QUESTION BANK

1) Derive an expression an Interplanar spacing in a cubic system by using Miller indices
2) Describe the seven crystal systems
3) Define coordination number and packing factor. Calculate the coordination number and packing factor for SC and BCC structures
4) With a neat figure, explain the structure of diamond and show that atomic packing factor of diamond is 0.34.
5) Define lattice points, primitive cell, Bravais lattice, and space lattice
6) Explain the procedure to find miller indices with an example.
7) Explain how Bragg's spectrometer is used for determination of interplanar spacing in a crystal.

MODULE: 5

Nanomaterials

Introduction;

- Materials with a characteristic length scale (diameter and size) less than 100nm are called Nanomaterials.
- The prefix 'nano' means a billionth 10^{-9}
- The field of nanotechnology deals with various structures of matter having dimensions of The order of a billionth of a meter these particles is called nano particles.
- Nanoscale materials are materials where at least one dimension is less than approximately 100nm.
- A nanometer is one millionth of a millimeter approximately 10^5 times smaller than the diameter of a human hair.
- Nanotechnology is based on the fact that particles which are smaller than about 100nm gives rise to new properties of nanostructures built from them. Particles which are smaller than the characteristic length for a particular phenomenon show different physical and chemical properties that the particles of larger sizes.
- Ex: mechanical properties, optical properties, conductivity, melting point and reactivity have all been observed to change when particles become smaller than the characteristic length., gold and silver nanoparticle were used in window glass planes to obtain a variety of beautiful colours.Nanotechnology has wide range of applications like producing lighter but stronger materials, constructing switches for computers, improving drug delivery to specific organs of the body etc.

Quantum structures:

*When the reduction from the bulk material is in one direction, it results in a structure called film. (I.e. from3-D to 2D)

* If the reduction in two directions, obviously the resultant will be in 1-D which is called quantum wire (i.e. From 2-D to 1-D)

* If the reduction in all the three directions, the material reduces to a point which is known as quantum dot. it is also called as a nanoparticles or cluster.

Density of states:

Density of states is the possible electron quantum energy states between energies E and E+dE per unit volume, the density of states for metals in three dimensions in a bulk material is given by,

$$D(E) = \frac{8\sqrt{2}\,\pi m^{3/2}}{h^3} E^{1/2}\, dE$$

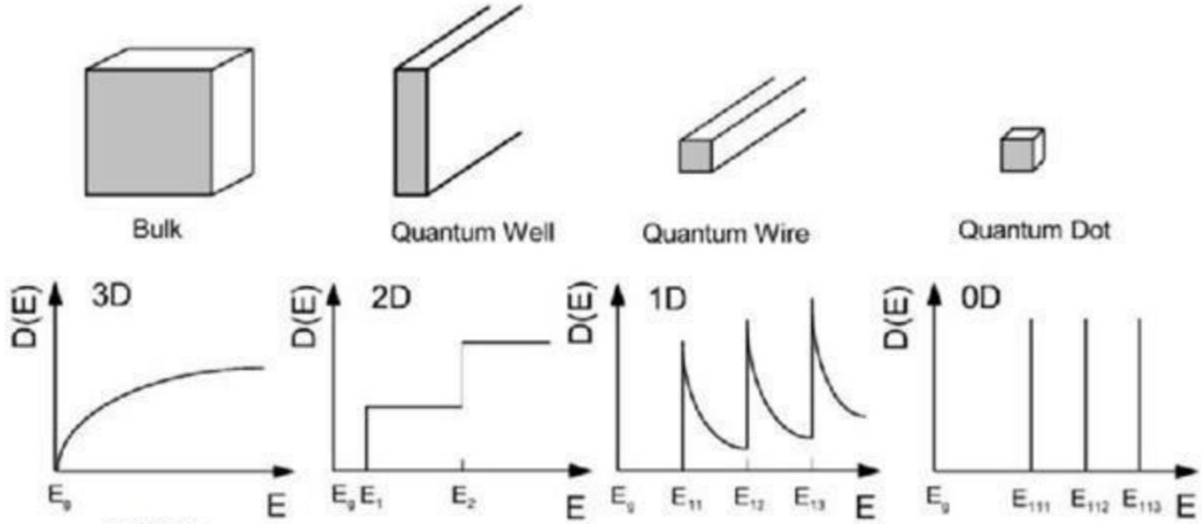
Hence the density of states with energy as shown in the fig 9.3.1.(a)

From the above equation we can conclude that the density of states in a bulk material is proportional to $E^{1/2}$ and hence increases with energy.

If the electrons are confined in one or more directions by reducing the dimensions of the material in those directions, the density of states changes due to quantization of energy.

- For a quantum well, which is a material reduced in one dimension to nano-scale there is quantization of energy due to confinement of electrons in one direction. The density of states for a quantum well is constant as shown in fig 9.3.1. (b).for different quantum states it has different constant values.
- For a quantum wire which is a material reduced in two dimension to nano-scale there is quantization of energy due to confinement of electrons in 2-D the density of states for a quantum wire.

  The density of state for a given quantum state will decrease with increasing energy as shown in fig 9.3.1.(c) , for the different quantum states , it has variation as shown in fig 9.3.1.(c).
- For a quantum dot, which is a material reduced in all three directions to nano scale, there is quantization of energy due to confinement of electrons in all the directions. Hence, for a quantum dot only some discrete energy states are allowed for the electrons. As only certain energy states are allowed. The density of states has a discrete structure as shown in fig 9.3.1.(d).



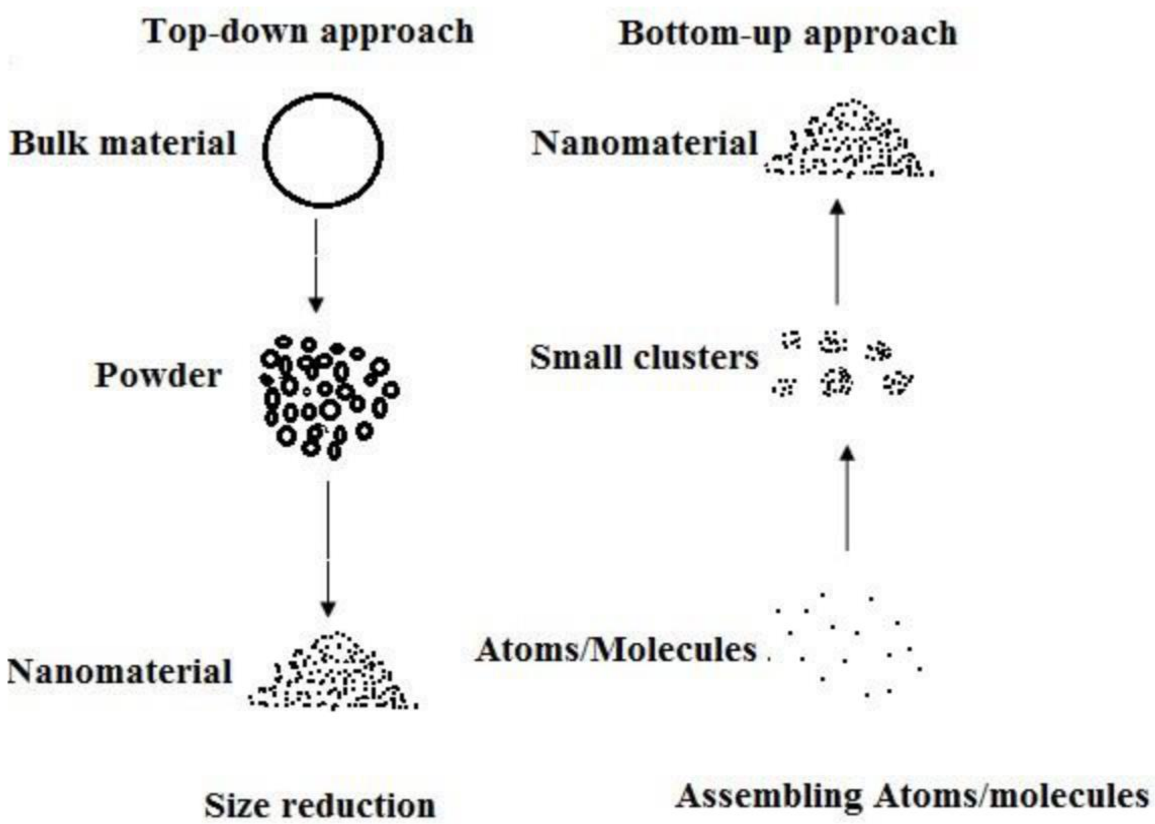
9.3.1.(a) 9.3.1.(b) 9.3.1.(c) 9.3.1.(d)

SYANTHESIS OF NANOMATERIALS

There are two methods followed in preparing nanomaterials.
*Top-down approach and *Bottom –up approach.
In the top-down approach, the material is reduced from bulk size to nano-scale.
There are many methods which follow this approach .the examples are, 1) Ball milling method and 2) Nanolithography.

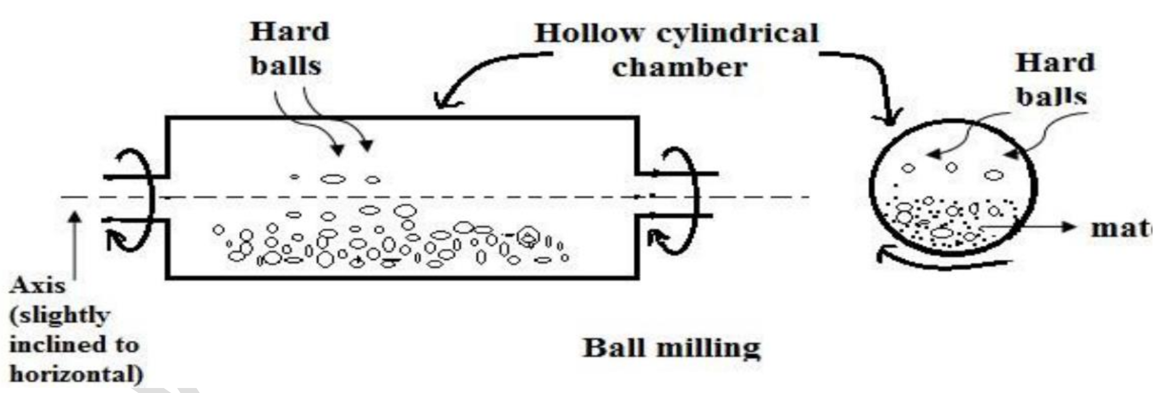
- In ball milling method, the bulk material which is taken in powdered form is reduced further by grinding technic until nano –scale size is reached.
- Lithography is a process which involves forming a thin film of material on substrate, (substrate: is a material on the surface of which an adhesive substance is spread as a coating) where in a precise control over its thickness and area is exercised. it is basically employed in semiconductor technology in the manufacture of integrated circuits & VLSI .

In the bottom-up approach, matter in atomic or molecular level gets assembled to form tiny clusters which grow to reach nano-size.
Few examples for this approach are Arc discharge, chemical vapour deposition, physical vapour deposition, sol-gel method.



Ball milling method:

This is a method used for top down approach .i.e., bulk material is broken down into nanosize particles.



Construction:

- The ball milling consists of a hollow cylindrical chamber that can rotate about its own axis.
- It consists of a hard and heavy balls made of tungsten carbide or steel inside the chamber.
- Larger balls are used for milling to produce smaller particle size.
- The chamber is mounted such that, its axis is slightly inclined to the horizontal to enable the material inside to slide, and accumulate around in one region.

Working:

- The given material is crushed into small grain size and fed into the chamber.
- The cylindrical chamber is rotated around its own axis, the ball get carried upwards. But under gravity, they drop down and hit the sample with the high speed.
- This happens repeatedly and the material to get reduced to nanosize particles.
- However The speed of rotation must be less than a critical speed beyond which , the balls, instead of falling down , will be carried along the periphery of the chamber all along. Then the material misses the hit & reduction in size stops before attaining the nanoparticle size.
- Ball milling method is employed while producing metallic and ceramic nanomaterials. When the milling time is around 20-200 hours, it will be called high energy ball milling which is capable of causing structural changes as chemical reaction. **Advantages:**

1) This method is suitable for large scale production at low cost.
2) It can be used to grind material irrespective of hardness.
3) Nanopowders of 2-20 nm size can be produced by using this technique and size of nanopowder depends on the speed of rotation of the balls. **Disadvantages:**

1) The shape of the nanomaterials produced by this method is irregular.
2) Many contaminates are inserted from ball and milling additives during this technique.
3) Crystal defects are produced during ball milling.

<u>Sol –gel method:</u>

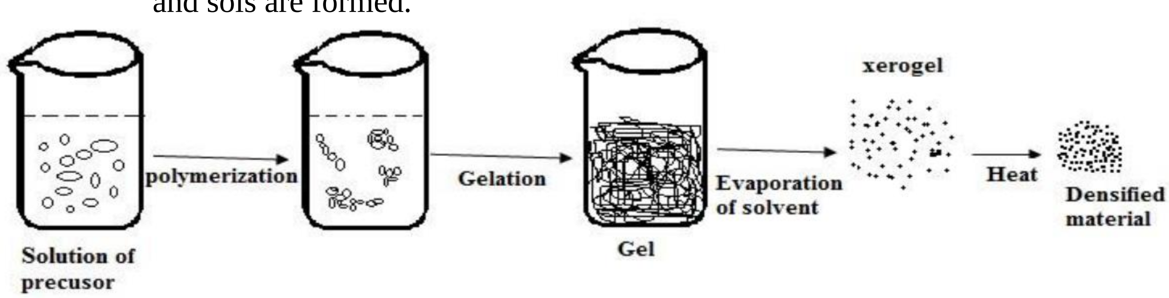
* Sols are solid particles suspended in liquid medium.

*Gels comprise of long networks of particles like polymers in which, the interspaces form pores that contain liquid.

*In the gel phase, both the liquid and the solid are dispersed in each other so that, the Material possesses the character of both the solid and the liquid phases.

"***Sol-gel is a process in which, precipitated tiny solid particles agglomerate to form long networks which are spread continuously throughout a liquid in the form of a gel".***

- In sol-gel method, precursors which have a tendency to form gel are chosen (Precursors: is a substance that leads to the formation of the desired substance after a certain chemical process.)
- A solution of the precursor is obtained by dissolving it in a suitable solvent.
- The precursors are generally inorganic metal salts or alkoxides which undergo hydrolysis. By polycondensation process, nucleation of solid particles starts and sols are formed.



Sol-Gel process

- Then the sols undergo polymerization (i.e., forming continuous network of particles) which in turn the solution into a gel.
- The sol-gel is then centrifugated form which a form of gel called Xeregel, which has zero or only traces of the dispersion medium, is obtained.
- The Xerogel is then dried by heating it up to a temperature of 800^0c during which time, the pores of the gel network collapse. This is called densification after which we obtain the desired nanomaterials.

Advantages:

1) Highly pure and uniform nanostructures can be obtained in sol-gel processing,
2) It is a least expensive technique with fine control of the products chemical composition.
3) With this method, powder, fiber, thin film, coating can be made. 4) Moderate temp are sufficient for drying or calcinations of the sample

Carbon nanotubes:

"A carbon nanotubes is a sheet of carbon atoms joined in a pattern of hexagonal, rolled into a cylinder."

In the year 1991, a Japanese researcher Ii jima of NEC, was synthesizing C_{60} fullerene by striking an electric arc between two graphite rods. He found that, needle like cylinder tubes of graphite sheet were formed on the graphite electrodes. He named those tubes as "nanotubes"

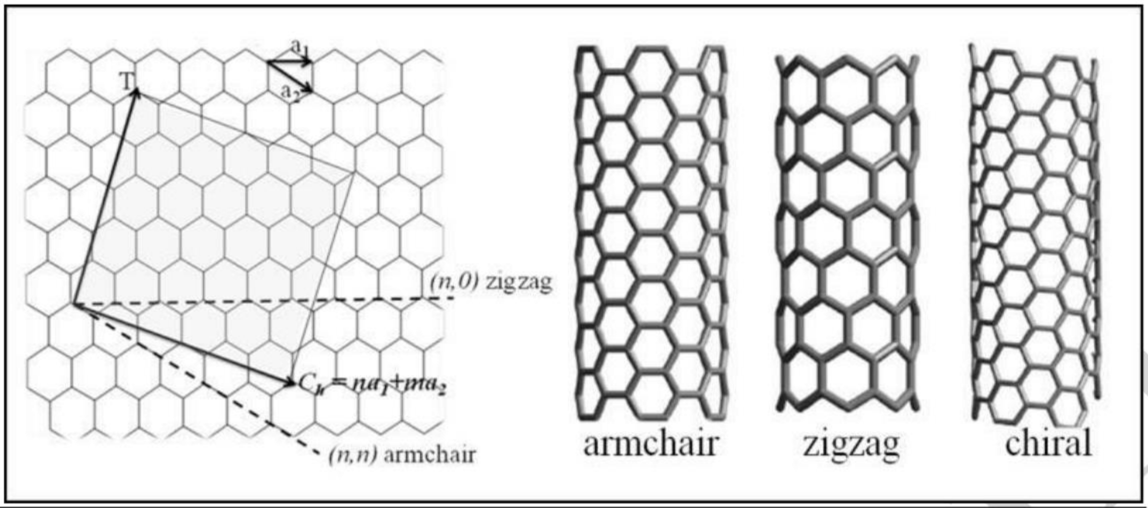
Types of the carbon nano tubes (CNTs):

1) Single wall nanotubes (SWNT); in these tube one or both the ends either open, or closed by half fullerene as cap. If there is only one layer of graphite sheet, then it is called single walled nanotubes.
2) Multiwalled nanotubes (MWNT): This can be considered as nanotubes with in nanotubes. Or bigger ones enclosing the smaller ones layer.

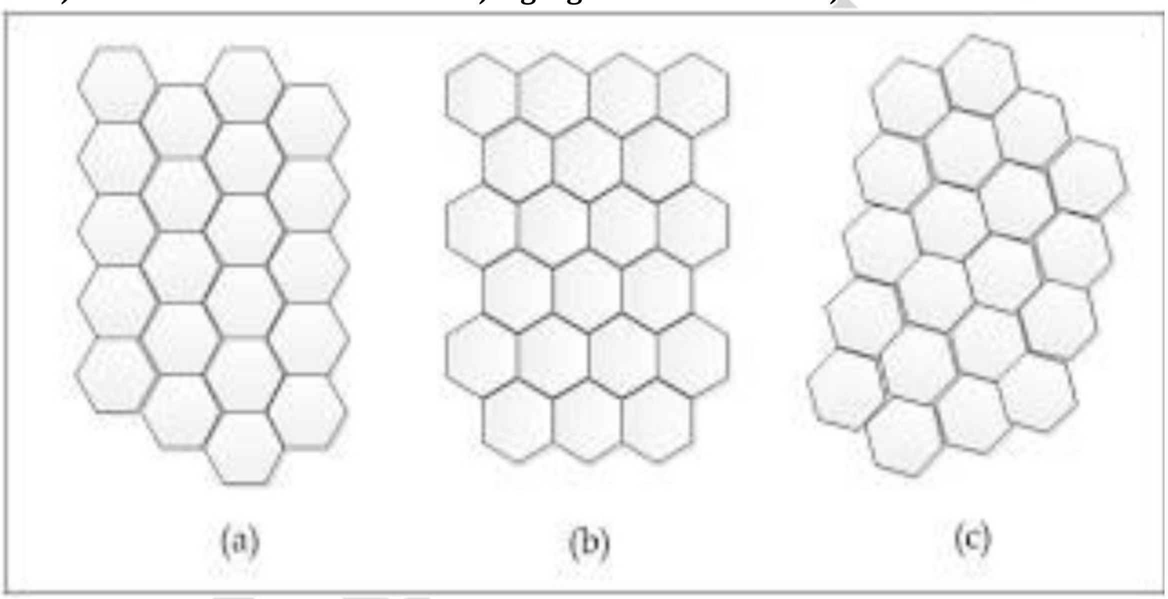
The nanotubes conducting properties depend upon how the two ends of the sheet meet along, it can happen in 3 different ways leading to 3 different verities. The resulting molecular structures are defined by roll-up vector, denoted by T. T signifies the axis about which the sheet is rolled. Fig 7.

- If T is parallel to C-C bonds, then it is "**armchair"** structure.fig 8
- There are two more structures in which the nanotubes are found" **zigzag"** structure and "**Chiral"** structure. To obtain these 2 structures the graphite sheet is to be rolled with T at certain angles to C-C bond. Fig 9,& 10.
- All nanotubes with armchair structure conduct like metals.
- The other two structures, depending on the actual angles made by T with respect to the bond angle, the conducting property also varies.

About one third of all zigzag and Chiral nanotubes conduct like metals , and remaining two third exhibit less conductivity (like semiconductors).



a) Armchair **b) zigzag** **c) Chiral**



Properties of carbon nanotubes:

1) **Thermal:** carbon nanotubes are very good conductors of heat, their thermal conductivity are more than twice that of diamond.
2) **Electrical;** Electrical properties depend on number of free electrons, collision of electrons, and dimensions of material. At the nano scale the dimension are altered. Carbon nanotubes have found to be metallic or semiconducting depending on their structure. The tube length and diameter are also responsible for change in electrical property.
   An insulator can become a conductor at the nano scale. **3)**

Mechanical:

*Mechanical properties of nanoparticles are decided by the size of the nanoparticles, surface atoms, etc.

*The carbon nanotubes are highly elastic. The young’s modulus is a measure of the elasticity. The young’s modulus of carbon nanotubes is about 1800Gpa where it is about 210Gpa for steel.

*carbon nanotubes exhibit large strength in tension. They are about twenty times stronger than steel.

* The carbon nanotubes strength is of about 45Gpa.but steel is 2Gpa.

*the carbon nanotubes can withstand larger strains then steel. They can be bent without breaking.

4) **Chemical;** a change in number of atoms on surface can change the chemical properties like catalytic activity, combustion, etc

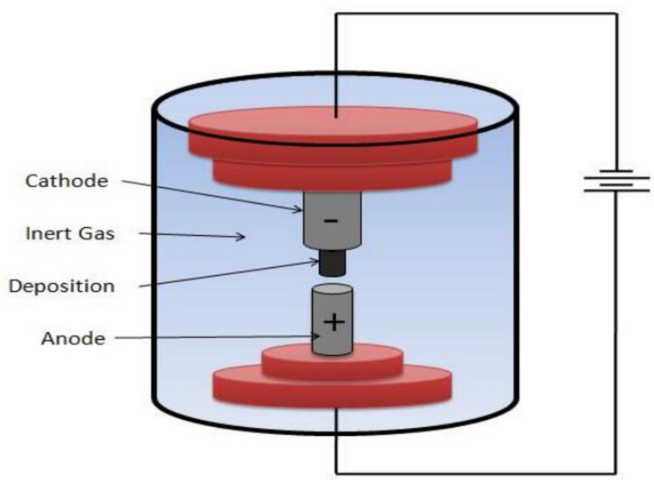
*CNTs are chemically more inert compared to other forms of carbon.

5) **Physical:** CNTs have very high strength to weight ratio, they have low density.

Synthesis of carbon nanotubes:

1) Arc discharge method
2) Pyrolysis method

Arc discharge Method:



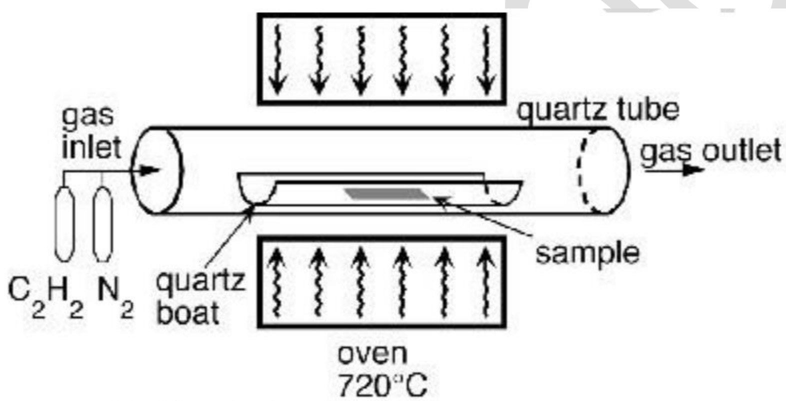
- It consists of a vacuum chamber in which two graphite rods are mounted on the two supports.
- The gap between two graphite rods is about 1-2 mm.
- The chamber is evacuated by using a vacuum pump, and a methane gas at certain pressure is introduced into the chamber.
- The two rods are maintained at a suitable dc potential difference to enable the discharge.
- On the application of the voltage, the arc discharge starts. Carbon evaporates from the anode.
- Some part of the evaporated carbon, deposits on the cathode tip layer. This is called hard deposit. And the rest condenses on the other parts of the cathode (called cathode soot) and on the walls of the chamber (called chamber soot). Both the cathode soot and the chamber soot yield, either single –walled or multi –walled carbon nano tubes.

- If the nickel, cobalt, iron catalyst is used in the central region of the positive electrode, single walled nanotubes are formed.
- In the absence of catalyst between two graphite electrodes multi –walled nanotubes are formed.
- Whereas the hard deposit does not yield any carbon nanotubes.
- Through this method can produce large quantities of nanotubes,
- It involves purification of the soot by oxidation, centrifugation, filtration and acid treatment.
- However the resulting products will be highly impure, as, 60-70% .if pure graphite rods are used means >95% products will get.

*This is a bottom-up approach in nanotechnology

Pyrolysis method (fabrication of carbon nanotubes using chemical vapour deposition.):

Pyrolysis is the decomposition of a chemical compound of higher molecular weight into simpler compounds by heating in the absence of oxygen (high temp), so that no oxidation occurs. It takes place at a temp in the range of 400^0C to 800^C.



- It consists of a quartz tube kept in a furnace. The quartz tube is connected to sources of acetylene (C_2H_2) and nitrogen.
- The substrate containing cobalt and nickel which act as catalyst is kept in a quartz plate. The quartz tube is provided with an outlet for the gas. The temperature in the quartz tube is maintained at about 400^0C – 800^0C .
- Due to the high temperature in the quartz tube, acetylene breaks down into carbon atoms. When these carbon atoms come near the substrate, they get absorbed and get converted into nanotubes due to the presence of catalyst. This method produces multi-walled nanotubes.
- To produce single walled nano –tubes, a methane or carbon monoxide source is used instead of acetylene. The temp for these sources is maintained at about 1200^0C.

*Pyrolysis is a bottom-up method..

Applications:

1) Using semiconductor nanotubes, it has been possible to make electronic components such as transistors and electronic logic gates which could be used for computing purposes.
2) CNTs are used to make high quality tennis rackets to build aircrafts and making micro mechanical systems(MEMS)
3) CNTs are used to develop flat panel displays for television and computer monitors.
4) CNTs are used in the tips for atomic force microscope probes.
5) CNTs are used to develop light weight shield for electromagnetic radiation 6) They are used in chemical sensors to detect gas.
7) They are also used in batteries (can store lithium).
8) Sensors: used in smoke detectors, gas sensors
9) Cosmetics: sun screen lotions containing nano Tio_2 provide enhanced sun protection factor. The added advantage of nano skin blocks arises they protect the skin by sitting onto it rather than penetrating into the skin, thus they block uv radiation effectively for prolonged duration
10) Based on optical property.
    Used in optical detector, imaging solar cell

Scanning electron microscope (SEM):

- A microscope is basically an instrument which provides a magnified image of an object.
- SEM is the kind of microscope that uses a beam of electrons to create a magnified image of the specimen. **Principle:**

The principle used in the working of an SEM is the wave nature of electron. An electron accelerated under a potential difference of V volts behave like a wave nature of light

$= h$ $= \frac{1.226}{\sqrt{}}$ nm

$\sqrt{}$ this is the basic principle made use of in the working of all kinds of electron microscope.

Construction:

- ➢ The apparatus consists of an highly evacuated chamber inside which there is an electron gun at the top, which consists of the filament and the anode.
- ➢ It consists of two magnetic lenses,1) one is the condensing lens ‘C’ and other one is the objective lens ‘O’(these are actually a pair of current carrying coils which provide magnetic field between them.
- ➢ A scan coil is accompanies the lens ‘O’.
- ➢ A flat surface called stage is provided at the bottom portion of the apparatus to place the specimen under study.
- ➢ There are 3 types of detectors in the apparatus, they are back scattered electron detectors, secondary electron detectors, x-ray detectors.
- ➢ The electrons incident on the sample are called primary electrons, out of these , some of them will be scattered by the sample and some of them knockout the electrons from the atoms in the specimen those which are scattered by the sample are back scattered electrons. and the one which are knocked off from the atoms are called secondary electrons

Working:

- The sample is to be placed on the specimen stage after which, inside the chamber is evacuated by connecting it to a high vacuum pump.
- Electrons are emitted by the filament by thermionic emission.
- A suitable + ve potential is applied to the anode with respect to the filament.
- The accelerated electrons from the electron gun passes through the condensing lens C. Converges the beam and the beam passes through the objective aperture, hence the size of the beam can be controlled. a thinner beam enters into the field of objective lens O. the objective lens focuses the beam onto the desired part of the specimen.

- A set of coils called scan coils placed along with the objective lens, enable the beam to scan. The specimen in a particular way called raster. The scan coils are connected to a raster scan generator which directs the beam onto a spot the specimen.
- Upon incidence, electrons are scattered out from the specimen, the back scattered electrons, secondary electrons and the X- ray emitted are detected by the respective detectors. As the case happens to be and a corresponding signal is produced.

  The signal is converted into a micro spot of corresponding brightness on a screen (which resembles the one in a TV)

  The beam focus is shifted to the next adjacent spot in order, where again dwells momentarily – and so on. This way image is built on the screen point tom point.

Applications:

- SEM is used to study biological specimens like pollen grains.
- Crystalline structure.
- SEM is used in forensic investigations.
- SEM is used to study external morphology of biological organisms in the sub microscope.
- SEM is used to study properties like hardness and melting point of elements and compounds in the sample.
- SEM it can be also used to study the properties like reflectivity and roughness of the sample.

Shock waves:

Mach number:

In aerodynamics the speeds of bodies moving in a fluid medium are classified into different categories on the basis of Mach number.

It is defined as "The ratio of the speed of the object to the speed of sound in the given medium".

i.e. .Mach number = ________________________

M=

Where, M= Mach number
V= object speed a =
Speed of sound in the medium
Note* It does not have any unit. It is a pure number.

Distinction between Acoustic, ultrasonic, Subsonic and Supersonic waves:

Acoustic waves: These are longitudinal waves that travel in a medium with the speed of sound in that medium .These waves can propagate in solids, liquids and gases.

Acoustic waves can be classified into the following three types depending upon their frequency. 1) Infrasonic: These acoustic waves have frequency less than 20HZ. The human ear cannot detect these waves.

2) Audible: These acoustic waves have frequency between 20HZ to 20KHZ. The human ear is sensitive to these waves. They cause sensation of hearing in human beings.
3) Ultrasonic: These acoustic waves have frequency more than 20KHZ.The human ear is not sensitive to these waves. *An acoustic wave is sound wave.

   * It moves with a speed of 333m/s in air at STP

   *Sound waves have frequencies between 20HZ to 20KHZ.

   * Amplitude of Acoustic wave is very small.

Ultrasonic waves: Ultrasonic waves are pressure waves having frequencies beyond 20KHZ. But they travel with the same speed as that of sound .The Mach number =1

- Amplitude of ultrasonic wave is also small.

Subsonic wave: If the speed of mechanical wave or body moving in the fluid is lesser than that of sound, such a speed is referred to as subsonic wave. The Mach number <1.

Ex: The vehicles such as motor cars, trains, flight of birds is also subsonic.

- For a body moving with subsonic speed, the sound emitted by it manages to move ahead and away from the body since it is faster than the body.

Supersonic waves: Supersonic waves are mechanical waves which travel with speeds greater than that of sound.i.e. with speed for which, Mach number >1

A body with supersonic speed zooms ahead by piercing its own sound curtain, leaving behind a series expanding sound waves with their centers displaced continuously along its trajectory.

Today's fighter planes can fly with supersonic speed .Amplitude of supersonic waves will be high it affects the medium in which it is travelling.

Shock waves:

- Any fluid that propagates at supersonic speeds, gives rise to a shock wave.
- Shock waves are produced in nature during earth quakes (as seismic waves which travel with speeds ranging from 2km/s to 8km/s).
- When lightning strikes.

Shock waves can be produced by a sudden dissipation of mechanical energy in a medium enclosed in a small space.

"A shock wave is a surface that manifests as a discontinuity in a fluid medium in which it is propagating with supersonic speed".

They are characterized by sudden increase in pressure, temperature and density of the gas. Through which it propagates.

Shock waves are as strong or weak depending on the magnitude of the instanteous change in pressure and temperature in the medium

Ex: The shock waves created by the explosion of crackers, bursting of an automobile tire, during lighting thunder, during nuclear explosion.

- For strong shock waves mach no is high.
- For weaker shock waves the mach no is low(lesser than 1) **Applications of Shock waves:**

➢ They are used in the treatment of kidney stones.

➢ Cell information

➢ Wood preservation

➢ Use in pencil industry

➢ Gas dynamic studies

➢ Shock waves assisted needle less drug delivery ➢ Treatment of dry bore wells.

Basic of conservation of mass, momentum, and energy.

Conservation means the maintenance of certain quantities unchanged during physical process.

- Conservation laws apply to closed systems.
- A closed system is the one that does not exchange any matter with the outside and is not acted on by outside forces.

The conservation of mass, momentum and energy are the three fundamentals principles of classical physics.

1) Law of conservation of mass:

"The total mass of any isolated system remains unchanged and is independent of any chemical and physical changes that could occur within the system"

Or

"The total mass of a system remains constant as mass can neither be created nor destroyed"

2) Law of conservation of momentum:

"In a closed system the total momentum remains a constant"

Or "When two objects collides in an isolated system, the total momentum of the objects before collision =the total momentum of the objects after collision" ***3) Law of conservation of Energy***:

"The total energy of a closed system remains constant and is independent of any changes occurring within the system"

Types of shock waves:

- ***Stationary shock wave:*** In a stationary shock wave, the shock front remains stationary with respect to fixed observer.
- ***Moving shock wave:*** such shock waves travel in fluids which are either stationary or move with small speeds with respect to the observer.
- ***Normal shock wave:*** if the shock wave is perpendicular to the flow of gas, it is known as normal shock wave.
- ***Oblique shock wave****:* if the shock wave is at some angle (other than 90^0) to the flow of gas it is known as oblique shock waves.

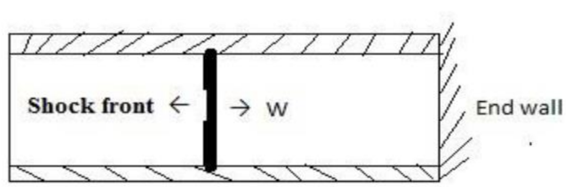
Derivation of normal shock relationship using simple basic conservation equations (Rankine-Hugonit equations):

Consider a shock wave propagating with a speed W in a shock tube.

The conditions of the shock wave at the downstream end can be determined by solving the equations for conservation of mass, momentum and energy, as applied to the shock region. These equations are known as Rankine-Hugonit relations.

* Consider two regions with reference to the shock front, one which is head of the shock front and the other behind it.

*Both the regions are at far enough distance from the shock front so that equilibrium conditions prevail the two regions where, the physical conditions such as pressure, density etc. are uniform.



Let us consider pressure (P_1) temperature (T_1), density ($_1$), and enthalpy (h_1) before creation of the shock wave. Similarly (P_2), (T_2), ($_2$) and (h_2) be the corresponding values after creation of the shock wave.

Then the three conservation relations which correspond to the conservation laws.

$_1u_1 = {}_2u_2$ ----------- (1) conservation of mass

Where u_1 is the velocity of the fluid ahead of the shock.
u_2 is the velocity of the fluid following shock

$P_1 + {}_1u_1^2 = P_2 + {}_2u_2^2$ ----------- (2) conservation momentum

And $h_1 + u_1^2/2 = h_2 + u_2^2/2$ ------- (3) conservation of energy

These 3 equations along with the equation of

states PV=RT------ (4)

Lie at the roots of all the aerodynamic problems and applications.

Using the above equations, the following normal shock relations called Rankine-Hugonit equations can be derived in which P_5 and T_5 represent pressure and temperature at the downstream and behind the reflected shock wave.

1) 2 – =[1+ 2(2−1)]

1 +1

+12

2) 21 = 21 [1(+ (− 1+)1+ 12] –

25= (−1) 1

3(−−11))

1221 +

−((+−11))

3)

+1 5

4) 52 = 52 [1(+ (− 1+)1+ 25]

−1) 2

Methods of creating shock waves in the laboratory using a shock tube:

Shock waves can be created in the laboratory by

(a) Using a Reddy shock tube
(b) Detonation
(c) Very high pressure gas cylinder
(d) Combustion
(e) Using small charge of explosives.

Characteristics of shock tube:

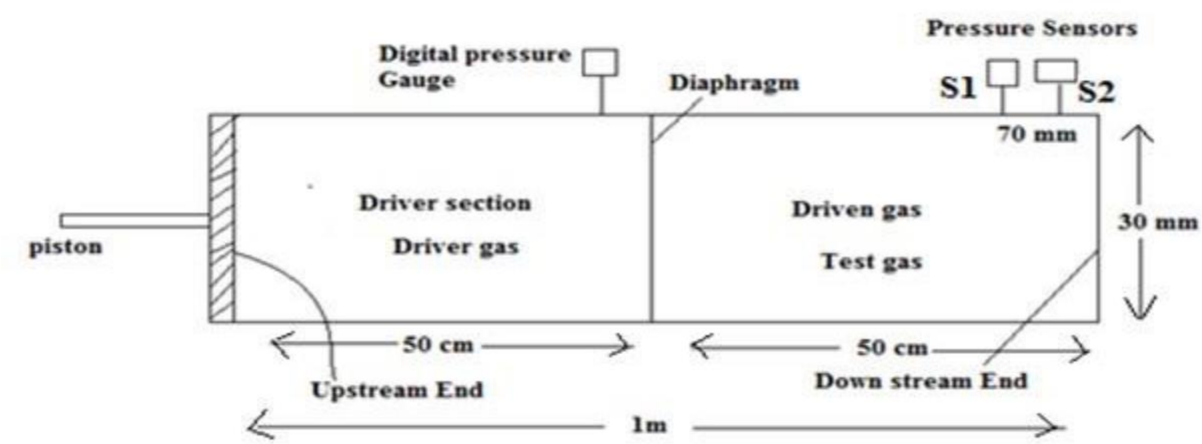
- The Reddy tube operates on the principle of free pistion driven shock tube (FPST)
- It is a hand operated shock producing device.
- It is capable of producing mach no exceeding 1.5
- The rupture pressure is a function of the thickness of the diaphragm
- Temperature exceeding 900K can be easily obtained by the Reddy tube by using helium as the driver gas and argon as the driven gas. This temperature is useful in the chemical kinetic studies.

Discription of hand operated Reddy shock tube:

Reddy tube is a hand operated shock tube capable of producing shock waves by using human energy.

It is a long cylindrical tube with two separated by a diaphragm.

It's one end is fitted with a piston and the other end is closed.



Description:

- ❖ Reddy tube consists of a cylindrical stainless steel tube of about 30mm diameter and length 1m.
- ❖ It is divided into two sections each of length 50cm.
- ❖ One is the driver tube and other one is the driven tube.
- ❖ The sections are separated by a 0.1mm thick aluminium or paper diaphragm.

- A piston is fitted at the far end of the driver section
- A digital pressure gauge is mounted in the driver section next to the diaphragm.
- Two piezoelectric sensors S_1 and S_2 are mounted 70mm apart towards the closed end of the shock tube.
- A port is provided at the closed end of the driven section for filling the test gas to the required pressure.
- The driver section is filled with a gas termed as the driver gas which is held at a relatively high pressure due to the compressing action of the piston .the gas in the driven section is termed as driven gas or test gas.

Working:

- The driver gas is compressed by pushing the piston hard into the driver tube until the diaphragm ruptures.
- The driver gas rushes into the driven section and pushes the driven gas towards the far downstream end. This generates a moving shock wave that traverses the length of the driven section
- The shockwave instaneously raises the temperature and pressure of the driven gas as the shock moves over it.
- The propagating primary shock wave is reflected from the downstream end. After the reflection, the test gas undergoes compression which boosts its temperature and pressure to still higher values by the reflected shockwaves. This state of high values of pressure and temperature is sustained at the downstream end until an expansion wave reflected from the upstream end of the driver tube arrives there and neutralizes the compressions partially expansion waves are created at the instant the diaphragm is ruptured and they travel in a direction opposite to that of the shock wave.
- The period over which the extreme temperature and pressure conditions at the downstream end is sustained, is typically in the order of millisecond, however , the actual duration depends on the properties of the driver and test gases and dimension of the shock tube.
- The pressure rise caused by the primary shock waves and also the reflected shock wave are sensed as signals by the sensors S_1 and S_2 respectively, and they are recorded in a digital cathode ray oscilloscope.
- Since the experiment involve typically, millisecond duration measurements, the rise time of the oscilloscope should be a few microsecond. Hence an oscilloscope with a band width of 1MHZ or more is required. From the recording in the CRO, the shock arrival times are found out by the associated time base calculations, using the data so obtained, Mach number, pressure and temperature can be calculated.

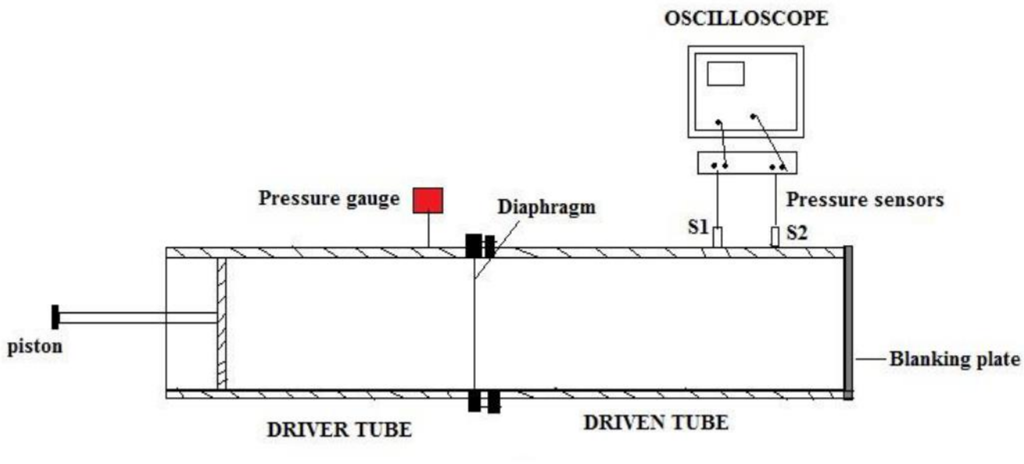
Experimental analysis using Reddy tube:

Aim: 1) To determine the speed of the primary shock wave and determine the mach number. 2) To determine (2) across the primary shock wave and evaluate P_5 and T_5 across the

Reflected shock wave and compare with the calculated values.

Apparatus: Reddy tube, digital pressure gauges, 2 pressure sensors, oscilloscope, diaphragm, blanking plate, a vacuum pump.

Experimental set up:



EXPERIMENTAL SET UP

Procedure:

- The end of the driven tube is closed with a blanking plate the pressure inside the driven section is reduced by connecting it to a vacuum pump and the value is then closed.
- The diaphragm is fitted into the reddy tube, the pressure sensors are connected to the CRO via the coupler and CRO is set for observations.
- The piston is driven hard into the driver tube till the repture sound of the diaphragm is heard. The pressure reading P4 from the pressure gauge in the driver tube is noted.
- Two signals of pressure rise are seen in the CRO display the first one appears when the primary shock passes the first sensor and the second one, when it passes the second sensor.
- From the CRO display, the time taken "t" for the shock to travel between the two pressure sensors is measured the distance x between the two pressure sensors is measured with a graduated scale.
- The experiment is repeated 3 or 4 times and the average value is taken following which the calculations are made.

CALCULATIONS:

1) Evaluation of Mach number M Shock speed of primary shock wave U_s=

   Mach number, M= -

2) Calculation of P_2(First pressure jump)

   Given P_1=1 bar and = 1

P_2=P_1 [1 + ——— ^{2}(^{2}−1)]

+1

3) Calculation of T_2

Given T_1= ambient temperature = 300K

21 = 21 [1(+ (− 1+)1+) 12]

4) Calculations of P_5

52 = (3(−−11)) 1221 + −((+−11))

5) Calculations of T_5

52 = 52 [1(+ (− 1+)1+ 25]

QUESTION BANK

1) What is Mach number? Distinguish between Acoustic, ultrasonic, subsonic and supersonic waves.
2) Describe the Reddy shock tube with the help of neat Diagram
3) State the three conservation laws.
4) Describe the ball milling method and sol-gel method to prepare the nano materials
5) Describe the construction and working of a scanning electron microscope.
6) Give an account of Rankine –Hugoniot equations.
7) Give the graphical representation of density of states with equation for 3D, 2D, 1D and 0D structures.
8) Write a note an carbon nanotubes.

9) What are the properties of carbon nanotubes?

10) Describe arc discharge method of obtaining CNTS with the help of a diagram Write a note on pyrolysis method of obtaining CNTS.