Non-elemental semi conducting materials :-

Besides 'Si' and 'Ge', many intermediate and ceramic compounds exhibit semi conductivity. these compounds are grouped into

① stoichiometric semi conducting compounds
② Defect semiconductors
③ controlled valency semiconductors
④ chalcogen photo conductors.

Q: Explain stoichiometric semi conducting compounds?

A ① **stoichiometric semi conducting compounds :-**

These are intermediate compounds having an average of four valency electrons per atom. these intermediate semi-conducting compounds prepared by combining,

(i) elements of Group-III (Ga, In) and Group-V (P, As, Sb)

(ii) elements of Group-IV (cd, Pb) and Group-VI (S, Se, Te)

For example,

GaAs is a III-V group combination,

Ga - $4s^2 4p^1$ As - $4s^2 4p^3$.

when Ga & As overlap and yield a hybrid band containing 4N electrons per 'N' atoms of Ga and As -

'GaAs' has wide energy gap (E_g) = 1.35 ev.

The energy gap in the stoichiometric semiconductors can be reduced by substituting one of it's element by an element of higher atomic number belong to the same group.

Ex :- GaP - 2.24 ev
GaAs - 1.35 ev
GaSb - 0.67 ev.

Energy gap of GaP - 2.24 ev is reduced to 1.35 ev in GaAs (since at.no. of As is higher than that of 'p' and both belongs to V group). the energy gap can further reduced to 0.67 ev on replacing As with sb.

Q. Explain Defect Semiconductors with examples?

A: ② Defect semiconductors :-

Many non-stoichiometric compounds act as semiconductors. For example, some metallic oxides and sulphides having non-stoichio-metric defects in their crystal structures.

FeO, which is made of Fe^{+2} and O^{-2} ions: on heating, some Fe^{+2} ions are oxidised to Fe^{+3}. For example, a crystal of compound $Fe_{0.90}O$ actually contains $Fe^{+2}_{0.70}Fe^{+3}_{0.20}O$. and Fe^{+3} ion is short by one electron and can considered as a positive hole. under the influence of electric field, the positive holes can move from Fe^{+3} to Fe^{+2}, there by producing electrical conductivity. these non-stoichiometric compounds, can be represented as $M_{(1-x)}Y$ and these metal-ion deficient compounds act as p-type semiconductors. Ex:- FeO, NiO,

when ZnO, is exposed to reducing atmosphere, non-stoichiometric compounds such as $Zn_{1.1}O$ ($Zn^{+2}_{0.9}Zn^{+}_{0.2}O$) are produced. In such compound, Zn^{+} ion is rich by one electron and Zn^{+} ion is capable of donating one electron. Hence, under the influence of electric field, ZnO act as an n-type semiconductor. these metal-ion excess non-stoichiometric semiconductors can be represented as $M_{1+x}Y$.

Q Explain controlled valency semiconductors?

A ③ Controlled valency semiconductors :-

There is one problem with defect semiconductor i.e the difficulty in controlling their conductivity. This limitation of defect-semiconductor is overcome by preparing controlled valency semi-conductor.

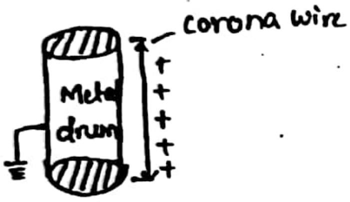
In order to control the concentration of Ni^{+3} ion in NiO and hence it's conductivity, a calculated amount of lithium oxide (Li_2O) is reacted with NiO and cause to form compound $Li_x Ni^{+2}_{1-2x} Ni^{+3}_{x} O$, which exhibit temperature dependent conductivities. such semiconductors are used in thermistors (thermally stable resistors).

Q. Discuss the working of xerox machine in chalcogen semiconductor? (7M)

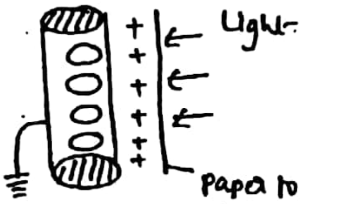
A: ④ chalcogen photo conductors :-

chalcogens (sulphur, Se, Te) on melting give viscous liquids, which quickly form glasses on cooling. chalcogen-based glasses behave as photo conductors. 'Se' is an excellent photo conductor and it's electronic conductivity enhances on exposure to light. the principle of photo conduction is used in xerography (photo copying) process.

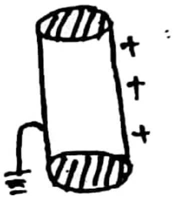
The xerox machine essentially consists of a cylindrical rotating metallic drum with a very thin film of amorphous selenium on it. the photocopying process involves the following steps:



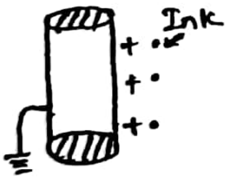
① charging of 'Se' film



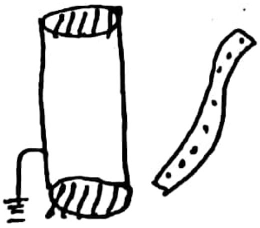
②. Exposure



③ Discharging



④ Developing



⑤ Image transfer

* preparation of semi conductors :- For preparing semi-conducting devices, the basic materials 'Si & Ge' must be pure. for preparation of highly pure Si & Ge, the following methods are used,

1) preparation of pure Si | Ge

2) Doping techniques.

3) cutting into chips.

1) preparation of pure Si/Ge :- This is carried by following methods,

a) Distillation

b) Zone refining

a) Distillation :- It is based on separation of materials due to difference in boiling points (b.p's). The raw materials $GeCl_4$ and $SiHCl_3$ are used for preparation of pure Ge & Si respectively.

pure $GeCl_4$ is obtained, by passing vapours through the fractionating column. pure $GeCl_4$ so, obtained is treated with extra pure water to get GeO_2, which is then reduced (in an atmosphere of Hydrogen) to get elemental germanium, which is then subjected to purification.

Q: Explain zone-refining method of semi conductor ?

A: b) Zone refining :- It is a technique of purification, which involves 're-crystallization', principle of this technique is "impurities are more soluble in the molten than in the solid material".

The following fig. shows a vertical zone refiner, used for the purification of 'Ge'.

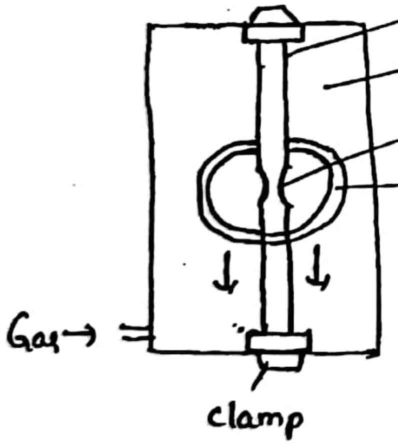


Fig: Zone refining of 'Ge'.

In this method, a rod of 'Ge' is placed vertically and heated by a RF coil to about 1000°c in a reducing atmosphere. when the heating coil moves slowly from top to bottom, the impurities are sweft down with molten material, while the pure 'Ge' rod solidifies at the upper portion. when the purification of upper portion of the rod is complete, the bottom portion of the rod (where impurities are more) is separated.

② Doping techniques :- For getting doped material, calculated amount of dopant ('B' (or) 'P') is added to the molten Si (or) Ge. and the dopants are added in order of 1 atom of 'B' (or) 'P' per 10^8 atoms of Ge (or) Si. Methods used for doping are,

a) Epitaxy
b) Diffusion
c) Ion implantation technique.

a) Epitaxy :- It involves deposition of thin layer of dopants on Si (or) Ge. In this method, Si (or) Ge wafer is placed in a long cylindrical Quartz tube reactor, which is then heated by RF coil. then, gases containing Ge (or) Si mixed with calculated amount of dopant are introduced into the reactor. The heating process is continued, till deposition of dopant over Si (or) Ge wafer.

b) Diffusion :- It involves diffusion of gaseous dopants into semi-conducting material without any melting. The process consists of heating dopants, and this cause dopants to condense on the surface of Si (or) Ge wafer and diffuse.

c) Ion implantation technique :- It involves in bombarding the semi conductor material with an electrically controlled beam of high energy ions of 'B' (or) 'P'. This causes implantation of dopant atoms into the crystal lattice of semi conductor.

③ Cutting into chips :- The wafers obtained by above methods, are then cut into 'chips' by using laser beams etc.

* Semi conductor devices :- semi conductors have unique electrical properties, hence they are used in devices to perform specific electrical functions.

Ex :- Diodes and transistors, which are replaced by old-vaccum tubes.

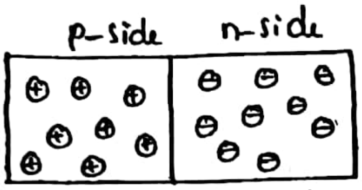
1) p-n junction diode as rectifier

2) Junction transistor.

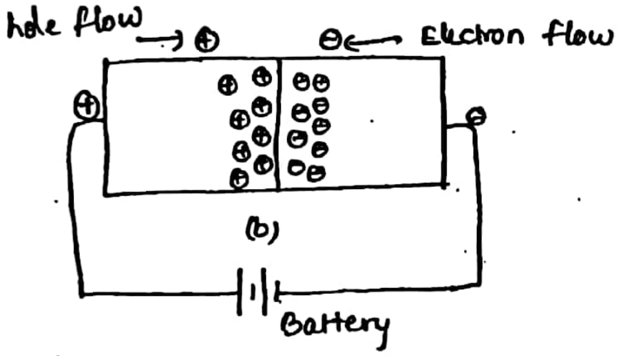
Q. Write notes on P-n Junction diode as rectifier?

A: __P-n junction diode as rectifier__ :- A rectifier is an electronic device that allows the current to flow in one direction only.

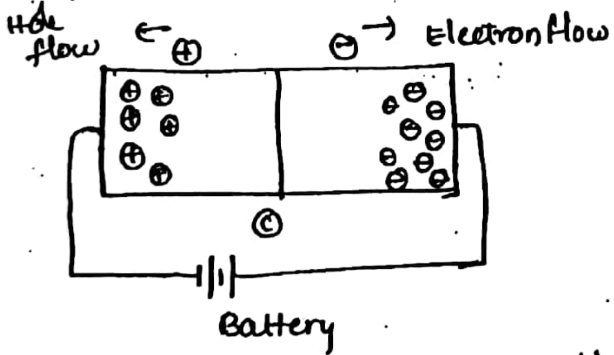
A rectifier transforms an alternating current (A.C) into direct current (D.C).



(a)



(b)



(c)

For p-n rectifying junction, representation of electron and hole distribution.

(a) No electrical potential

(b) forward bias

(c) Reverse bias.

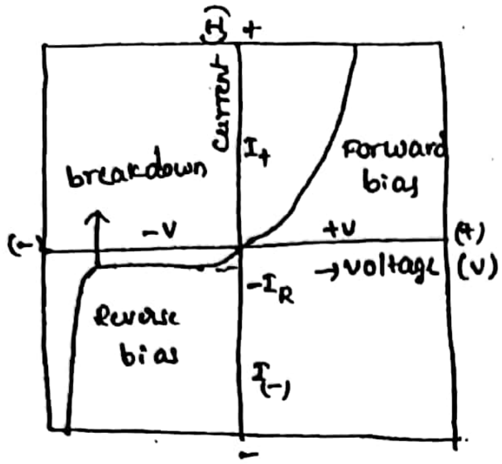
__Forward-biase__ :- when p-terminal (positive) ~~connect~~ of battery is connected to the p-side and the negative-terminal to the n-side, is reffered to as forward bias.

The holes on the p-side and the electrons on the n-side are attracted to the junction.

Electron + hole → Energy.

For this bias, large number of charge carriers flow across the semiconductor and towards the junction, as junction by an appreciable current and a low resistivity.

The current - voltage characteristics of p-n junction for forward and reverse biases,



Reverse bias :- when positive terminal of battery is connected to n-side and negative terminal to p-side, is referred as reverse bias.

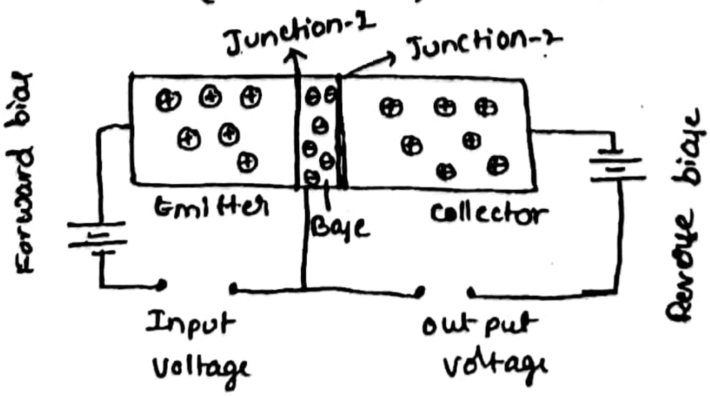
For this bias, both holes and electrons are drawn rapidly away from the junction and the junction is highly insulative.

At high reverse bias voltages, large number of electrons and holes are generated and gives rise to increase in current, this phenomenon is known as 'break down'.

Q. Write notes on P-N Junction transistor? 7M

A:- 2) Junction transistor :- Transistors can amplify an electrical signal.

p-n-p junction transistor is formed when a thin n-type (base) is sandwiched in between p-type (emitter) and (collector) regions. The emitter-base junction (junction 1) is forward biased, whereas base-collector junction (Junction 2) is reverse biased.



The emitter is p-type and junction-I is forward biased, so a large number of holes enter the base region. If the base is extremely narrow, most of the injected holes move through the base without recombination, then across the junction-2 and enter into p-type collector.

A small increase in input voltage within the emitter-base circuit produces a large increase in voltage across junction-2.

* Magnetic materials :-

Every substance has some magnetic property. The origin of property lies in the electrons. Each electron in an atom behaves like a tiny magnet.

Q. What are Ferro and Ferri magnetism ? Give examples.

A: Ferromagnetism :- Substances like Iron, cobalt, Ni, are attracted very strongly by a magnetic field. Such substances are called ferromagnetic substances. and these substances are permanently magnetised.

. In solid state, the metal ions of ferromagnetic substances are grouped together into small regions called 'domains' and each domain acts as a tiny magnet. In an un-magnetised piece of a ferromagnetic substance, the domains are randomly oriented and net magnetic moments are non-zero.

. When the substance is placed in a magnetic field, all the domains oriented in the direction of magnetic field and a strong magnetic effect is produced. This ordering of domains persist even when magnetic field is removed and ferromagnetic substance becomes a permanent magnet.

Ferrimagnetism :- Ferrimagnetism is observed when the magnetic moments of the domains in the substance are alligned in parallel and anti-parallel directions in unequal numbers. They are weakly attracted by magnetic field as compared to ferro magnetic substances. Fe_3O_4 (magnetite) and ferrites like $MgFe_2O_4$ and $NiFe_2O_4$ are examples of such substances. These substances lose ferri magnetism on heating and in the absence of magnetic field.

(a) ↑ ↑ ↑ ↑ ↑ ↑ – Ferro magnetic

(b) ↑ ↓ ↑ ↓ ↑ ↑ – Ferri magnetic.

~~Hall effect~~

Q. what are Insulators? Explain Thermal Insulators?

A: **Insulators :-**

Insulating materials are the substances which resist the flow of heat, sound and electricity through them.

There are two types of insulators,

① Thermal insulators

② Electrical insulators. (or) Di electrics.

thermal insulators :- They resist the flow of heat.

Ex:- asbestos, glass wool, Fibre board, foamed polystyrenen etc.

" A substance that reduces the rate of transfer of heat between objects in thermal contact, is a thermal insulator".

A thermal insulating material is placed between a warm region and a cooler region to reduce the rate of heat flow to the cooler region.

properties :- A thermal insulator should have,

(a) Thermal stability
(b) Dimensional stability
(c) chemical stability
(d) light in weight
(e) Non inflammable and water proof.

Applications :- Thermal insulators are used in

(a) Buildings

(b) Industries

(c) Space crafts.

Q Explain Electrical insulators?

A ② Electrical insulators (or) Di electrics :-

These are also called as di electrics and these materials resist the flow of electric current.

Some materials such as glass, paper and teflon have high resistivity are regarded as good electrical insulators.

characteristics :-

(a) They possess low conductivity.

(b) They have high di-electric strength.

(c) They should have low thermal contraction and expansion.

(d) They should be resistant to chemicals, solvents, acids and alkalis etc.

(e) should have low porosity.

(f) They should have high mechanical strength and tensile strength

Ex :- ⓐ Gaseous electrical insulators – SF_6.

ⓑ liquid electrical insulators – oils, chlorinated hydro carbons.

ⓒ solid electrical insulators – Glass, Synthetic rubber, paper, poly ester etc.

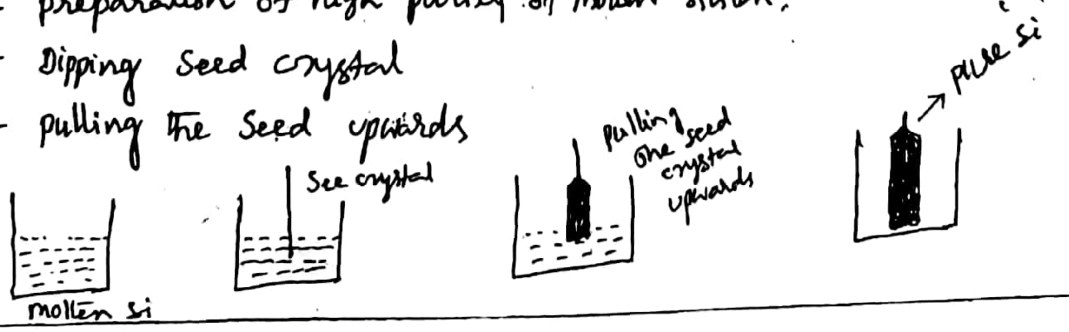
Q Explain CZOCHRALSKI process of Si wafer's?

A:- It is a step wise process, to preparation of Si

step :1 - preparation of high purity of molten silicon.

step : 2 - Dipping Seed crystal

step : 3 - pulling the Seed upwards



— THE END —

CSE-A & B , EEE , IT

UNIT – 3
PART - II

Nanomaterials: A nanomaterial is defined as a material having at least one dimension in the nanometer range. Nanoparticles have great scientific interest because they are effective intermediates between bulk materials and atomic or molecular structures. A bulk material should have constant physical properties irrespective of its size, but at the nano-scale this is always not the same.

Size-dependent properties such as quantum confinement in semiconductor particles, surface Plasmon resonance in some metal particles and super Para magnetism in magnetic materials.

Q1) Explain the Sol-gel process for the preparation of Nanomaterials?

Sol-Gel process: The sol-gel process is an example of bottom-up process and is very long known since the late 1800s. Sol-gel is a chemical solution process used to make ceramic and glass materials in the form of thin films, fibers, or powders. A sol is a colloidal (the dispersed phase is so small that only Van der Waals forces and surface charges are present) or molecular suspension of metal or metalloid dispersed in a solvent. A gel is a semi-rigid mass that forms when the solvent from the sol begins to evaporate and the particles or ions left behind begin to join together in a continuous network.

$$M - OR + H_2O \rightarrow M - OH + R - OH \ (Hydrolysis)$$

$$M - OH + RO - M \rightarrow M - O - M + R - OH \ (Condensation)$$

- The sol-gel process is a wet-chemical technique that uses either a chemical solution (sol) or colloidal particles (sol for nanoscale particle) to produce an integrated network (gel).
- Metal alkoxides and metal chlorides are common starting materials. They undergo **hydrolysis and polycondensation reactions** to form a colloid, a system composed of nanoparticles dispersed in a solvent which is generally an alcohol. The sol evolves then towards the formation of an inorganic continuous network containing a liquid phase (gel).
- Formation of a metal oxide involves connecting the metal centers with oxo (M-O-M) or hydroxo (M-OH-M) bridges, therefore generating **metal-oxo or metal-hydroxo polymers** in solution.
- After a drying process, the liquid phase is removed from the gel. Then, a thermal treatment **(calcination)** may be performed in order enhance mechanical properties.

Advantages: (i) Able to get uniform and controlled size of nanoparticles. (ii) Can be carried out at low temperatures and can have better control over the reactions.

Q2) How nano-materials are characterized using BET, TEM and SEM methods?

- The characterization of nanoparticles can be done by using BET, SEM and TEM methods.

1. **Brunauer Emmett Teller (BET) method:** This method is used to determine Specific surface area (m^2/g) of nanoparticles by the absorption of an inert gas (typically N_2) on the surface.

   Working: The sample is weighed and placed into a vacuum chamber to remove moisture and absorbed gases. The sample is then cooled down to a constant temperature by means of liquid nitrogen. N_2 gas is adsorbed on the sample surface. From the amount of gas adsorbed at a given pressure an adsorption isotherm is derived. The BET theory is then used to determine the amount of gas necessary to form a monolayer on the surface, also called the monolayer capacity. From the monolayer capacity, the specific surface area in m^2/g can be calculated. Other inert gases, such as Ar or Kr, can also be used.

   Note: Dry samples required. Fast and relatively cheaper method.

2.Transmission Electron Microscopy (TEM): This method is used to determine primary particle size, aggregate (particle size) and agglomerate size of nanoparticles.

Working: Transmission electron microscopy (TEM) is a technique involves a beam of electrons is transmitted through a thin sample. An image is formed from the interaction of the electrons transmitted through the sample, the image is magnified and focused onto an imaging device such as a fluorescent screen, for viewing the sample, or onto photographic film, for a record of the sample. Areas of dense material (such as solid nanoparticles) absorb the electrons and appear as dark areas on the viewing screen. Less dense material (such as coating around the nanoparticles) allows the electrons to pass through more freely and appear as lighter areas. Typically a final image will be 200,000 times normal magnification and the TEM is capable of achieving a magnification as high as 1 million, but the quality of the image decreases as magnification increases.

3. **Scanning Electron Microscopy** (SEM): is a test process that scans a sample with an electron beam to produce a magnified image for **analysis**. The method is also known as SEM **analysis** and SEM microscopy, and is used very effectively in microanalysis.

SEM is a method for high resolution surface imaging. The SEM uses electrons for imaging, much as light microscopy uses visible light. The advantages of SEM over light microscopy include greater magnification (up to 100,000X) and much greater depth of field. A random straight line is drawn though the micrograph. The number of **grain** boundaries intersecting the line are counted. The average **grain size** is found by dividing the number of intersections by the actual line length. Average **grain size** =1/(number of intersections/actual length of the line). TEM give information about the internal structure of a sample, but can only produce a 2D image of a small area, where as SEM is better of 3D surface morphology. TEM would be useful for imaging protein molecules, for example, and SEM would more likely be used to look at the surface features on a cell membrane.

Q3) Give the preparation, properties and applications of Carbon nano tubes?

Carbon nanotubes (CNTs): Carbon nanotubes are composed of carbon atoms linked in hexagonal shapes, with each carbon atom covalently bonded to three other carbon atoms. Carbon nanotubes have diameters as small as 1 nm and lengths up to several centimeters. Carbon nanotubes are strong, they are not brittle. They can be bent, and when released, they will spring back to their original shape.

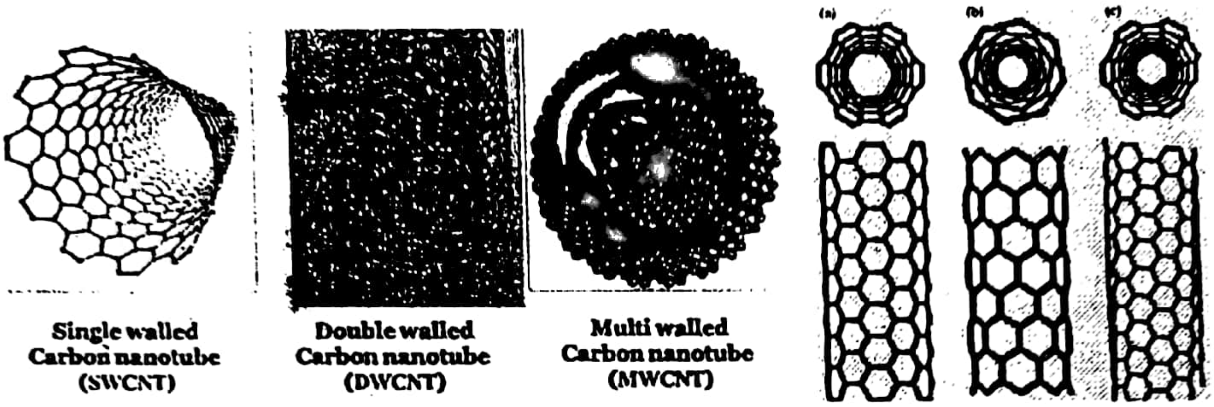
The cylindrical allotropes of carbon having length to diameter ratio 1 lakh times are called Carbon Nano Tubes.

These sheets can be tightened (rolled) into different form, which have different (mechanical) properties. The names for these twisted forms are: (a) **Armchair**, (b) **Zigzag**, and (c) **Chiral.**

Depending on the number of layers present, carbon nanotubes are classified into three types.

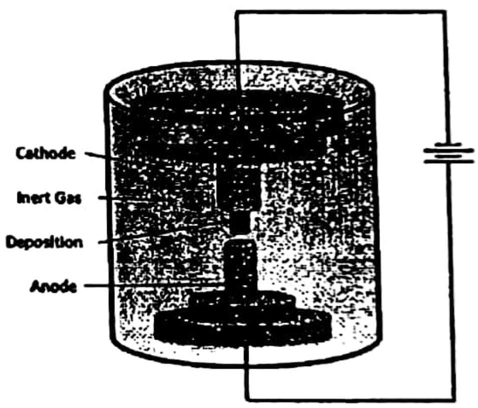
1. single-walled nanotubes (SWNTs),
2. Double-walled nanotubes (DWNTs), and
3. Multi-walled nanotubes (MWNTs).

Single-wall carbon nanotubes (SWNTs) are a special class of carbon materials known as one-dimensional materials. They consist of sheets of graphene, rolled up to form hollow tubes with walls one atom thick. Much like graphene, SWNTs have properties that differ considerably to those of bulk carbon (e.g. graphite). Due to its chemical structure and dimensional constraints, this material exhibits exceptional mechanical, electrical, thermal, and optical properties.

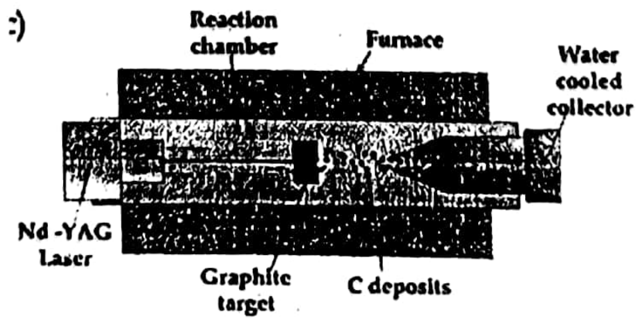


Synthesis of Carbon nanotubes: Carbon nanotubes can be synthesized by using the following methods.

1. **Arc-discharge method:** This method was first used by Sumio Iijima in 1991, this technique is also used for the synthesis of fullerenes. The experiment is carried out in a reaction vessel containing an inert gas such as helium, argon, etc. at a constant pressure. A potential of around 18 V (50-100 A) is applied across two graphite electrodes separated by a short distance of usually 1–4 mm within this chamber. As a result, carbon atoms are ejected from the anode and are deposited onto the cathode. The black carbonaceous deposit containing CNTs is seen growing on the cathode. The produced CNTs will have fewer structural defects, better electrical, mechanical and thermal properties. The synthesis product yield is 60%.

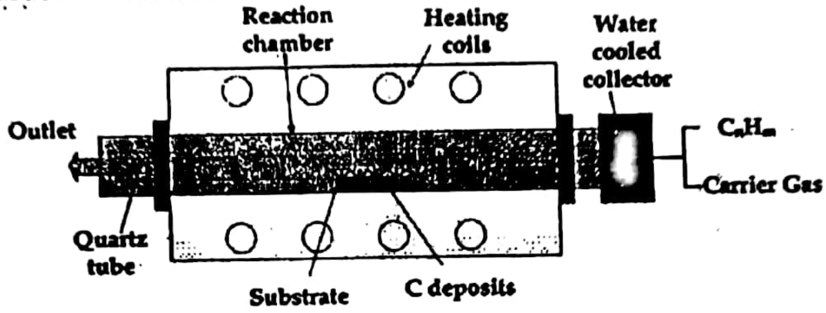


2. **Laser ablation method:** This process was developed by Dr. Richard Smalley and co-workers at Rice University in 1955. In laser ablation, a pulsed laser vaporizes a graphite target at 1200 °C in a high-temperature reactor while an inert gas like helium or argon is sent into the chamber. A water- cooled Cu surface may be used to collect the vaporized carbon as nanotubes by condensation.



The laser ablation method yields around 70% and produces mainly contains single-walled carbon nanotubes with a controllable diameter. However, it is more expensive than either arc discharge or chemical vapor deposition.

3. **Chemical Vapour Deposition method:** The chemical vapour deposition method (CVD) is an alternative method in which CNTs are developed on metal catalyst surface like Ni, Co, Fe, etc. and their alloys. The gaseous hydrocarbon like methane (CH_4) or ethane (C_2H_6) along with a carrier gas like nitrogen, helium or argon are sent into the reaction chamber at 700° C. The CNTs grow at the surface of the metal catalyst surface by dissociation of hydrocarbon molecules. Use of catalysis reduces the need for high temperatures. Very high yields (90%) are reported by using this method. CVD is the most widely used method for the commercial production of carbon nanotubes.



Properties of Carbon Nanotubes:

1) Carbon nanotubes are one dimensional conductor along the tubular axis with conductivity either metallic or semiconducting nature.
2) Carbon nanotubes are the strongest and stiffest materials due to presence of covalent sp^2 bonds between the individual C atoms.
3) CNTs are highly flexible- can be bent considerably without damage
4) CNTs are very elastic ~18% elongation to failure
5) CNTs have high thermal conductivity along the axis but these are good insulators lateral to the tubular axis.
6) CNTs have a low thermal expansion coefficient.
7) CNTs are good electron field emitters.
8) MWCNTs possess kinetic properties with inner nanotube core may slide without friction, within its outer nanotube shell, thus creating an atomically perfect linear or rotational bearing.
9) CNTs have good optical properties due to absorption, fluorescence, Raman spectroscopy.

Applications of Carbon Nanotubes:

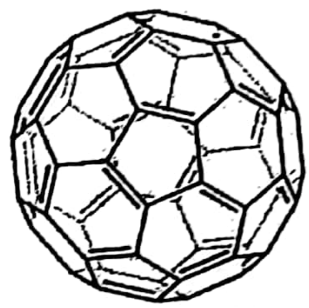
1) Because of superior mechanical properties, CNTs are used to make space elevators, bullet-proof clothing.
2) CNTs are used for producing field effect transistors provided with digital switching.
3) These are also used for making polymer nano composites used for making wires and cables.
4) CNTs are used to make paper batteries which can provide stable output comparable to conventional batteries.
5) CNTs are used to prepare solar panels due to their strong UV-Vis, near IR radiation.
6) There are used in fuel cells to store fuel like hydrogen.
7) CNTs are used in treatment of cancerous cells by exciting with radio waves.
8) Because of the high surface energy, CNTs are used in catalysis.

Q4) Explain the properties and applications of Fullerenes.

C_{60} is most studied fullerene due to its availability, high symmetry and low price. In 1985, James R. Heath, Robert Curl and Richard Smalley, from Rice University discovered C_{60}, and shortly thereafter came to discover the fullerenes. Buckminster fullerene (C_{60}) was named after Richard Buckminster Fuller, a noted architectural modeler who popularized the geodesic dome.

Definition:The spherical alltropes of carbon containing 60 carbon atoms are called fullerenes.

Fullerenes are closed hollow cages consisting of carbon atoms interconnected in pentagonal and hexagonal rings. Each carbon atom on the cage surface is bonded to three carbon neighbors therefore is sp^2 hybridized.



- In fullerenes, 12 pentagonal rings are necessary and sufficient to affect the cage closure.
- Fullerenes contain carbon atoms arranged as a combination of 12 pentagonal rings and n hexagonal rings.
- Fullerene cages are about 7-15 Å in diameter, and are one carbon atom thick.
- The chemical formula is C_{20+2n}.

Types of Fullerenes:

i. **Buckyball clusters:** smallest member is C_{20} (unsaturated version of dodecahedrane) and the most common is C_{60}.

ii. **Nanotubes:** Hollow tubes of very small dimensions, having single or multiple walls.

iii. **Megatubes:** Larger in diameter than nanotubes and prepared with walls of different thickness.

Preparation of fullerenes: The fullerenes were prepared by evaporation of carbon electrodes in an electric arc discharge process in helium atmosphere. In a chamber, an electrical discharge is applied between graphite electrodes in Helium atmosphere at 100 torr. As a result, soot is ejected from the graphite and is deposited inside the chamber. The resulting soot is scraped from the evaporation chamber and dissolved in benzene. Further separation and purification leads to C_{60} in gram scale.

Properties of C_{60} and its derivatives:

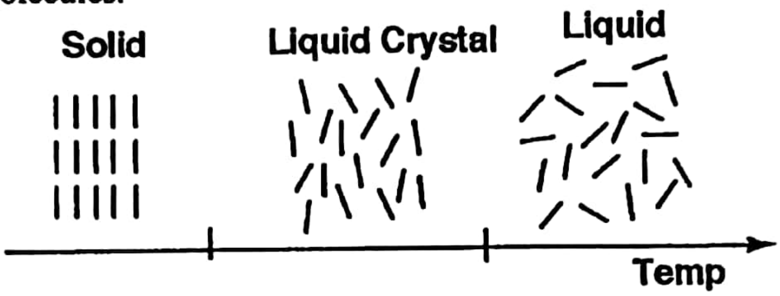
1. Fullerenes are sparingly soluble in many solvents. Common solvents for fullerenes are toluene, CS_2, benzene, CH_2Cl_2, etc.
2. Fullerene is a black crystalline solid and is thermally stable up to 400 °C.
3. When doped with alkali metals, they act as conductors and superconductors.
4. Fullerenes are very difficult to oxidize but can easily reducible.
5. Because of presence of unsaturation, fullerenes show broad UV-vis absorption.
6. Fullerenes behave like an electron deficient alkenes and reacts readily with electron rich species and acts as acceptors of electrons and electronic energy.

Applications of fullerenes:

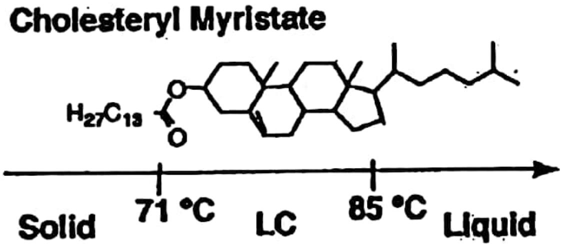
1. Fullerenes have been extensively used for several biomedical applications including MRI, X-Ray imaging, drug and gene delivery.
2. Bucky balls may be used to store hydrogen, possibly as a fuel tank for fuel cell.
3. They inhibit the spread of the HIV virus and are used in treatment of HIV.
4. Fullerenes are chemically reactive and can be added to polymer composites with specific physical and mechanical properties.
5. Fullerenes are also used to produce inexpensive solar cells.
6. These are used in several applications like coatings, lubricants, catalyst, electronic and optical devices.

Q5) Give the types and applications of Liquid crystals?

Liquid crystal is a state that occurs between a solid & a liquid. They possess properties characteristics of both liquids & crystalline solids. It also possesses properties not found in either liquids or solids. A fluid phase in which a liquid crystal flows and will take the shape of its container. It differs from liquid that there are still some orientational order possessed by the molecules.

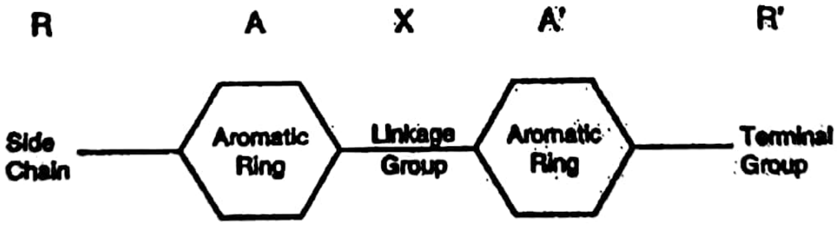


Liquid crystals are discovered in 19th century when studying a cholesterol derivative.



Orientational Order: Assuming that the direction of preferred orientation in a liquid crystal is ↑, this direction can be represented by an arrow, called the ***director*** of the liquid crystal.

Criteria for a molecule being liquid crystalline: The molecule must be elongated in shape-length should be significantly greater than its width. Molecule must have some rigidity in its central region. The ends of the molecule are somewhat flexible.



Types of Liquid Crystals: The liquid crystal state can be attained either by the action of heat or by action of solvent on amphiphilic systems. These are classified into two types.

1. ***Lytropic Liquid Crystals:*** LC phases formed by dissolving the compound in an appropriate solvent (under given concentration and temperature conditions) are known as lyotropic LCs.

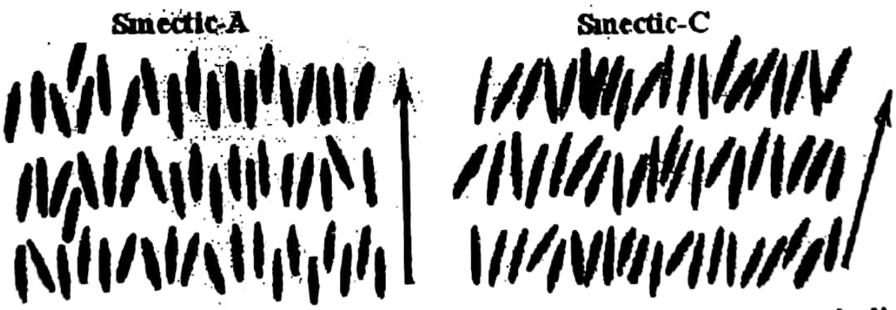
2. ***Thermotropic Liquid Crystals:*** The liquid crystal phases obtained by changing the temperature are called thermotropic LCs.

Thermotropic LCs are further classified into three types

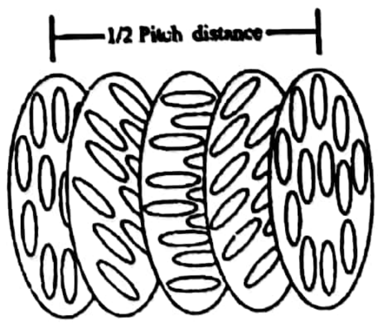
A **Nematic Phase:** One of the most familiar liquid phase phases is the nematic. The word *nematic* derived from the Greek word, *„nema"* which means "thread". In nematic phase molecules have same direction in space but change the order.

B **Smectic Phase:** "Smectic" is a Greek word which means soap. This is just like a slippery soap which is present in the lower side of soap dish. In the smectic state, the molecules are arranged in layers or planes they show general structural order in nematics. Some compound are develop many types of smectic phase.

- ***Smectic-A:*** In smectic-A, there is parallel position of director and smectic plane. The orientation of molecules is disturbed in the plane.
- ***Smectic-B:*** In mesophase, orientation of molecules are just like a smectic A, the molecules are arranged in layer which form hexagonal structure.
- ***Smectic-C:*** In mesophase, molecules are oriented as same order A, B but in smectic-c smetic having a tilted angle between molecular alignment and the surface of the layer, the phase is measure by rotation of angle.



C **Cholesteric Phase:** These types of liquid are also known as chiral nematic liquid crystal. Like the nematic phase, the molecules in this phase are also parallel to each other within layers. The director axis changes regularly in nature to form a helical structure. This regular change is called pitch. The pitch changes with temperature and by the boundary conditions.
Eg: Hydroxypropyl cellulose and cholesteryl benzoate.



Applications of liquid crystals:

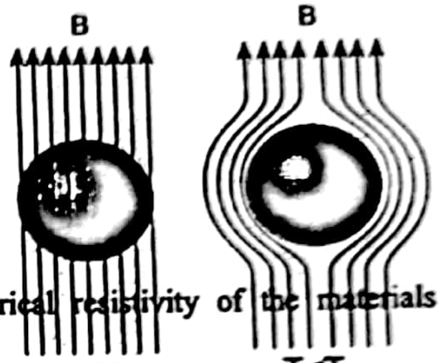
1. These are used in Liquid Crystal Displays (LCDs).
2. These are used in Liquid Crystal Thermometers.
3. These are used in Helmets and Bullet-proof vests.
4. These are used in Battery testing strips (used by DuraCell).
5. These are used in Radiation and Sensors.
6. These are used in Switchable Light Panels for windows.

7. These are used in In Optical Memories.
8. These are used in solvents for GC, NMR, reactions, etc.
9. These are used in Biological systems and medicine.

Superconductors

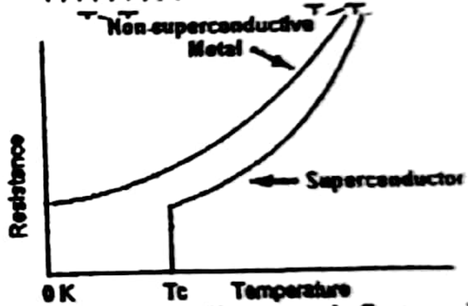
Q1) Explain the Meissner effect.

1. When Superconducting material cooled bellow its critical temperature (T_c), it becomes resistance less and perfect diamagnetic.
2. When superconductor placed inside a magnetic field in (T_c), all magnetic flux is expelled out of it the effect is called Meissner effect.
3. Perfect diamagnetism arises from some special magnetic property of Superconductor.
4. If there is no magnetic field inside the superconductor relative permeability or diamagnetic constant μ_r=0.



Q2) What are SuperConductors and their types.

Superconductors: The phenomenon in which the electrical resistivity of the materials suddenly falls to nearly zero when it is cooled to a very low temperature is known as ***superconductivity***, and the materials under this condition are called ***super conductors***.



Super conductors are classified into two types:

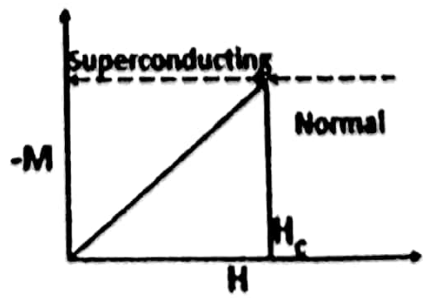
1. Type-I super conductors or Soft super conductors, and
2. Type-II super conductors or Hard super conductors.

1. **Type-I Super conductors or Soft super conductors:** These were discovered first and usually consist of pure metals, elemental metals and not alloys, they show some conductivity at room temperature. These were discovered first and usually consist of pure metals. Type-1 superconductors are also called as the "soft" superconductors. When the magnetic field is applied on a super conductor and increased gradually, the inverse magnetization increases linearly up to a certain value called critical field (Hc) and then sharply falls to zero.

   i. Type-I super conductors have only one critical field.

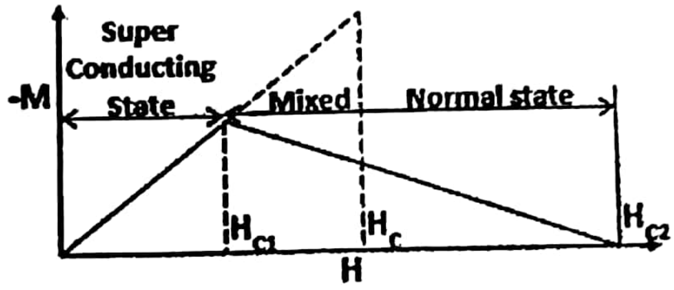
   ii. These exhibit complete Meissner effect.

   iii. The values of Hc are too low to have any useful magnetic applications.



2. **Type-II super conductors or Hard super conductors:** Type-2 superconductors are also known as the "hard" superconductors. In Type-2 superconductors, the transition from a superconducting state to a normal does not occurs sharply but is occurs through a mixed

region. When magnetic field is applied on a super conductor and increased gradually, the inverse magnetization increases linearly up to a certain value called first critical field (Hc1). From theis point, the penetration of magnetic field into type-2 super conductor begins. After another value of magnetic field called second critical field (Hc2) or vortex region, the superconductivity disappears and material returns to the normal state.



i. Most of these are developed from alloys, ceramics, transition metals, etc.
ii. These do not exhibit complete Meissner Effect.
iii. The transition between super conducting and normal state is not sharp.
iv. They have higher T_cs than Type 1 superconductors.

Properties of superconductors:

1. Superconductors offer more resistance than other elements at room temperature.
2. Critical temperature of super conductor is low when a small amount of impurity is added.
3. The superconducting state will be lost in the presence of a magnetic field greater than a critical value, even at absolute zero.
4. In superconducting state, the material becomes diamagnetic.
5. The thermal expansion and elastic properties of material remain unchanged during phase change from normal to superconducting state.

Applications of superconductors:

1. Superconductors were used to build experimental digital computers.
2. They are used in diagnostic tools like MRI in the field of medicine, NMR machines, and mass spectrometers.
3. They are used in transformers, power storage devices, electric power transmission to transmit power over long distances without resistive loses.
4. They are used in electric motors (e.g. for vehicle propulsion, as in bullet trains), magnetic levitation devices, etc.
5. These can be used as memory and storage devices in computers.
6. These can be used in wind turbines, the lower weight and volume of superconducting generators could lead to minimize construction and tower costs.
7. Some super conductors are acts as excellent catalyst for industrial process.
8. For computers, super chips made up of superconductors can function 1000 times faster than silicon chips.