technique to reveal the orientation of CNT and to distinguish between the "spaghetti" type and aligned CNT arrays. [14] In addition, it can focus on fine feature related to the CNT morphology. The samples are directly mounted onto a standard aluminum fixture using double sided carbon adhesive type. No further sample preparation or metallization is carried out, allowing the Nanotubes to be imaged in their natural condition. [15] The following set of parameters is used to obtain high resolution images of CNT: working distance between 8 to 10 nm, accelerating voltage of 1030kg and a chamber pressure between 0.9-1.3 torr.

The images reveal CNT dimension of about 1 micrometer long and 2-3nm in diameter, which suggest that the specimen SWCNT**[22].** The Nanotubes forms a spaghetti-type pattern with tubes lying over each other, displays typical morphology of SWCNT grown on alumina supported catalyst particle [16] , shows grown of SWCNT between catalyst particle on a silicon substrate, indicating that CNT could be synthesized by bridging catalyst particles. It is observed that long SWCNT originate from one mound of catalyst and terminate at a different mound of catalyst running over the dark silicon substrate. [17]

3.1-2) Transmission Electron Spectroscopy:-

The internal microstructure and crystal structure of samples which are thin enough to transmit electrons can be analyzed with Transmission Electron Microscopy TEM is used to measure outer and inner radius and linear absorption coefficient for CNT studies. It is the most useful instrument in order to determine the diameter of SWNTs and MWNTs and the number of walls. The inter shell spacing of MWNTs (Kiang, et al. 1998) also studied with high resolution TEM and found between the range of 0.34-0.39nm. Another subject studied with TEM is SWNT's helicity. [18]

High Transmission Electron Microscopy (HTEM) is most powerful instrument that reveals the diameter of SWCNT and MWCNT, the number of walls, and the distance between the walls. In additions, the electron diffraction mode of the TEM helps to identify the nature of can on top of the CNT. Which is usually composed of the metal catalyst.[19]

In TEM, a thin solid specimen (≤ 200 nm thick) is bombarded in vacuum with a highly focused, monoenergetic beam of electrons. The beam is of sufficient energy to propogate through the specimen. A series of electromagnetic lenses then magnifies this transmitted electron signal. Diffrracted electron is observed in the form of a diffraction pattern beneath the specimen. This information is used to determine atomic structure of the material in the sample. [20] The transmitted electron form images from small regions of the sample that contain contrast, due to several scattering mechanism associated with interactions between electrons and the atomic constituents of the sample. Analysis of transmitted electron images yields information both about the atomic structure and defects present in the lateral resolution is better than 0.2 nm on some instruments. [21]

The Nanotube arrays wire harvested from the substrate, and dispersed in dumethylamide using tip ultrasonification the samples were prepared by placing a droplet of the suspension on to carbon coated grid and dried in air, [22] displays a HRTEM image of a 20 wall MWCNT, The internal structure of the Nanotubes and their dimensions are clearly revealed in figure 3.3, where the encapsulated catalyst particle is revealed inside the MWCNT. [23]

3.1-3) Raman Spectroscopy:-

Micro-Raman spectroscopy is generally used to study the quality of CNTs. This technique gives information with details about configuration of CNTs. Number of walls, the presence of crystalline and amorphous carbon and diameter of SWNTs can be determined with the Raman spectroscopy.

When a beam of light passes through a transparent sample of a chemical compound, a small part of the light emerges in different directions than the incoming beam. Most of this scattered light is of unchanged wavelength, however, a small part has wavelengths different from the incident light, and its presence is a result of Raman Effect. The pattern of the Raman spectrum is characteristic for every molecular species and the intensity is proportional to the number of scattering molecules in the path of the light. Resonance peaks are also observed in the spectrum, which symbolize the presence of a particular specie type that is in abundance.

The characteristic spectrum of SWNTs includes three main zones. At low (100-250 cm^{-1}), intermediate (300-1300 cm^{-1}) and high (1500-1600cm^{-1}) frequencies. There are two main first order peaks for carbon-based materials. The first one is the D peak; it is observed around 1300 cm^{-1} for excitation He-Ne laser, or at 1350 cm^{-1} for an Ar ion laser. The D peak shows the presence of defects. [24] The other one is the G peak and observed at about 1580 cm^{-1}, which is related to the in-plane vibrations of the Graphene sheet

.Ratios of the D peak to the G peak are significant for CNT characterization because it gives the amount of disorder within Nanotubes (Tans, et al. 1997). A small ID/IG ratio, in the range of 0.1-0.2, indicates that the defect level in the atomic carbon structure is low, and it means that reasonable crystalline quality observed .Low energy peaks around 191 and 216 cm^{-1} are the radial breathing modes of CNTs , and can be clearly observed using He-Ne laser. [25]The spectrum in the low frequency domain reflects the SWCNT diameter and can be used to calculate it, the frequency increases with decreasing tube diameter (*d*). The frequency *v* of these modes is inversely proportional to the diameter of the SWCNT. The diameter of the SWCNT can be determined using equation below:

$$\nu(\text{cm-1}) = 223.75 / d\ (\text{nm}).$$

3.2 Properties of Carbon Nanotube:-

Nanotubes possess many unique properties and have a very broad range of electronic, kinetic, electrical thermal, structural properties that change, depending on different kinds of Nanotubes (defines by its diameter, length, chirality or twist).In fact, carbon Nanotubes are the strongest and stiffest materials on the earth, in term of tensile strength (It is a measure of the amount of force an object can withstand tearing apart) and elastic modulus respectively. It is stiff as diamond. The estimated tensile strength is 200 Giga Pascal. In 2000, a multiwall carbon Nanotube was tested to have a tensile strength is 200 Giga Pascal (G Pa).Since carbon Nanotubes have a low density for solid of 1.3-1.4 g cm^{-3}, its specific strength up to 48000 kN-mg^{-1} .Nanotubes are also elastically buckle rather than break when deformed, which result is highly robust probes. Because of the elastic behavior a lot of force is required to bend a Nanotube, but it comes to its original shape when released. Because of their hollow structure, the Nanotubes tend to undergo bucking when placed under compressive, torsional or bending stress. Under excessive strain the tube will undergo permanent deformation, that is, plastic deformation. Carbon Nanotube exhibit extraordinary mechanical properties depending upon the way the graphite structure spiral around the tube and either factor such as doping .Nanotubes can be superconducting, insulating, semiconducting or conducting (metallic).

Table 3.1: Comparison of mechanical properties of different types of Nanotubes:

S. No.	Material	Young's modulus (T Pa)	Tensile Strength (G Pa)	Elongation at Break (1%)
1	Stainless steel	~ 0.2	~0.65-1.0	15-50
2	Kevlar	~0.15	~3.5	~2.0
3	Single walled Nanotubes (SWCNT)	~1	13~53	16.0
4	Armchair (SWCNT)	0.94	126.2	23.1
5	Zigzag (SWCNT)	0.94	94.5	15.6-17.5
6	Chiral (SWCNT)	0.92	-	-
7	Multiwalled Nanotube(MWCNT)	0.8~0.9	150.0	-

3.2-1) Electrical Property:-

The electrical properties of Nanotubes are greatly affected by the symmetric and unique electronic structure of grapheme with which it is manufactured. For a give (n, m) Nanotube, if n & m is a multiple of 3, then the Nanotube is metallic, otherwise it is semiconductor. Therefore all armchair Nanotubes (n=m) are metallic and Nanotubes (5, 0), (6, 4), (9, 1) etc. are semiconducting. According to theory, the electrical current density of metallic Nanotubes is more than 100 times greater than electrical current density of metal, such as silver and copper.

3.2-2) Kinetic Property:-

Multiwalled nanotubes is a combination of multiple concentric single walled Nanotubes precisely nested with one another .MWCNTs exhibits a striking telescopic properties whereby inner Nanotube core may slide, almost without friction, within its outer Nanotubes shell, thus creating an atomically perfect linear or rotational bearing .This is the first true example of molecular nanotechnology .This property has been utilized to create world smallest rotational motor.

3.2-3) Thermal Property:-

Nanotubes are good thermal conductors along the tube, but good insulators laterally to the tube axis .It is forecasted that at the room temperature the carbon Nanotubes will be able to transmit up to 6000 watt per meter Kelvin compare this to copper which only transmits 385 $Wm^{-1}K^{-1}$. The temperature stability of carbon Nanotubes is expected to be up to 2800^0C in vacuum and approximately 750^0C in air.

Electron transport in Nanotubes will take place through quantum effects and will propagate along the axis of the tube .Defects occurred in Nanotubes affected its properties, thermal properties and electrical properties. Defects present in the Nanotubes can lower the tensile strength, mean free path thermal conductivity and electrical conductivity etc.

3.2-4) Mechanical Property:-

The carbon Nanotubes are 100 times stronger than steel but have one sixth of its weight. Therefore, they are ideal in lightweight construction, for instance for the automotive and aviation industries. Carbon Nanotubes are already used in some consumer products to add strength (without compromising weight) such as tennis rackets. The mechanical properties of carbon Nanotubes are summarized in the table below. Young's modulus is a measure of how stiff, or elastic, a material is tensile strength describes the maximum force that can be applied per unit area before the material snaps or breaks. A third interesting measure of a material is its density, which gives an idea of how light a material is. From the table below it can be seen that wood is very light but weak, while Nanotubes are many times stronger than steel and yet much lighter.

Table (3.2) Mechanical properties of Carbon Nanotube

Material	Young's Modulus(GPa)	Tensile Strength (GPa)	Density(g/cm^3)
Single-wall Nanotube	800	>30	1.8
Multi-wall Nanotube	800	>30	2.6
Diamond	1140	>20	3.52
Graphite	8	0.2	2.25
Steel	208	0.4	7.8
Wood	16	0.008	0.6

Because of their mechanical properties carbon Nanotubes are very interesting as filters in polymeric and inorganic composites.

3.2-5 Potential Properties:-

Within materials science, the optical properties of carbon Nanotubes refer specifically to the absorption, photoluminescence (fluorescence), and Raman spectroscopy of carbon Nanotubes. Spectroscopic methods offer the possibility of quick and non-destructive characterization of relatively large amounts of carbon Nanotubes. There is a strong demand for such characterization from the industrial point of view: numerous parameters of the Nanotube synthesis can be changed, intentionally or unintentionally, to alter the Nanotube quality. As shown below, optical absorption, photoluminescence and Raman Spectroscopies allow quick and reliable characterization of this "Nanotube quality" in terms of non-tubular carbon content, structure (chirality) of the produced Nanotubes, and structural defects. Those features determine nearly any other properties such as optical, mechanical, and electrical properties.

CHAPTER 4

4.1 APPLICATION OF CARBON NANOTUBE:-

Current use and application of Nanotubes has mostly been limited to the use of bulk Nanotubes, which is a mass of rather unorganized fragments of Nanotubes. Bulk Nanotube materials may never achieve a tensile strength similar to that of individual tubes, but such composites may, nevertheless, yield strengths sufficient for many applications. Bulk carbon Nanotubes have already been used as composite fibers in polymers to improve the mechanical, thermal and electrical properties of the bulk product. Nowadays, various prototype electronic devices have been developed using single and multi-walled CNTs. In the following sections, we brief some applications that could become a reality in the near future. There are many potential applications of Carbon Nanotubes in waterproof and tear resistant cloth fabrics, concrete and steel like applications (a space elevator has even been proposed) based on the property of strength, electrical circuits, electrical conductivity and sensors based on the property of thermal conductivity, vacuum proof food packaging, and even as a vessel for delivering drugs. In this chapter I am going to focus on the applications related to Nano-electronics. In figure 4.1 several applications of CNTs are given.

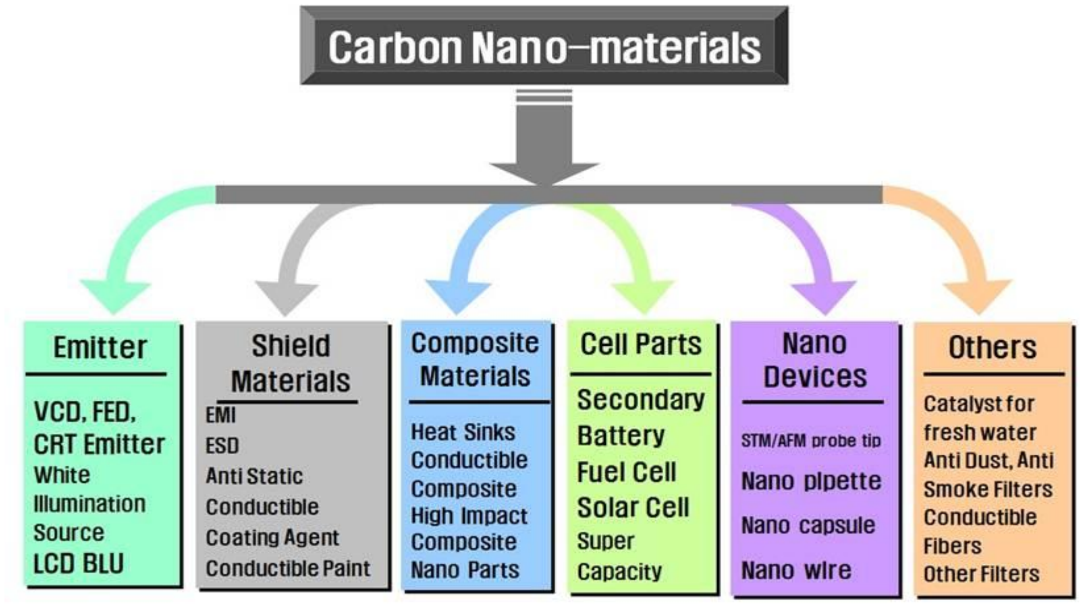


Figure 4.1: Application of carbon Nanotube

4.1-1) NVRAM data storage device:-

In June 2008, the University of Nottingham, UK, in collaboration with Nantero Inc., USA, presented a carbon-nanotube-based electromechanical data storage device. The high-density Nanotube-based non-volatile random access memory (NRAM) device was fabricated incorporating suspended, single or multiwalled CNTs. A bundle of these was suspended across a gap and connected to the two source and drain electrodes, as shown in the figure 26. By applying a voltage the Nanotubes is forced to flex and to come into Vander Waals contact with the gate. This switches the device into the state '1'. This bent position is maintained until an applied pull-out voltage forces the Nanotube to stretch back in the '0' state. In figure 4.2

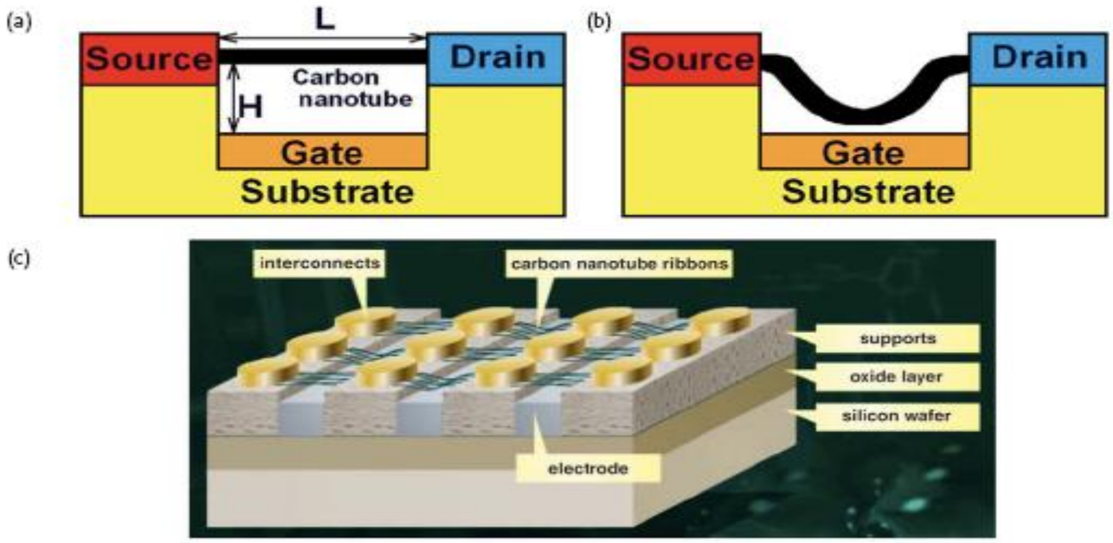


Figure 4.2: A three-terminal memory cell based on suspended carbon Nanotubes: (a) nonconductingstate ‘0’, (b) conducting state ‘1’, and (c) Nantero’s NVRAM.

4.1-2) Application in Infrared solar cells:-

Physicists at the UCLA recently found that thin films of SWCNTs could also improve the efficiency of infrared solar cells due to their good infrared transmission. To form thin films Liangbing Hu, David Hecht, and George Grüner dispersed SWCNTs in water using a surfactant and sprayed them onto a heated substrate. The resulting SWCNT films have a sheet resistance value of 200 Ohm/sqand the average transmittance rate proved to be >90% for wavelengths from 450nm to 20micron.“One major application is the infrared solar cells, where transparent CNT films as well Graphenefilms would allow the transmission of infrared energy to the active layer, which allows the fabrication of infrared solar cells. The fabricated films could also be used for other applications like an infrared camera, which will be investigated soon by the researchers.

4.1-3) Supercapacitors and/or Batteries:-

Apart from the good electrical conductivity, the extremely high surface area of CNTs makes them a very good choice for electrodes in batteries and capacitors. CNTs have the highest reversible capacity of any carbon material, as shown in the following figure 27. Batteries have a high energy density but are slow to recharge, whereas, capacitors have the opposite problem. CNT based Supercapacitors are being developed to bridge the gap. In figure 4.3, there are huge requirements for this in energy harvesting devices for small electronics, such wireless sensors.

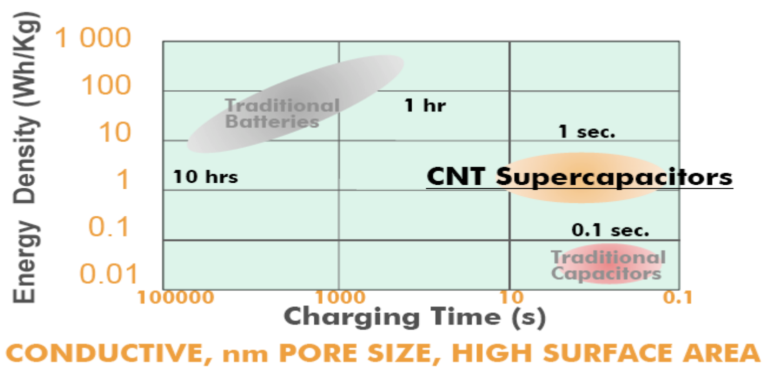


Figure4.3: CNT Supercapacitor

4.1-4) In Battery:-

A new energy storage device using carbon Nanotubes was developed in August 2007 by researchers at Rensselaer Polytechnic Institute, USA. The Nanoengineered battery is lightweight, ultra-thin, completely flexible, and likely to meet the demands of the next generation of gadgets, implantable medical equipment, and transportation vehicles. More than 90 percent of the device is made up of cellulose. The paper is infused with aligned CNTs that act as electrodes and allow the storage devices to conduct electricity. The components are molecularly attached to each other: the carbon Nanotube print is embedded in the paper, and the electrolyte is soaked into the paper. The device, engineered to function as both a lithium-ion battery and a Supercapacitor, can provide the long, steady power output comparable to a conventional battery, as well as a Supercapacitor'squick burst of high energy. Additionally, it can function in temperatures up to 300 degrees

Fahrenheit and down to 100 below zero. It is completely integrated and can be printed like paper. The goal is to print the paper using a roll-to-roll system, but so far it is not developed in an inexpensively way attractive for mass production.

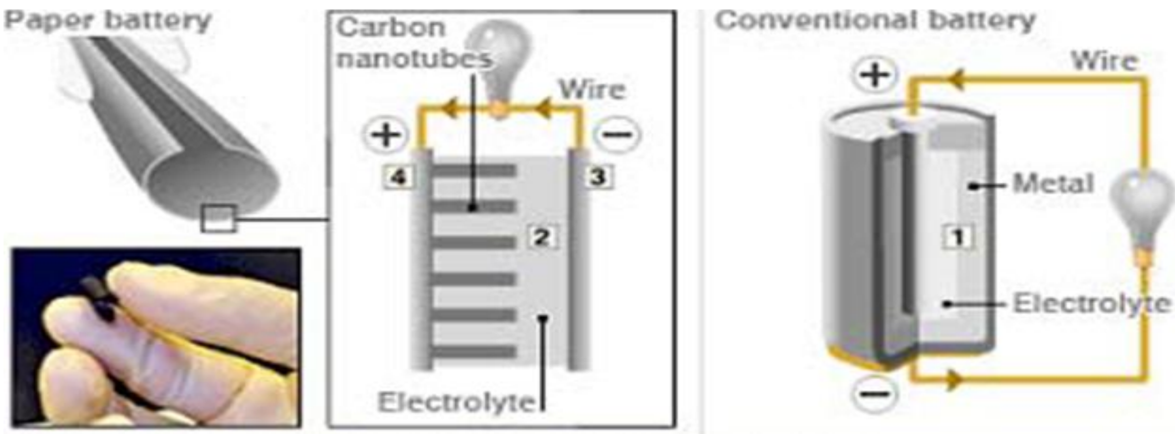


Figure4.4: Battery from Rensselaer

Electricity is flow of electrical power or electrons:

1) Batteries produce electrons through a chemical reaction between electrolyte and metal in the traditional battery.

2) Chemical reaction in the paper battery is between electrolyte and Carbon Nanotubes.

3) Electrons collect on the negative terminal of the battery and flow along a connected wire to the positive terminal.

4) Electrons must flow from the negative to positive terminal for the chemical reaction to continue.

4.1-5 Potential Application of Carbon Nanotubes:-

Recently, several studies have highlighted the prospect of using carbon Nanotubes as building blocks to fabricate three-dimensional macroscopic

(>1mm in all three dimensions) all-carbon devices. Lalwani et al. have reported a novel radical initiated thermal crosslinking method to fabricated macroscopic, free-standing, porous, all-carbon scaffolds using single- and multi-walled carbon Nanotubes as building blocks. These scaffolds possess macro-, micro-, and Nano- structured pores and the porosity can be tailored for specific applications. These 3D all-carbon scaffolds/architectures may be used for the fabrication of the next generation of energy storage, Supercapacitors, field emission transistors, high-performance catalysis, Photovoltaics, and biomedical devices and implants.

4.1-6) Thin film loudspeakers:-

In September 2008 Tsinghua University, China, and Beijing Normal University, China, presented their collaboration work on flexible, stretchable, transparent thin film loudspeakers that incorporate CNT Nano-ribbons. This device sounds roughly 260 times louder than that which can be produced from platinum foils. Applying an audio signal to the CNT thin film loudspeaker through a pair of electrodes causes the film’s temperature to briefly spike and by that the directly surrounding air to oscillate, which produces sound waves.

Figure4.5: The CNT thin film was put on a flag to make a flexible flag loudspeaker

CHAPTER 5

LITERATURE WORK

Single wall carbon Nanotubes pack into crystalline ropes that aggregated into tangled networks due to strong van der Waals attraction. Aggregation acts as an obstacle to most applications, and dimisishes the special propertiese of the individual tubes. Rajdip Bandyopadhyya et al [26] described a simple procedure for dispersing as- produced Nanotubes powder in aqueous solutions of Gum Arabic. In a single step, a stable dispersion of full-length, well separated, individual tubes is formed, apparently due to physical adsorption of the polymer.

Carbon Nanotubes uniformly 50 nm in diameter were directly grown on graphite foil. Cyclic voltammetry (CV) shows that the carbon

Nanotube/ graphite foil electrode has a high specific capacitance (115.7 F/g at a scan rate of 100 mV/ s) and exhibits typical double-layer behavior. A rectangular-shaped CV curve persists even at a scan rate of 100 mV/ s in 1.0 M H SO aqueous solution, which suggests that the carbon Nanotube electrode could be an excellent candidate as the electrode 2 4 in electrochemical double-layer capacitors. In addition, the influence of the potential scan rate, aging, and the electrolyte solution on the specific capacitance of Nanotube electrodes was also studied by J.H. et al. [27]

Nearly monodisperse iron Nanoclusters have been used to define the diameters of carbon Nanotubes grown by chemical vapor deposition (CVD). Iron Nanoparticles with average diameters of 3, 9, and 13 nm were used to grow carbon Nanotubes with average diameters of 3, 7, and 12 nm, respectively. Transmission electron microscopy studies of the Nanotubes show that the as-grown Nanotubes are single-walled carbon Nanotubes (SWNTs) or thin multiwalled carbon Nanotubes (MWNTs) with 2 or 3 layers. Investigations of the growth conditions also demonstrate that the supply of carbon reactant is critical for enabling the growth of large diameter Nanotubes from large iron Nanoclusters, and that the growth temperature is especially important for achieving high-quality large diameter Nanotubes. The implications of these results and possible applications of the Nanotubes are discussed by Chin Li Cheung et al. [28]

Synthesis of carbon Nanotubes by chemical vapor deposition over patterned catalyst arrays leads to Nanotubes grown from specific sites on surfaces was discovered by Hongjie Dai. [29] The growth directions of the Nanotubes can be controlled by van der Waals self-assembly forces and applied electric fields. The patterned growth approach is feasible with discrete catalytic Nanoparticles and scalable on large wafers for massive arrays of novel Nanowires. Controlled synthesis of Nanotubes opens up exciting opportunities in Nanoscience and nanotechnology, including electrical, mechanical, and electromechanical properties and devices, chemical functionalization, surface chemistry and photochemistry, molecular sensors, and interfacing with soft biological systems.

The catalytic synthesis of carbon Nanotubes by pyrolysis of acetylene over Zr based AB2 and Mm (Misch metal) based AB5 alloy hydrides are discussed by M. M. Shaijumon and S. Ramaprabhu. [30] The alloy-hydrides have been prepared using hydrogen decrepitation technique. The samples were purified by acid and heat treatment and were characterized by XRD, BET surface area measurements, SEM, TEM and Raman spectroscopy. A maximum adsorption capacity of 3.3 and 3.1 wt% are obtained at 298 K and 100 bar for carbon Nanotubes prepared with Mm based AB5 and Zr based AB2 hydrogen storage alloy hydride catalysts, respectively.

Multiwall carbon Nanotube (MWNT) reinforced silicon nitride ceramics matrix composites have been prepared by Cs. Bala zaia et al. [31] The hot isostatic press (HIP)-sintering method was used for composite processing. Bending strength and elastic modulus of MWNT-silicon nitride composites showed a considerable improvement compared to matrices with added carbon fiber, carbon black or graphite. However, the silicon nitride samples without any carbon addition, because of higher densities present an even higher value. In the case of carbon fibers addition, deterioration during sintering has been observed. The increasing pressure and sintering time resulted in carbon Nanotube free structures.

Semiconducting carbon Nanotube transistors with channel lengths exceeding 300 microns have been fabricated. In these long transistors, carrier transport is diffusive and the channel resistance dominates the transport. Transport characteristics are used to extract the field-effect mobility (79 000 cm2/Vs) and estimate the intrinsic mobility (>100 000 cm2/Vs) at room temperature. These values exceed those for all known semiconductors, which bodes well for application of Nanotubes in high-speed transistors, single- and few-electron memories, and chemical/ biochemical sensors was proposed by T. Dulrkop et al. [32]

Howard Wang, et al [33] has investigated the dispersion of single-walled carbon Nanotubes (SWNTs) in heavy water with the surfactant octyl-phenol-ethoxylate (Triton X-100) using small angle neutron scattering. The results indicate an optimal surfactant concentration for dispersion, which suggest results from competition between maximization of surfactant adsorption onto SWNT surfaces and a depletion interaction between SWNT bundles mediated by surfactant micelles. The latter effect drives SWNT reaggregation above a critical volume fraction of micelles. These behaviors could be general in dispersing SWNTs using amphiphilic surfactant. The data also reveal significant incoherent scattering from hydrogen in SWNTs, most likely due to acid and water residues from the purification process.

Wenzhong Wang, et al [34] have successfully synthesized multiwall carbon Nanotubes by a low temperature solvothermal approach at 310 ◦C, in which ethoxylated alcohol polyoxyethylene (4) ether was used as carbon source. Transmission electron microscopy observations indicated that the multiwall carbon Nanotubes have outer diameters between 5 and 20 nm, and inner diameters between 2 and 8 nm. The length of the multiwall carbon Nanotubes is of several micrometres. Since the discovery of carbon Nanotubes, their applications benefit to a wide range of engineering, applied physics and biomaterials areas, because of their superior mechanical and electrical properties.

In the advanced composite society, substantial works including the synthesis of different types of Nanotubes, manufacturing process of Nanotube-related composites, mechanical characterizations of these composites, have been conducted by Kin Tak Lau, et al [35] in the past few years. One of the major focuses, has not yet been solved, is on how to ensure a good bonding between straight Nanotubes and their surrounding matrix, and also the integrity of the Nanotubes' structures, in their atomic scale level after being bonded with the matrix. Physical Nanotube pullout and push in tests can be used to determine the interfacial bonding properties of the Nanotube/polymer composites. However, due to their size constraint, it is impossible to precisely conduct such tests, based on current testing technology. Although molecular dynamics (MD) simulations are another alternative to roughly estimate the bonding behaviour of the composites, the results are highly dependent on the basic assumptions applied to models. Recently, the development of coiled carbon Nanotubes opens a new alternative to reinforce the traditional composites. The coiled configuration of the Nanotubes can enhance the fracture toughness as well as mechanical strength of the composites even there is no direct chemical bonding between the Nanotubes and matrix. Their coiled shape induces mechanical interlocking when the composites are subjected to loading. In this paper, a critical review on the synthesis of the coiled Nanotubes and their applications in advanced composites is given.

Carbon Nanotubes (CNTs) have many unique physical, mechanical, and electronic properties. These distinct properties may be exploited such that they can be used for numerous applications ranging from sensors and actuators to composites. As a result, in a very short duration, CNTs appear to have drawn the attention of both the industry and the academia. However, there are certain challenges that need proper attention before the CNT based devices can be realized on a large scale in the commercial market. Niraj Sinha [36] reported the use of CNTs for biomedical applications. The paper describes the distinct physical, electronic, and mechanical properties of Nanotubes. The basics of synthesis and purification of CNTs are also reviewed. The challenges associated with CNTs, which remain to be fully addressed for their maximum utilization for biomedical applications, are discussed.

Multi-wall carbon Nanotubes were synthesized by Tarek Abdel-Fattah [37] from sucrose by a pyrolytic technique using mesopourous MCM-41 silicate templates without transition metal catalysts. The Nanotubes were examined in the carbon/silicate composite and after dissolution of the silicate. High-resolution transmission electron microscopy study of the multi-wall Nanotubes showed them to be 15 nm in diameter, 200 nm in length and close-ended. There was variation in crystallinity with some Nanotubes showing disordered wall structures.

A review on the syntheses and electrical characterization of Y-shaped multi-walled carbon Nanotube morphologies was presented by R. Bandaru [38] modified thermal CVD processes, using Ti precursors, are used to grow Y-junctions of different geometries and distribution of catalyst particles. It has been established that novel electrical switching behavior is feasible, where any one of the three branches of the Y-junction can be used for modulating the electrical current flow through the other two branches. Current blocking behavior, leading to perfect rectification, is seen which could be related to the interplay of the carrier lifetime and the transit time. The overall goal is to investigate the possibility of obtaining novel functionality at the Nanoscale, which can lead to new device paradigms.

To fully realize the potential for the many applications of carbon Nanotubes, it is necessary to control their morphology at will. Here Xueliang Sun, et al [39] described the controlled synthesis, on the fibers of a carbon paper, of multi-walled carbon Nanotubes having either a regular cylindrical morphology or a novel morphology consisting of Nanometric cylindrical tubes terminated by pointed tips about 0.5–1 lm long. Reshaping of the Ni–Co catalyst particle during the growth process has been directly observed for both regular and pointed Nanotubes. However, total liquefaction of the catalyst particle is only observed during the growth of pointed tubes. Regular tubes result from the spiral scrolling of a Graphene sheet resulting in a herringbone texture, while the tip of the pointed tubes displays a concentric textural character. The change in growth mechanism seems to occur upon total liquefaction of the catalyst.

The state-of-art and key problems of carbon Nanotube (CNT) based polymer composites (CNT/polymer composites) including CNT/polymer structural composites and CNT/polymer functional composites are reviewed by J. H. Dul., and J, Bai., [40] based on the results reported up to now, CNTs can be an effective reinforcement for polymer matrices, and the tensile strength and elastic modulus of CNT/polymer composites can reach as high as 3600 MPa and 80 GPa, respectively. CNT/polymer composites are also promising functional composite materials with improved electrical and thermal conductivity, etc. Due to their multi-functional properties, CNT/polymer composites are expected to be used as low weight structural materials, optical devices, thermal interface materials, electric components, electromagnetic absorption materials, etc. However, the full potential of CNT/polymer composites still remains to be realized. A few key problems, such as how to prepare structurecontrollable CNTs with high purity and consistently dependable high performance, how to break up entangled or bundled CNTs and then uniformly disperse and align them within a polymer matrix, how to improve the load transfer from matrix to CNT reinforcement, etc, still exist and need to be solved in order to realize the wide applications of these advanced composites.

This report is focused by K. Safarova et al [41] on a studying of single-walled carbon Nanotubes (SWCNTs) by different microscopic methods. It is important for the number of researches to know basic parameters of SWCNTs, especially a diameter and length of one Nanotube or a bundle of Nanotubes and a number of Nanotubes in the bundle. For determination of these parameters Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM) were used.

Since the discovery of carbon Nanotubes in 1991 by Iijima, they have been of great interest both from the fundamental point of view and for future applications. The most eye catching features of this structure are their electronic, mechanical, optical and chemical characteristics, which opens a way to future applications. These properties can even be measured on single Nanotubes. For commercial applications, large quantities of purified Nanotubes are needed. In this paper, recent research on preparation of carbon Nanotubes with special reference to low temperature synthesis of high purity is reviewed by S. Karthikeyan et al [42] the reported achievements in this area will open up more knowledge on carbon Nanostructured materials in many areas of emerging Nanoscale science and Nanotechnology.

Carbon Nanotubes have highly promising applications in future molecular electronics due to their unique electronic properties. This review begins with a brief introduction to experimental facts of structural and electronic properties of carbon Nanotubes. The next section focuses on electronic structures of single walled carbon Nanotube using the tight-binding model. Following that, applications of both semiconducting and metalic carbon Nanotubes are presented. Finally the future developments of carbon Nanotubes in both academic research industrial applicatons are discussed by Nan Zheng. [43]

Application of Raman spectroscopy to analyse carbon Nanotubes has been presented by S. Costa, et al [44] having a mixture of various carbon Nanotube samples, one can easily distinguish, in a quick experiment, presence of singlewalled, doublewalled and multiwalled carbon Nanotubes (SWCNT, DWCNT, MWCNT, respectively). The so-called G-line is a characteristic feature of the graphitic layers and corresponds to the tangential vibration of carbon atoms. Another characteristic mode is a typical sign of defective graphitic structures (D-line). A comparison of the intensity ratios of these two peaks gives a measure of the quality of the bulk samples. In addition, there is a third mode, named the radial breathing mode (RBM) which is very sensitive to the diameter of SWCNT and DWCNT. Additional option is application of Raman microscopy for mapping analysis and depth profiling to view the changes of intensity in various directions in the sample.

The microwave plasma torch (2.45 GHz) was used by Lenka Zajickova, et al [45] for the synthesis of carbon Nanotubes from the mixture of CH4/H2/Ar or C2H2/H2/Ar on different substrates with iron catalyst. Iron catalyst was prepared by vacuum evaporation of iron on Si, Si/SiOx or Si/AlxOy substrates or by deposition of iron oxide Nanoparticles on Si/SiOx substrate by decomposion of Fe(CO)5 in gas feed. Such prepared substrates were used for growth of carbon Nanotubes. Recostruction of the iron catalyst layer into Nanoparticles was also studied in dependence on substrate buffer layer, gas atmosphere and temperature. Samples were studied by scanning and transmission electron microscopy and Raman spectroscopy. Synthesis resulted in rapid growth of MWNTs on all samples but the density, purity and Nanotube diameter distribution varied. Such prepared carbon Nanotube layers were used for sensing applications.

Carbon Nanotubes (CNTs) are allotropes of carbon with a nanostructure that can have a length-to-diameter ratio greater than 1,000,000. These cylindrical carbon molecules have novel properties that make them potentially useful in many applications in nanotechnology. Their unique surface area, stiffness, strength and resilience have led to much excitement in the field of pharmacy. Nanotubes are categorized as single-walled Nanotubes and multiple walled Nanotubes. Techniques have been developed to produce Nanotubes in sizeable quantities, including arc discharge, laser ablation, chemical vapor deposition, silane solution method and flame synthesis method. The properties and characteristics of CNTs are still being researched heavily and scientists have barely begun to tap the potential of these structures. They can pass through membranes, carrying therapeutic drugs, vaccines and nucleic acids deep into the cell to targets previously unreachable. Overall, recent studies regarding CNTs have shown a very promising glimpse of what lies ahead in the future of medicines that work was proposed by Rajasheree Hirlekar et al. [46]

In presented work results of synthesis of carbon Nanotubes decorated with platinum Nanoparticles by organic colloidal process as an example of direct formation of Nanoparticles onto CNTs are reported by L. A. Dobrzański, et al. [47] CNT were grown by chemical vapour deposition (CVD) by the catalytic decomposition of CO. To improve metal deposition onto CNTs the purification procedure with a mixture of concentrated HNO3–H2SO4 and H2O2 reduction reagent was applied. CNT–nanocrystal composite was fabricated by direct deposition of Nanoparticles onto the surface of CNTs. Chemical composition and crystallographic structure of the obtained Pt/CNT composites were confirmed by energy dispersive X-ray spectroscopy (EDS) and by X-ray diffraction (XRD) measurements, while transmission (TEM) and scanning electron microscopy (SEM) were used for characterization of the morphology of composite as well as the distribution of Nanocrystals on the CNTs surfaces. Findings: High efficiency of proposed method was confirmed as well as possibility of the coating of Pt Nanoparticles onto CNTs, without aggregation of these particles. Many others noble metals such as palladium, platinum, gold and iridium can be used for deposition on the CNTs using described procedure. Originality/value: Obtained material can be employed in constructing various electrochemical sensors. As a result of increasing of the surface area of Pt caused by the reduction of the size of used particles, fabricated sensor may be characterized by higher sensitivity.

The field of nanotechnology continues to develop. Carbon based materials with different structure and dimensions become increasingly important in the field. Carbon Nanotubes (CNTs) are particularly promising due to their anisotropic extraordinary electrical, thermal and mechanical properties that have captured the imagination of researchers worldwide. However, the complexity involved in synthesis of Nanotubes in a predictable manner has held back the development of real-world carbon Nanotube based applications. In this chapter the structure and synthesis methods was discussed by K. Koziol and N. Yahya, [48] of CNTs and other forms of nanostructures of carbons. Furthermore, their structuring into macroscopic assemblies, like mats and fibres will be presented as it has important role in future industrial applications of these materials.

The initial development of carbon Nanotube synthesis revolved heavily around the use of 3d valence transition metals such as Fe, Ni, and Co. More recently, noble metals (e.g. Au) and poor metals (e.g. In, Pb) have been shown to also yield carbon Nanotubes. In addition, various ceramics and semiconductors can serve as catalytic particles suitable for tube formation and in some cases hybrid metal/metal oxide systems are possible. All-carbon systems for carbon Nanotube growth without any catalytic particles have also been demonstrated. These different growth systems are briefly examined in this article and serve to highlighted by Rummeli et al [49] the breadth of avenues available for carbon Nanotube synthesis.

Carbon Nanotubes are one the most important materials of future. Discovered in 1991, they have reached a stage of attracting the interests of many companies worldwide for their large scale production. They possess remarkable electrical, mechanical, optical, thermal and chemical properties, which make them a perfect "fit" for many engineering applications. In this paper various methods of production of carbon Nanotubes are dis-cussed by Muhammad Musaddique Ali Rafique and Javed Iqbal [50] efficiencies and possible exploitation as economic large scale production methods. Chemical vapor disposition (CVD) is proposed as a potential method for economic large scale production of carbon Nanotubes due to its relative simplicity of operation, process control, energy efficiency, raw materials used, capability to scale up as large unit operation, high yield and purity.

Carbon Nanotubes (CNTs) have been under scientific investigation for more than fifteen years because of their unique properties that predestine them for many potential applications. The field of nanotechnology and Nanoscience push their investigation forward to produce CNTs with suitable parameters for future applications. It is evident that new approaches of their synthesis need to be developed and optimized. In this paper Jan Prasek et al [51] reviewed history, types, structure and especially the different synthesis methods for CNTs preparation including arc discharge, laser ablation and chemical vapour deposition. Moreover, mention some rarely used ways of arc discharge deposition which involves arc discharge in liquid solutions in contrary to standard used deposition in a gas atmosphere. In addition, the methods for uniform vertically aligned CNTs synthesis using lithographic techniques for catalyst deposition as well as a method utilizing a Nanoporous anodized aluminium oxide as a pattern for selective CNTs growth are reported too.

In the present work, magnetic Nanocomposites of the multi-walled carbonnanotubes (MWCNTs) decorated by R. Sepahvand and R. Mohamadzade, [52] with magnesium ferrite (MgFe2O4) Nanoparticles were synthesized successfully by citrate-gel method. The shape, structure, size, and properties of the as-synthesized sample were characterized by Fourier transform infrared spectroscopy (FTIR), X-ray diffraction pattern (XRD), transmission electron microscope (TEM), vibrating sample magnetometry (VSM), and AC susceptibility measurements. The results showed that MWCNTs and MgFe2O4 coexisted in the Nanocomposite and a large number of the high purity magnesium ferrite MgFe2O4 Nanoparticles was attached on the surface of the MWCNTs. The hysteresis loop of the MgFe2O4/MWCNTs Nanocomposites showed that the Nanocomposites were superparamagnetic with the saturated magnetization of 11.79 emu/g, and the coercive of 49 Oe.

A screen printed electrode (SPE) based sensor for determination of Pb2+ has been developed by modifying the SPE with multiwall carbon Nanotubes (MWCNTs), Nafion and aspartic acid for determination of Pb2+ using cyclic voltammetry. The electrochemical characteristics of CNTs /Nafion/aspartic acid modified SPE were examined in several conditions such as pH, different concentration of Pb2+ and reproducibility of the detection. It was observed by Nor Azah Yosuf, et al [53] the CNTs/Nafion/aspartic acid modified SPE has significantly superior analytical performance in determination of Pb2+ compared to the unmodified electrode. The determination of Pb2+ by using modified electrode was reproducible with R.S.D of 1.76%. The electrochemical redox peak current of Pb2+ showed a linear response towards different concentration of Pb2+ and linear calibration curve was obtained in the range of 1 to 50 μM. The sensitivity expressed as the slope of the calibration curve is 5.22 μA/μM.

Worldwide commercial interest in carbon Nanotubes (CNTs) is reflected in a production capacity that presently described by Michael F. L. De Volder et al. [54] currently, bulk CNT powders are incorporated in diverse commercial products ranging from rechargeable batteries, automotive parts, and sporting goods to boat hulls and water filters. Advances in CNT synthesis, purification, and chemical modification are enabling integration of CNTs in thin-film electronics and large-area coatings. Although not yet providing compelling mechanical strength or electrical or thermal conductivities for many applications, CNT yarns and sheets already have promising performance for applications including Supercapacitors, actuators, and lightweight electromagnetic shields. Nanotechnology has become an area of significant research during the last decade, due to scientific advances in the discovery and development of novel materials with unique electrical and mechanical characteristics.

Carbon Nanotubes is such a material. Properties such as electrical and thermal conductivity have been of Carbon Nanotubes potentially suitable for use in a wide range of fields such as medicine, engineering, manufacturing, military and energy storage and distribution. This has led to Carbon Nanotubes being investigated meticulously; as such, this paper presented by Andres Felipe and Diaz Cruz, [55] a general overview on the main characteristics, fabrication methods current state of the art and a discussion on future potential applications of this material.

Carbon Nanotubes have exceptional mechanical and electrical properties. Various methods have been thoroughly investigated for the growth of CNTs. The best and the most commonly used method is Chemical Vapour Deposition (CVD). The various techniques include Reaction Chamber heating, Plasma Enhanced CVD, Hot filament CVD, Microwave CVD. The structural uniformity of carbon Nanotubes produced by plasma enhanced Chemical Vapour Deposition gives uniform height and diameter. This paper discussed by E. N. Ganesh, [56] about all the methods listed above and detail comparisons are listed. The simulated the single layer and multi layer Carbon Nanotube using Nano explorer tool and enumerated its properties for various applications like power storage and medical applications. The simulated properties of CNT would be used for energy storage purpose as well for transmission of electrical energy. Though it is known that CNT's have high aspect ratio, Young's modulus over one terra pascal, Tensile strength of 200 Gigapascal, these properties never remain the same for all the CNT'S. It depends upon the method of preparation, catalyst used etc. So the properties of CNT are studied for specific conditions. Here it is proposed CNT can be modeled for particularly electrical storage purpose.

Carbon Nanotubes (CNTs) are allotropes of carbon with a nanostructure that can have a length-to-diameter ratio greater than 1,000,000. These cylindrical carbon molecules have novel properties that make them potentially useful in many applications in Formally derived the work of Kalpna Varshney, [57] the grapheme sheet they exhibit unusual mechanical properties such as high toughness and high elastic moduli. Referring to their electronic structure, they exhibit semiconducting as well as metallic behavior and thus cover the full range of properties important for technology. Nanotubes are categorized as single-walled Nanotubes and multiple walled Nanotubes. Techniques have been developed to produce Nanotubes in sizeable quantities, including arc discharge, laser ablation, chemical vapor deposition, silane solution method and flame synthesis method. The properties and characteristics of CNTs are still being researched heavily and scientists have barely begun to tap the potential of these structures. Without doubt, carbon Nanotubes represent a material that offers great potential, bringing with it the possibility of breakthroughs in a new generation of devices, electric equipment and bio fields. Overall, recent studies regarding CNTs have shown a very promising glimpse of what lies ahead in the future of CNTs in nanotechnology, optics, electronics, and other fields of materials science.

Computer simulation and modeling results for the Nanomechanics of carbon Nanotubes and carbon Nanotube-polyethylene composite materials are described and compared with experimental by Dipak Srivastva and Chenyu Wei, [58] observations. Young's modulus of individual single-wall Nanotubes is found to be in the range of 1 TPa within the elastic limit. At room temperature and experimentally realizable strain rates, the tubes typically yield at about 5–10% axial strain; bending and torsional stiffness and different mechanisms of plastic yielding of individual single-wall Nanotubes are discussed in detail. For Nanotube-polyethylene composites, we find that thermal expansion and diffusion coefficients increase significantly, over their bulk polyethylene values, above glass transition temperature, and Young's modulus of the composite is found to increase through van der Waals interaction.

Result & Conclusion:-

In the present dissertation, I have reviewed about Synthesis of Carbon Nanotube, their characterization and application. These materials surface can be easily understood by surface analysis with the help of AFM and TEM. Both techniques help to understand the surface morphological features of Nanomaterials. There is also the brief introduction about carbon Nanotube. There can be two types of CNTs SWCNT and MWCNT depending on number of concentric Graphene cylinder that tube contains. Different preparation methods are discussed here like Arc Discharge Method, Chemical Vapour Depositions and Laser Ablation. TEM was utilized to observe these CNTs. Several other characterizations were done to understand the structural, mechanical and electrical properties of CNTs. Carbon Nanotubes (CNTs) have many potential applications due to their electrical conductivity, excellent chemical properties, mechanical strength, and high surface area.

References:

[1] Ram. T., Nanochemistry, Shree Publishers& Distributor, New Delhi **110 -002, 2012.**

[2] Kchattapdhayay K. K., and Banerjee A. N., Introduction to Nanoscience and Nanotechnology, PHI Lerarning Private Limited, New Delhi **110001**, **2012.**

[3] Dr. S. K. Gupta., Engineering Physics Vol II, **2010.**

[4] Syeda Amber Yousaf and Salamat Ali., Journal of faculty of engineering & Technologgy, **2007-2008.**

[5] Bruus, H. and K. flensberg, Quantum theory in condensed matter physics, oxford university press oxford, **2004.**

[6] Bruus, H. and K. flensberg, many-body quantum theory in condensed matter physics, oxford university press oxford, **2004.**

[7] The Royal society and The Royal Academy of Engineering, http://www.nanotec.org.uk, **2004.**

[8] Sulabha k. kulkarni, Nanotechnology principles and practices, capital publishing company, **2007.**

[9] http://powersof10.com

[10] Lusia., Filipponi and Ducan Sutherland., Aarhusuniversity, Denmark September, **2010.**

[11] Pacios Pujadó Mercè., Carbon Nanotubes as Platforms for Biosensors with Electrochemical and Electronic Transduction. Springer Heidelberg. **10.1007/978-3-642-31421-6, 2012.**

[12] M. S. Bobji and Nitin Kumar., **(09266)** Uttiya Mukherjee **(09372)** Deep. Shekhar Dewangan, **(09437).**

[13] Yusuf Selamet, SelahattinYilmaz, SerdarÖzçelik. Belin T. and Epron F., Characterization methods of carbon nanotubes. Materials Science and Engineering B. **119: 105–118, 2005.**

[14] Thess, A., Lee, R., Nikolaev, P., Dai, H., Petit, P.,Robert,J., Xu,C.,Lee, H., Kim, S.G.,Rizler, A.G.Colbert, D.T., Scuseria,G.E., Tomαnek,D., Fisher,J.E., and Smalley, R.E., Crystalline Ropes of Matellic CNT, Science **273,483,1996.**

[15] Liu,J., Fan,S and Dai, H., Recent Advances In Method of Forming CNT, Mrs Bulletin V, **294,224,2004.**

[16] Li, W., Wen, J., and Ren, Z., Effect of Temperature on Growth and Structure Of CNT by CVD, Application, Phys, A, **7374, 397, 2002.**

[17] V. Shanov., Yeo-Heung Yun, and M. J. Schulz., Synthesis and Characterization of Carbon Nanotube Materials, **2006.**

[18] Cowley, and Qin, Dept. of Nanotechnology **1998.**

[29]Journet,C.,Maser,W.K.,Bernier,P.,Loiseau,A.,Chapelle,M.,Lefant,S.,Deniard,P., Lee,A., Chapelle, M., Lee,R., and Fischer,J.E., Large Scale Production of SWCNTs by the Electric-Arc-Technique Nature, **388,756,1997.**

[20] Cassel, A., Raymarkers, J., Kong, J. and Dai, H., Large Scale Synthesis of SWCNTs J. Phys, Chem, B., **103, 6484, 1999.**

[21] Lee, C., and Park, J., Growth Model of Bamboo-Shaped CNTs by Thermal Chemical Vapour Deposition, Applied Physical Letters, **77,21,3397, 2000.**

[22] Kong, J., Soh, H., Cassel, A., Quatte, C., and Dai, H., Synthesis of Individual Single Walled Carbon Nanaotubes on Patterned Silicon Wafers, Nature, **395,878,1998.**

[23]Slaon, J., Luzzi, D., Kirkland, A., Hutchison, J., and Green, M., Imaging and Characterization of Molecules and One Dimensional Crystals Formed Within CNTs, Mrs Bulletin **29, 265, 2004.**

[24] M.S. Bobji. Nitin Kumar., Uttiya Mukherjee., and Deep Shekhar Dewangan, **(09437).**

[25] Shanov, Dresselhaus, M.S., Y. M. Lin., O. Rabin, A. Jorio, A.G. Souza., M. A. Pimenta., R. Saito, G. G. Samsonidze., and G. Dresselhaus. Nanowires and nanotubes. Materials Science and Engineering **C 23(1-2):129-140, 2006.**

[26] Rajdip Bandyopadhyaya., Einat Nativ-Roth., and Oren Regev., Dep. Of chemical Eng. And the Ilse Katz Centre for Meso and Nanoscale Science and Technology, Ben Gurion University of the Negev, Beer Sheva, Israel, **84105. 2001.**

[27] J.H. Chen., W.Z. Li., D.Z. Wang., S.X. Yang., J.G. Wen., and Z.F. Ren Dept. of Physics, Boston College, 140 Commonwealth Avenue, Chestnut Hill, MA **02467, USA, 2001.**

[28] Chin Li Cheung., Andrea Kurtz., Hongkun Park., and Charles M. Lieber Dept. of Chemistry and Chemical Biology, HarVard University, 12 Oxford Street, Cambridge, Massachusetts **02138, 2002.**

[29] Hongjiedai., Dept. of Chemistry, Stanford University, Stanford, California **94305, 2002.**

[30] M. M. Shaijumon., and S. Ramaprabhu., Alternate Energy Technology and Magnetic Materials Laboratory, Indian Institute of Technology Madras, Chennai **600 036,** India, **2003.**

[31] Cs. Bala´zsia., Z. Konyab, F. We bera, and L. P. Birc. P., Research Institute for Technical Physics and Materials Science, Hungarian Academy of Sciences, 1121 Konkoly-Thege 29-33, Budapest, Hungary, **(2003) 1133–1137.**

[32] T. Du1rkop. S. A. Getty., Enrique Cobas., and M. S. Fuhrer., Dept. of Physics and Center for SuperconductiVity Research, UniVersity of Maryland, **20742 , 2003.**

[33] Howard Wang., Wei Zhou., Derek L. Ho, Karen I. Winey., John E. Fischer., Charles J. Glinka., and Erik K. Hobbie., Dept. of Materials Science and Engineering, Michigan Technological UniVersity, Houghton, **49931, 2004.**

[34] Wenzhong Wang., S. Kunwar., J Y Huang., D Zwang and Z. F. Ren1 Dept. of Phsics, Boston College, Chestnut Hill, MA **02467,** USA **2004.**

[35] Kin Tak Lau., Mei Lu., and David Hui., Dep. of Mechanical Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR, LA **70148,** USA , **2005.**

[36] Niraj Sinha., Student Member, IEEE, and John T.W. Yeow, Member, IEEE, IEEE Transactions on Nanobiosence, Vol. 4, No. **2005,**

[37] Tarek Abdel-Fattah., Dept. of Biology, Chemistry and Environmental Science, DOI: **10.1080/15363830600811995, 2006**

[38] Prabhakar R., and Bandaru., Springer Science, Business Media, LLC., **2006.**

[39] Xueliang Sun., Ruying Li., Barry Stansfield., Jean-Pol Dodelet., and Georges Menard., Sylvain Desilets INRS-Energie, Materiaux et Te lecommunications, Canada, **2007.**

[40]J-H. Du., J. Bai., and H-M. Cheng., Institute of Metal Research, Chinese Academy of Sciences, **72110016**, P.R. China 2Lab. MSS/MAT, CNRS UMR **8579,2007.**

[41] K. Safarova., A. Dvorak, R. Kubinek, M.Vujtek1, and A. Rek., Dept. of Experimental Physics, Faculty of Science, Palacky **147, 612 64** Brno, Czech Republic, FORMATEX., **2007.**

[42] S.Karthikeyan., P. Mahalingam., and M. Karthik Dept. of Chemistry, Erode Sengunthar Engineering College, Thudupathi, Erode, India **2008.**

[43] Nan Zheng Course., Solid State II Instructor: Elbio Dagotto Spring, Dept. of Physics University of Tennessee, **2008.**

[44] S. Costa., E. Borowiak-Palen., M. Kurszynska., A. Bachmatiuk., and R. J. Kaleńczuk., Institute of Chemical and Environment, Engineering, Szczecin University of Technology, ul. Pułaskiego **10, 70-310 Vol. 26, No. 2, 2008**

[45] Lenka Zajícková., Ondrej Jašek., Petr Synek., Marek Eliáš., Vít Kudrle., Magdaléna Kadlecíková., Juraj Breza, and Renáta Hanzlíková **20. - 22. 10. 2009,**

[46] Rajashree hirlekar., Manohar yamagar., Harshal garse., Mohit vij, and Vilasrao kadam., Bharati Vidyapeeth's College of Pharmacy, CBD Belapur, Navi Mumbai- **400 614** (M.S.), Vol.2 , India, **2009.**

[47] L. A. Dobrzański., M. Pawlyta., A. Krztoń., B. Liszka ., and K. Labisz., Institute of Engineering Materials and Biomaterials, Silesian University of Technology **5, 44-121 , 2010,**

[48] K. Koziol., Dept. of Materials Science and Metallurgy, University of Cambridge, CB2 3QZ, UK Carbon and Oxide Nanostructures, Springer-Verlag Berlin Heidelberg, **2010.**

[49] Rümmeli., Nanoscale Research Letters, 6:303 http://www.nanoscalereslett. com content/**6/1/303, 2011.**

[50] Muhammad Musaddique Ali Rafique., and Javed Iqbal., Dept. of Metallurgical & Materials Engineering, University of Engineering & Technology, Lahore, Pakistan., **2011 .**

[51] Jan Prasek., Jana Drbohlavova., Jana Chomoucka., Jaromir Hubalek, Ondrej Jasek, Vojtech Adamc and Rene Kizek, **2011.**

[52] R. Sepahvand and R. Mohamadzade Dept. of Physics, Lorestan University, Khoramabad, Islamic Republic of Iran., **2011.**

[53] Nor Azah Yusof., Nurulhaidah Daud., Siti Zareena Mohd. Saat, Tan Wee Tee1, and Abdul Halim Abdullah., Chemistry Dept., Universiti Putra Malaysia, **43400** UPM Serdang, Selangor, **2012.**

[54] Michael F. L. De Volde. r, Sameh H. Tawfick., Ray H. Baughman, and A. John Hart, Science Vol **339., 2013.**

[55]Andres Felipe Diaz Cruz., 2928703 EEE-5425 Introductions to Nanotechnology Spring, **2013.**

[56] E.N. Ganesh., International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN, **2278-3075**, Volume-2, **2013.**

[57] Kalpna Varshney., International Journal of Engineering Research and General Science Volume 2, ISSN **2091-2730., 2014.**

[58] Deepak Srivastava and Chenyu Wei, Computational Nanotechnology, NASA Ames Research Center, Moffett Field, California **94035-1000;**

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