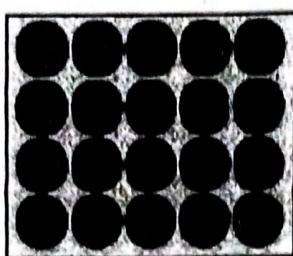


**UNIT -2****MODERN ENGINEERING MATERIALS****BAND THEORY OF SOLIDS****❖ BAND THEORY OF SOLIDS**

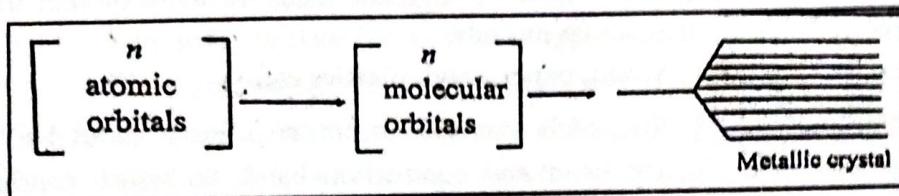
The band theory may be considered as the MOT of covalent bonds extended to solids. That is this theory is an extension of molecular orbital treatment for large number of atoms.

**Salient features of band theory :**

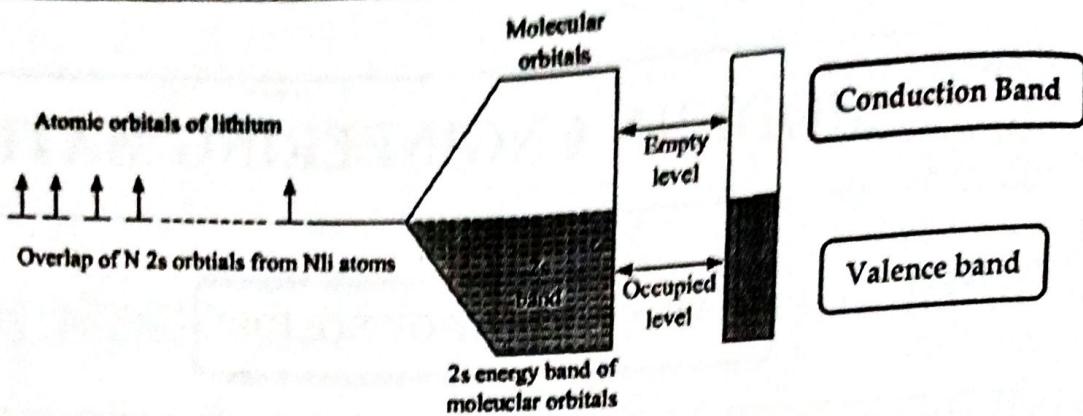
1. In Solid crystals, a large number of spherical atoms are arranged in a regular close-packed pattern in the form of crystal



2. When atoms are brought together in solids, the atomic orbitals of the valence shells interact forming molecular orbitals.
3. In solids,  $n$  atomic orbitals combined together to form  $n$  molecular orbitals.



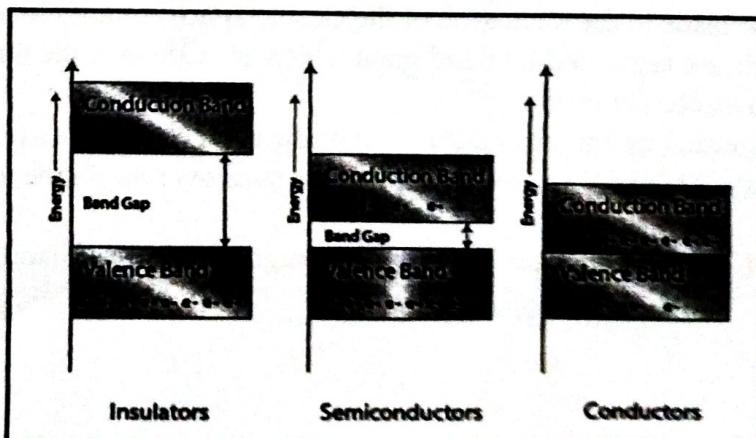
4. The difference in the energy between various molecular orbitals will be very small.
5. These lead to the formation of the closely spaced energy levels called bands.
6. Bands are separated by band gaps which are values of the energy for which there is no molecular orbital.
7. Depending upon the composition of the solid, the bands are of two types.
  - a) Overlapping bands: The higher bands overlap on the lower band to some extent
  - b) Non-overlapping Bands : The higher and lower bands separate and do not overlap.



8. **Valence Band:** The band which is completely (or) partially filled by the electrons is called Valency Band
9. **Conduction band :** The band which contains the empty molecular orbitals is called Conduction band. It is always above the valency band.
10. **Forbidden Zone:** The gap between the Valence band and the conduction band is called the forbidden gap. The width of the forbidden gap is called energy gap ( $E_g$ ).

**Classification of Metals :** On the basis of band theory, solids can be broadly classified into three categories, They are insulators, semiconductors and conductor.

1. **Conductors :** In which the valence band and conduction band are actually overlap on each other. i.e., there is no gap between the valency band and conduction band. Therefore, without any heat energy, a small potential difference across conductors causes electric current.
2. Ex: Ag, Cu, Au, Al etc., metals
3. **Insulators :** In which the valence band and the conduction band, are separated by large extent of forbidden zone about 5 eV and more. So the electrons can not promote from valency band to conduction band at ordinary temperature. Hence, current does not flow through the insulator even though the potential difference is applied across its ends.  
Ex: Rubber, glass, wood, paper, sand, plastics etc.,
4. **Semiconductors :** In which a narrow forbidden zone is about 1 eV is present between the valency band and conduction band. So which conduct directly under suitable conditions  
Ex: Silicon and Germanium



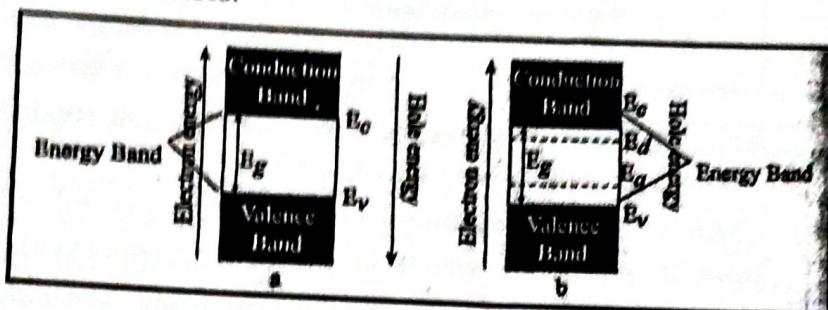


## LITTLE OF DOPING ON BAND STRUCTURE

1a)

**Doping :** The process of incorporating of other desired atoms (impurities) in a crystal lattice to convert semiconductors as conductors at room temperature is called *doping* and the atoms are called *doping atoms*.

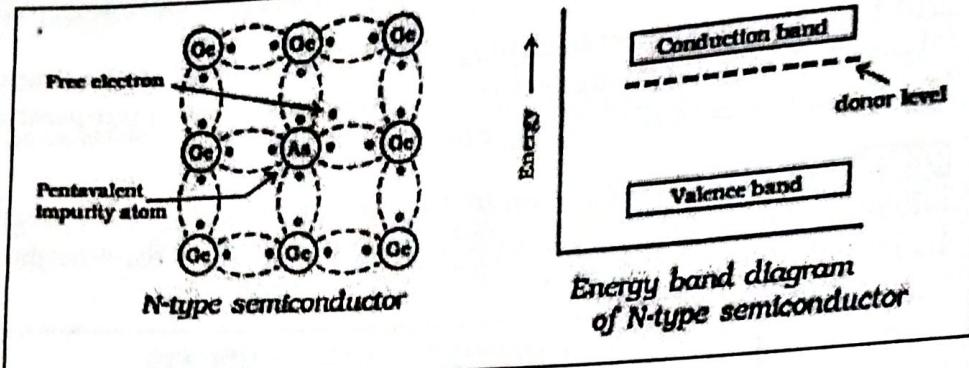
**Role of Doping :** The addition of doping agents reduce the energy gap ( $E_g$ ), thereby allowing the more electrons to flow from the valence band to the empty conduction band in the semi-conductors.



**Types of Semiconductors on the basis of Doping :** Silicon and Germanium act as semi-conductors. They exhibit conductivity upon addition of impurities (Doping) as V-group element (P, As or Sb) and III group elements (B or Al). On the basis of doping process Semiconductors are classified two types.

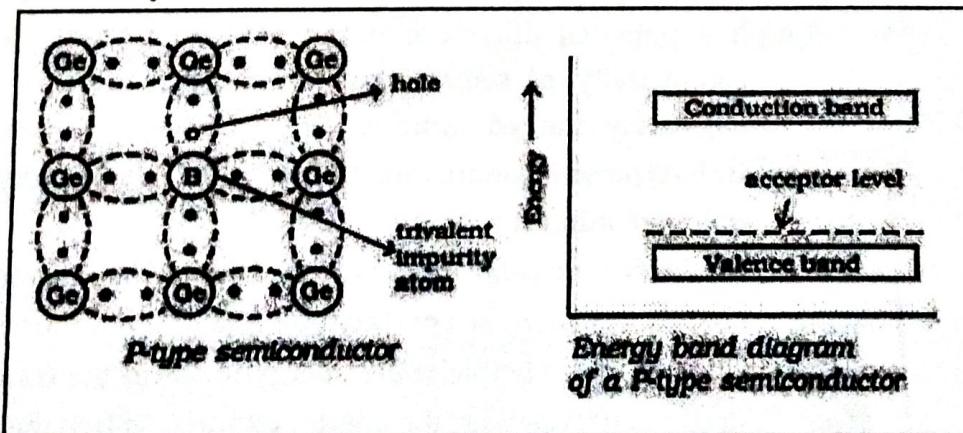
1. **n-type semiconductors:** Semi-conductors which exhibit conductivity due to the flow of excess negative electrons are called n-type semiconductors.

- Consider the small amount of arsenic impurity (Called donor impurity) from V<sup>th</sup> group of periodic table is added to pure Germanium crystal.
- Each atom of 'As' has five valence electrons, out of these, four electrons form four covalent bonds with neighboring germanium atoms and in each 'As' atom one-electron is free which is loosely bounded by arsenic.
- The small amount of impurity consists of large number of atoms and therefore, there will be large number of free electrons.
- If a potential difference is applied to such crystals then the electrical conductivity of semiconductors increases due to electrons which are negatively charged particles. Hence, it is called n-type semiconductors.
- In N-type semiconductors, the electrons are majority charge carriers and holes are minority charge carriers.
- In the N-type semiconductor, the effect of doping creates an energy level slightly less than the conduction band called donor energy level.
- The difference between the energy levels of the conducting band and the donor energy level is the energy required to free the fifth valence electron. This leads to enhance conductivity



2. **p-type semiconductors:** Semi-conductors which exhibit conductivity due to the positive holes are called p-type semi-conductors.

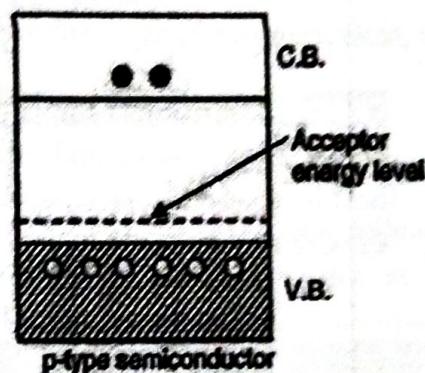
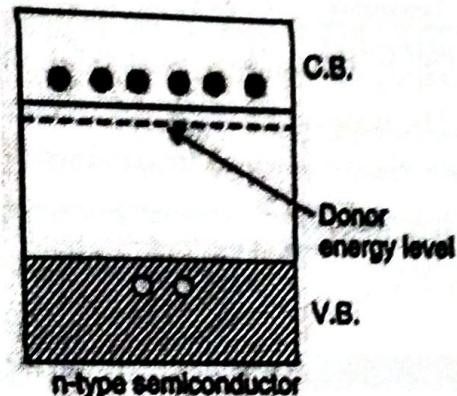
- Consider the small amount of impurity (accepter impurity) like boron (B) from III<sup>rd</sup> group of periodic table is added to pure Germanium crystal
- Each atom of boron has three valence electrons. These electrons form three covalent bonds with neighboring germanium atom.
- Around each 'B' atom, there is absence of electron called as hole. The small amount of impurity consists of large number holes.
- If a potential difference is applied to such crystals then the electrical conductivity is increases due to holes which are positive charg. Hence, it is called as p- type semiconductors.
- In P-type semiconductors, the holes are majority charge carriers and electrons are minority charge carriers.
- In the P-type semiconductor, the effect of doping creates an energy level just above the valence band called acceptor energy level.
- Since, the energy difference between acceptor energy level and the valence band is much smaller, electrons from the valence band can easily jump into the acceptor level by thermal agitation. This leads to enhance conductivity





## DIFFERENCES BETWEEN N-TYPE AND P-TYPE SEMICONDUCTORS

S.No	N-type Semiconductors	P-type Semiconductors
1	It is obtained by doping pentavalent impurity like P, As, Sb, Bi etc.,	It is obtained by doping trivalent impurity like B, Al, In, Ga etc.,
2	The impurity is called donor impurity.	The impurity is called acceptor impurity
3	It is donor type semiconductor.	It is acceptor type semiconductor
4	The electrons are the majority carriers.	The holes are the majority carriers
5	The holes are the majority charge carriers.	The electrons are the majority charge carriers.
6	The density of electron is very high than the density of hole ( $n_e >> n_h$ ).	The density of the hole is very high than the density of electron ( $n_h >> n_e$ )
7	The majority of charge carriers move from low potential to high potential	The majority of charge carriers move from high potential to low potential..
8	It has donor energy levels very close to the conduction band.	It has acceptor energy levels very close to the valence band



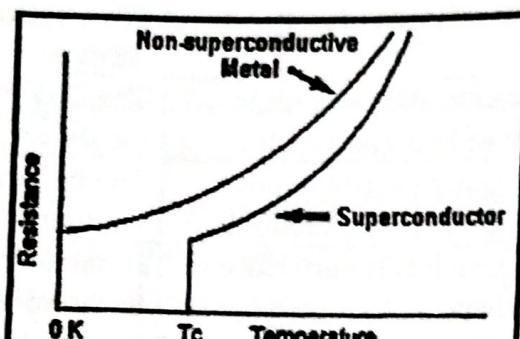
### WHY P-TYPE SEMICONDUCTORS HAVE LESS CONDUCTIVITY THAN N-TYPE SEMICONDUCTOR?

As, we know that electrical conductivity depends on the mobility of charge carriers. In p-type semiconductors the charge carriers are holes and the holes having lesser mobility than that of electrons this is because electrons are free carriers and are present in the conduction band where they are not bounded but holes are in valence band and not free. So p-type semiconductor have less conductivity.

## SUPERCONDUCTOR MATERIALS

### ❖ SUPERCONDUCTORS

**Super Conductors :** An element, inter-metallic alloy or compound that will conduct electricity without resistance below a "critical temperature. ( $T_c$ )" This phenomenon is called "*Superconductivity*". This phenomenon was first of all discovered by H. K. Onnes in 1911 when measuring the electrical conductivity of metals at low temperatures.



*Superconductor Graph*

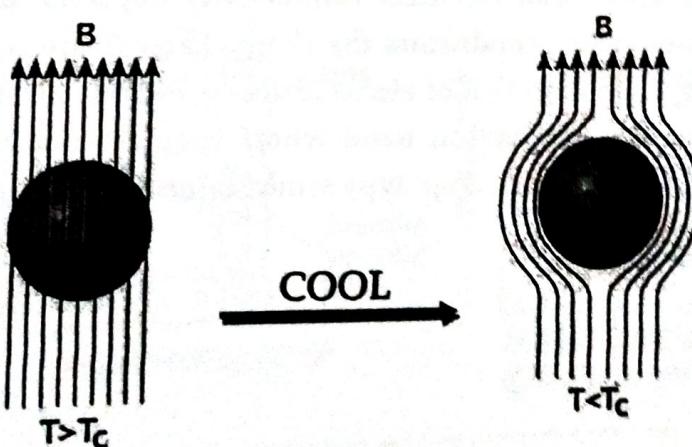
**Critical or transition temperature ( $T_c$ ) :** The temperature at which the transition from normal state to superconducting state takes place on cooling in the absence of magnetic field is called critical temperature or transition temperature.

**Ex :** Critical temperature for various materials: Aluminium : 1.2 K , Indium : 3.4 K , Mercury: 4.2 K, Lead : 7.2 K

### MEISSNER EFFECT

The Meissner effect was first discovered by *Meissner* and *Ochsenfeld* in 1933.

**Definition :** When a weak magnetic field is applied to a superconducting specimen at temperature below transition temperature(  $T_c$ ), the magnetic flux lines are expelled. The specimen act as a ideal diamagnet. This effect is called "*Meissner effect*"



**Explanation:**

Under normal state the magnetic induction inside the specimen is

Where  $H$  = External applied magnetic field

$B = \mu_0 (H + I)$

$I$  = Magnetization produced inside the specimen.

When the specimen is in superconducting state  $B = 0$  (Meissner effect)

$$0 = \mu_0 (H + I)$$

$$\Rightarrow H = -I$$

$$\therefore \chi = -\frac{I}{H} = -1$$

Thus the material acts as a perfectly diamagnetic (for diamagnetic material  $\chi = -1$ ).

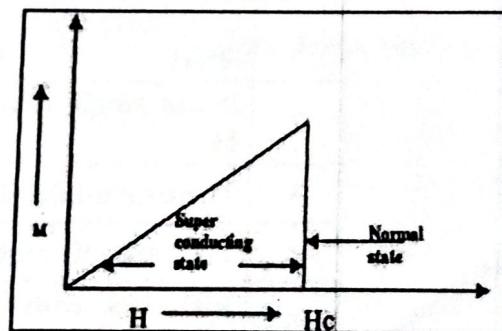
**TYPES OF SUPERCONDUCTORS**

Depending upon the behavior of Superconductors in the external magnetic field, they have been classified into two categories.

1. Type - I (or) Soft Superconductors
2. Type - II (or) Hard Superconductors

**Type : 1 (or) Soft Super Conductors :** Superconductors which one follows a complete Meissner effect is called type I superconductors (also known as soft superconductors).

When the magnetic field strength is gradually increased from its initial value  $H < H_c$ , at  $H_c$  the diamagnetism disappears and the transition from superconducting state to normal state is sharp as shown in figure. These superconductors are known as soft superconductors



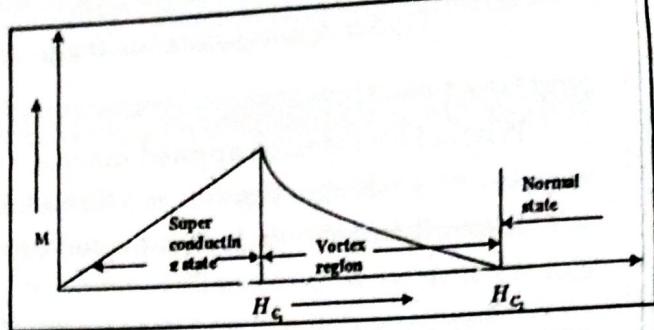
Ex : Al, Zn, Hg and Sn etc.,

**Properties:**

1. They show magnetisation curve as shown in figure
2. They are perfectly diamagnetic
3. They follow Meissner effect strictly
4. The value of  $H_c$  for these superconductors is low (0.1T)
5. These superconductors find very limited applications.

**Type : 2 (or) hard Super Conductors :** Superconductors which does not follow the complete Meissner effect is called type II superconductors

In type II superconductors, the specimen is in pure superconducting state up to the field  $H_{c1}$  (lower critical field) when the field is increased beyond  $H_{c2}$  (upper critical state) the magnetic flux lines start penetrating. The specimen is in mixed state between  $H_{c1}$  and  $H_{c2}$ . Above  $H_{c2}$ , the specimen is in normal state. This means that the Meissner effect is incomplete in the region between  $H_{c1}$  and  $H_{c2}$ . This region is known as vertex region. These superconductors are known as hard superconductors



Ex: Zr, Nb, V, Tc etc.,

**Properties:**

1. They show magnetisation curve as shown in figure
2. They do not follow Meissner effect strictly
3. They do not jump suddenly to normal state like Type-I superconductors as the field is increased.

#### Difference between Type-I and Type - II semiconductors

S.No	Type-I semiconductors	Type - II semiconductors
1	It follows complete Meissner effect	It does not follow the complete Meissner effect
2	It has single critical field value $H_c$	It has two critical field values $H_{c1}$ and $H_{c2}$
3	There no mixed state.	There is a mixed state
4	They are soft superconductors	They are hard superconductors
5	Materials with pure form are type-I superconductors	Materials with impurities or alloys are type - II superconductors
6	Examples: Al, Zn, Sn, Pb , Ga, Zr etc.,	Examples: Nb, V, Tc etc.,
7		



## PROPERTIES OF SUPERCONDUCTORS

The superconducting material shows some extraordinary properties which are

1. Superconducting material shows the zero electric resistance
2. A superconductor exhibits perfect diamagnetism
3. At room temperature resistivity of superconductivity material is greater than other elements.
4. At superconductivity state all thermoelectric effects disappears.
5. Superconductors are brittle in nature
6. When impurities are added to superconducting elements, the superconductivity is not loss but  $T_c$  is lowered.
7. When current is passed through the superconducting materials the heating loss is zero.

## APPLICATIONS OF SUPERCONDUCTORS

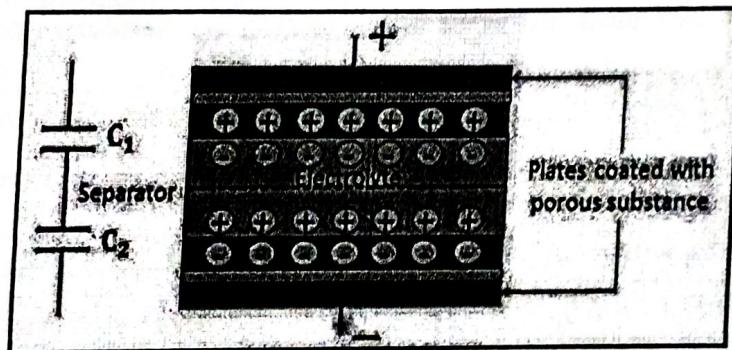
1. Superconductors mainly used for creating powerful electromagnets in MRI scanners especially body scans in medical practice.
2. Superconducting magnets are also used in fusion experiments and high energy physics.
3. Superconducting msterials can be used in levigation transportation (for example, the trains which move in air without rails).
4. This conductor is used to transmit power for long distances
5. These are used in generators, particle accelerators, transportation, electric motors, computing, medical, power transmission.
6. These are used in memory or storage elements

## SUPERCAPACITORS

### ❖ SUPERCAPACITORS

**Supercapacitors (SCs)** : These are electrochemical energy storage devices that store and release energy by reversible adsorption and desorption of ions at the interfaces between electrode materials and electrolytes.

- ✓ Supercapacitors can also be known as Ultracapacitors since it has a higher capacitance value than other normal capacitors
- ✓ They can have high capacitance values ranging from a few milli-farads (mF) to ten's of farads in a very small size.
- ✓ Due to the high capacitance values, the supercapacitors can store much more electrical energy stored between their plates compared to the normal capacitors.
- ✓ As we know the capacitance is directly proportional to the surface area (A) of the conduction plates and inversely proportional to the distance (d) between the plates. So it can be built by providing large surface area and very small distance (d) between the conduction plates.
- ✓ In supercapacitors use liquid (or) wet electrolyte between its electrodes
- ✓ Then Ultracapacitors is a type of electrochemical device but no chemical reactions are involved for strong electrical energy.



The two electrodes form a series circuit of two individual capacitors  $C_1$  and  $C_2$ . The total capacitance  $C_{\text{total}}$  is given by the formula

$$\text{Total Capacitance} = C_{\text{Total}} = \frac{C_1 \cdot C_2}{C_1 + C_2}$$

**Principle:** A supercapacitor typically works on the principle of storing electrical energy between two electrostatic double layers that are formed due to the deposition of thin layers of charge on the interface of the electrolyte and the inner side of the capacitor electrode plates.

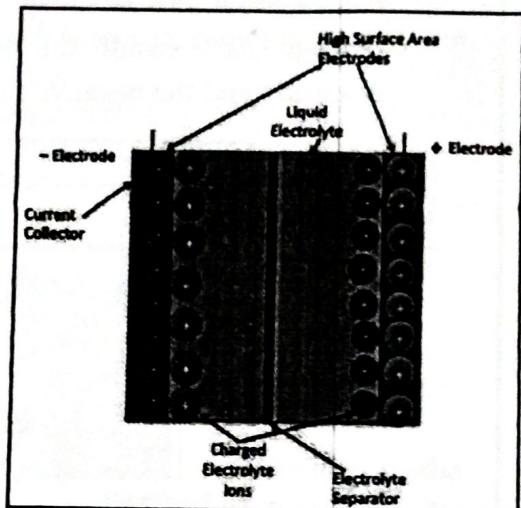


**Classification of Supercapacitor:** Supercapacitors are divided into three families based on the design of the electrodes:

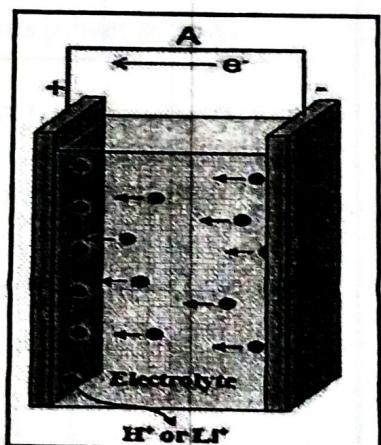
- 1) Electrostatic Double-layer capacitors: In which Charge storage by electrostatically
- 2) Pseudo capacitors : In which Charge storage by Electrochemically.
- 3) Hybrid capacitors : In which Charge storage by both Electrostatically and electrochemically

### 1. Electrostatic Double Layered Capacitors :

- ✓ Electrical energy is stored by charge separation in Helmholtz double layer.
- ✓ The electrodes are used in this capacitors are carbon electrodes or derivatives like charcoal powder rods and the two electrodes are separated by a separator
- ✓ Charge storage by electrostatically
- ✓ The separation of charge in electrostatic double-layer capacitors is less than in a conventional capacitor. It ranges from 0.3–0.8 nm.



- ### 2. Pseudocapacitors :
- Pseudo capacitors are also referred to as electrochemical pseudo-capacitors. These capacitors make use of metal oxide or conducting polymer electrodes with a high amount of electrochemical pseudocapacitance. These types of components store electrical energy by electron charge transfer between electrode and electrolyte. This can be done by a reduction-oxidation reaction commonly known as a redox reaction.



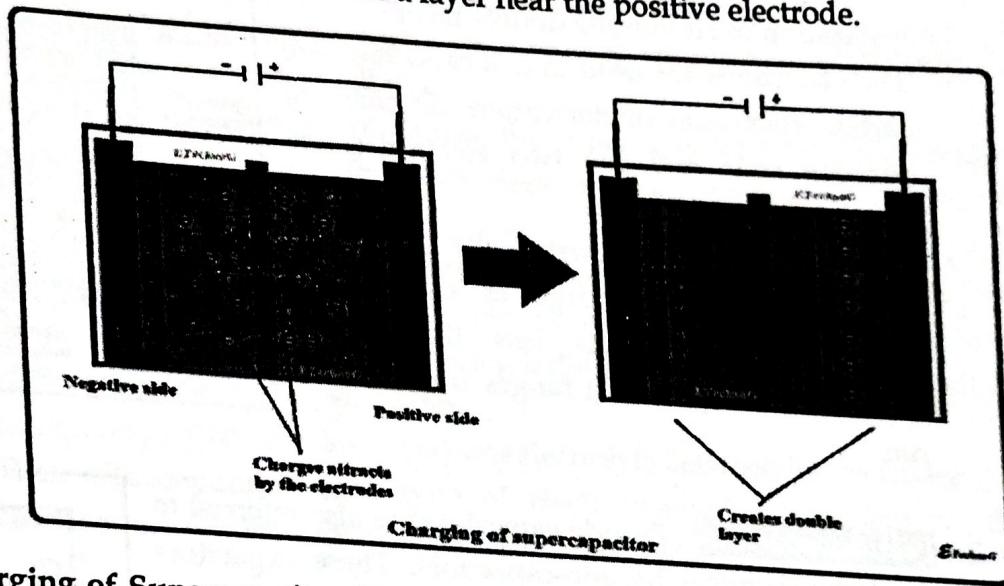
- ### 3. Hybrid Capacitors :
- The hybrid capacitors are developed by using the techniques of double-layer capacitors and pseudo-capacitors. In these components, electrodes with different characteristics are used. One electrode with the capacity to display electrostatic capacitance, and the other electrode with electrochemical capacitance.

**Examples of hybrid capacitors:** The lithium-ion capacitor

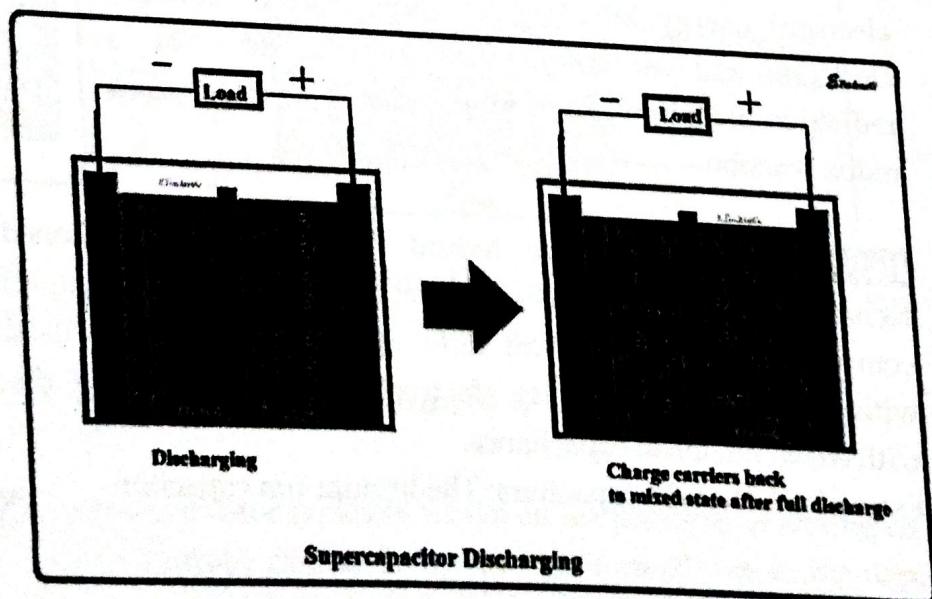
## WORKING OF SUPERCAPACITORS

**Working of Super capacitors:** It contain Charging and discharging concepts of the Supercapacitor

**Charging of the Super capacitors:** When we apply a voltage across the electrodes of the supercapacitor then it starts charging by attracting the positive and negative Ions which are present in the electrolyte solution. That means the positive electrode attracts the negative Ions or charges and the negative electrode attracts the positive Ions or charges. As a result, the positive ions or charges create a layer near the negative electrode and the negative ions create a layer near the positive electrode.



**Discharging of Supercapacitor:** When we connected a load across the supercapacitor, the electrodes cannot attract the ions and the ions start distributing through the electrolyte solutions and go to the mixed state





### Properties of Supercapacitor:

- 1) Supercapacitors can handle very high current rates.
- 2) Supercapacitors have low energy density to unit weight and volume
- 3) Supercapacitors have capacitance ranging from  $1 \text{ mF}$  to  $> 10 \text{ kF}$ .
- 4) Supercapacitors have energy density of up to  $\text{Wh/Kg}$
- 5) There is less potential for pollution in supercapacitors as no heavy metals are used in their development.
- 6) The charge/discharge time of supercapacitors ranges from milliseconds to a few seconds
- 7) As per the supercapacitors have capacitance with lower voltage limits, they are preferred over batteries and conventional capacitors.
- 8) Supercapacitors have a long cycling time with high cycle efficiency.

### Applications of Supercapacitor:

1. Used in power conditioning and UPS.
2. The supercapacitor is used in digital cameras for flashing of light.
3. Supercapacitors are used in electric vehicles to charge in a very short time.
4. They are also used in defibrillators to shock the human heart.
5. They are used in electrical devices such as laptop computers, portable media players, handheld devices and photovoltaic system to stabilize the power supply.
6. It is used in Armed automobiles.
7. Used in wireless communication systems for the continuous power supply.
8. It is used in waterproof energy storing devices.

**NANOCHEMISTRY****❖ INTRODUCTION**

Nanochemistry is a relatively new branch of chemistry concerned with the unique properties associated with assemblies of atoms or molecules of nanoscale ( $\sim 1\text{-}100\text{ nm}$ ), so the size of nanoparticles lies somewhere between individual atoms or molecules (the 'building blocks') and larger assemblies of bulk material which we are more familiar with.

Nanochemistry is being used in chemical, materials and physical, science as well as engineering, biological and medical applications.

Overall, nanochemistry is not related to the atomic structure of compounds. Rather, it is about different ways to transform materials into solutions to solve problems. Chemistry mainly deals with degrees of freedom of atoms in the periodic table however nanochemistry brought other degrees of freedom that controls material's behaviors

**Nano Material:** Nano materials are the materials having components within size less than  $100\text{ nm}$  atleast in one dimension.

1. Nano is a measure of unit like feet, inch and kilometers. The nanometer is abbreviated as  $nm$
2. Nano is the unit of size (or) diameter.
3. A nanometer is one billionth of a meter

$$1\text{ nm} = 10^{-9}\text{ m} = \frac{1}{1000000000}\text{ m}$$

4. Nanometer size practices can observe only through a powerful microscope like force microscopic

Ex: DNA width =  $2\text{ nm}$ , RBC width =  $5000\text{ nm}$

5. Materials reduced to nano size, can suddenly shows very different properties compared to what they exhibit on a macroscale(Bulk phase)

Ex : 1. Inert materials (Pt, Au) reduced to nano size, then it act as Catalyst

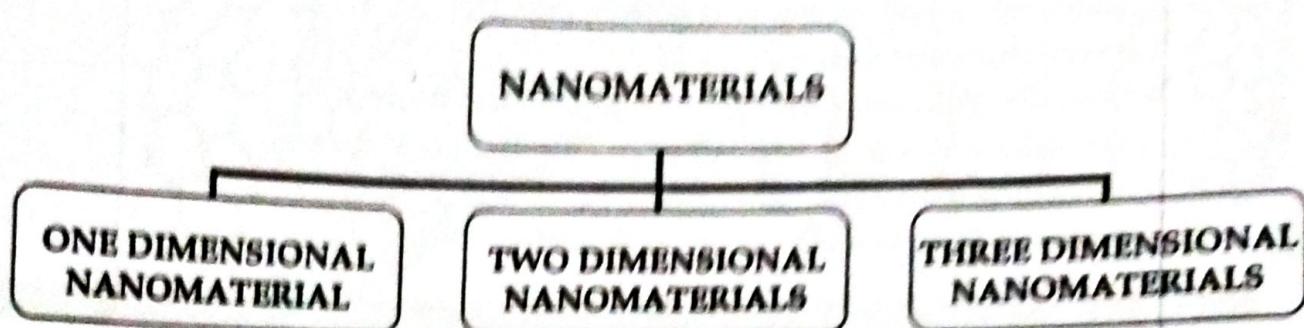
2. Insulators (Si) becomes conductors

3. Stable material (Al) become combustable



## ❖ CLASSIFICATIONS OF NANOMATERIALS

**Classification of nanomaterials:** The types of nanomaterials are explained in the below figure:



1. **One dimensional nanomaterial:** This type of material has one dimension arrangement of atoms in the nanoscale range.

Ex: Surface coatings and thin films.

2. **Two-dimensional nanomaterial:** This type of material has two dimension arrangements of atoms in the nanoscale range.

Ex: Biopolymers, nanotubes, nanowires.

3. **Three-dimensional nanomaterial:** This type of material has three dimension arrangements of atoms in the nanoscale range.

Ex: fullerenes.

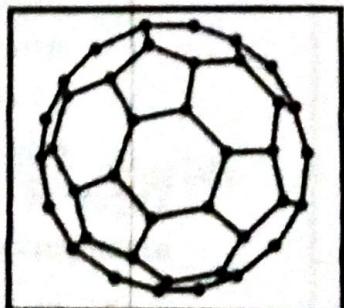
## ❖ FULLERENES

**Fullerenes :** Fullerenes are allotropes of carbon appears in the form of hallow spear. It was discovered by an American Architect Buckminster Fuller.

**Types of Fullerenes:** Fullerenes can be classified in to 3 types on the basis of arrangement.

1. **Spherical Fullerenes:** They look like a soccer ball and these are often called bucky balls
2. **Cylindrical Fullerenes:** These are called nanotubes or bucky tubes
3. **Planar Fullerenes:** Graphine is an examples of planar fullerence sheet

**Structure of Fullerenes:** Fullerenes are a class of closed -cage carbon molecules. The most commonly created fullerene is the  $C_{60}$  molecule. It has 60 carbon atoms arranged as 12 pentagons and 20 hexagons in the form of sphere is called buck mister fullerene  $C_{60}$ . In every fullerene, the hollow cage structure contains twelve pentagons. The number of hexagons, however can be varied to give you other configurations like  $C_{20}$  and  $C_{70}$



### PROPERTIES OF FULLERENES

1.  $C_{60}$  is mustered coloured solid. When the thickness of the film increases, it appears brown to black.
2. It moderately soluble in common organic solvents
3. It is very tough and thermally stable.
4. It forms deep megenta solution when dissolved in Benzene
5. Fullerenes are chemically stable, but no completely un reactive
6. It has highest tensile strength
7. It exists as a discrete molecule

### APPLICATIONS OF FULLERENS

- 1) Fullerene is used in personal care products
- 2) Fullerene is used as dry lubricants in coating application.
- 3) Fullerene is used in cancer therapy
- 4) They are used as biological antioxidants.
- 5) Fullerene is used in medical science as a vehicle for drug delivery
- 6) Fullerene is used in water purification and biohazard protection
- 7) Fullerene is used in hydrogen gas storage.
- 8) Fullerene is used as sensors
- 9) They are used in making bullet proof vents with inorganic buckyballs
- 10) They are used as organic photovoltaics

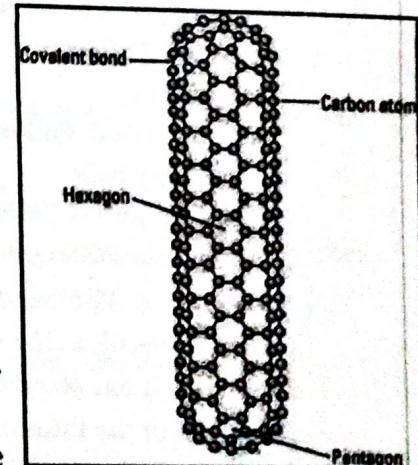
### ❖ CARBON NANOTUBES

**Carbon nanotubes :** Carbon nanotubes are allotropes of carbon with a nano structure having few nanometers in diameter and several microns in length.

1. Sumio Iijima discovered carbon nanotubes in 1991
2. Carbon nanotubes are composed of carbon atoms linked in hexagonal shapes, with each carbon atom covalently bonded to three other carbon atoms.
3. Carbon nanotubes have diameters as small as 1 nm and lengths up to several centimeters. Although, like buckyballs, carbon nanotubes are <sup>breakable</sup> strong, they are not brittle. They can be bent, and when released, they will spring back to their original shape.

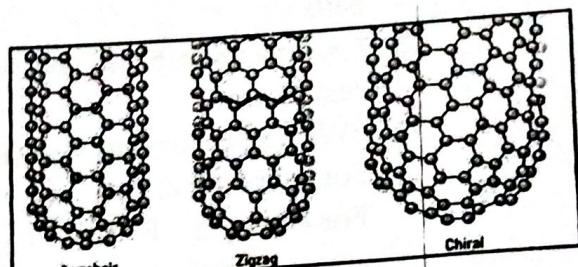
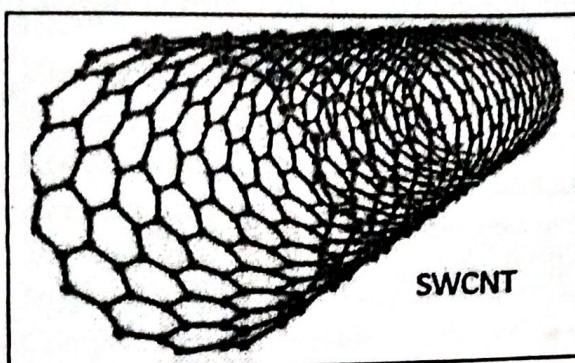
**Types of Carbon nano tubes:** Depending up on the arrangement, these can be classified in two types

1. **Single walled nanotubes (SWCNT) :** They are formed by rolling up of single graphine layer. The diameter of SWCNT is 1-4nm and lengt can go up to few

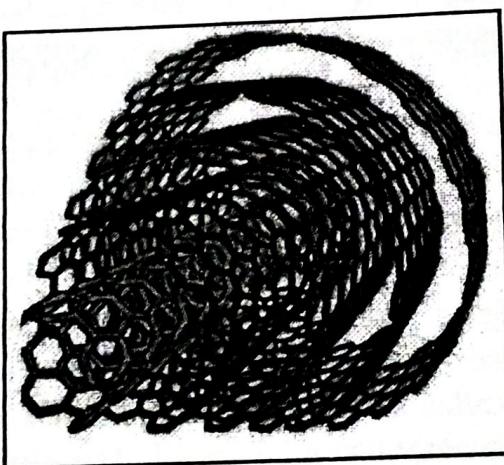




micrometers. Some of the examples for a Single-walled CNT are zig-zag armchair and Chiral Single-walled Carbon nanotubes.



2. **Multy walled nanotubes (MWCNT):** It is composed of several nested carbon nanotubes. This type of nanotubes has two diameters, one is known as outer diameter and another one is known as inner diameter. The outer diameter of Multi-walled Carbon nanotubes is around 2-20 nanometres. The inner diameter of Multi-walled Carbon nanotubes is 1-3 nm. The length of Multi-walled Carbon nanotubes is around 5-6 micrometers. An example of Multi-walled Carbon nanotubes is chiral Multi-walled Carbon nanotubes.

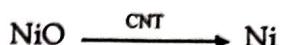


#### PROPERTIES OF CARBON NANOTUBES (CNTs)

1. The carbon nanotube is 100 times stronger than steel and is one-sixth the weight.
2. Carbon nanotubes shows a unique combination of stiffness and strength
3. CNTs have highly thermal conductivity and kinetic property
4. CNTs have high sensitivity to gas adsorption
5. It is highly conducting and behaves like metallic or semiconducting materials.
6. It posses elastic flexibility.

## APPLICATIONS OF CARBON NANOTUBES

1. Hydrogen can be stored in the carbon nanotubes which in turn is used for fuel cells
2. Carbon nano tubes can replace Pt as a catalyst in fuel cell due to the corrosion resistance.
3. SWNTs are used in transistors and solar panels
4. Some chemical reactions are carried out inside the nanotubes  
For example : Reduction of NiO to the base metal Ni

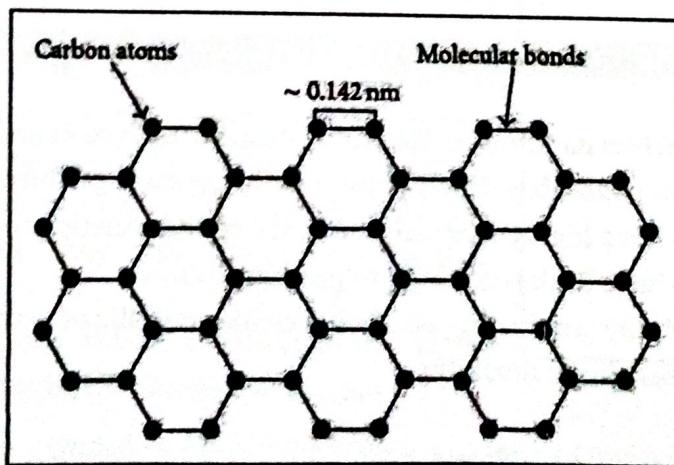


5. Magnetic nanoparticles are used for the treatment of hyperthermia.
6. Due to highly electrical conductivity of nano-tubes are used in glucose detectors.
7. Carbon nanotubes are being highly used in drug delivery and bio-sensing methods for disease treatment and health maintaining.
8. It is also used in water softening process as a filter.
9. MWNTs are used in lithium ion batteries to enhance cycle life
10. Nanotubes can potentially replace indium tin oxide in solar cells to generate photocurrent

## ❖ GRAPHENES NANOPARTICLES

**Graphenes:** Graphene was first isolated by A.K. Geim and K.S. Novoselov at the University of Manchester in 2004.

Graphenes are basically a single atomic layer of graphite, an abundant material which is an allotrope of Carbon. This is made up of very tightly bonded carbon atoms organised into a hexagonal lattice. (In this each carbon atom undergoes sp<sup>2</sup> hybridization.) It is the basic structural element of other allotropes like graphite, fullerene, nanotubes, nanocones, etc. hence called mother of all carbon nanomaterials.





## PROPERTIES OF GRAPHENES

1. High surface area
2. Excellent electrical conductivity
3. Ultra light
4. Strong mechanical strength
5. High thermal conductivity
6. Almost transparent
7. Thinnest, strongest and stiffest imaginable material
8. High current density at room temperature
9. Completely impermeable
10. Chemically stable

## APPLICATIONS OF GRAPHENES

1. Graphene is used to develop bioelectric sensory devices.
2. Graphene is very promising material for use in batteries and supercapacitors to store more energy and charge faster due to extremely high surface-area to volume ratio.
3. Graphenes are used to prepare thermal foils for mobile devices.
4. As graphene is strong and light it is used to prepare Aircraft Wings.
5. Graphene is used to prepare anti-corrosion coatings and paints.
6. Engineering toxic graphene is used in antibiotics, tissue regeneration and anticancer treatment.
7. A high quality graphene possessing high tensile strength and flexibility is used for flexible displays.
8. Graphene is used in water filtration system and desalination system.
9. Graphene can be used as the electronics parts in computer circuites to enable better conduction.
10. It is used as transparent electrodes for touch screens and photovoltaics.