Dhanaprakash

SUPERCONDCUTIVITY

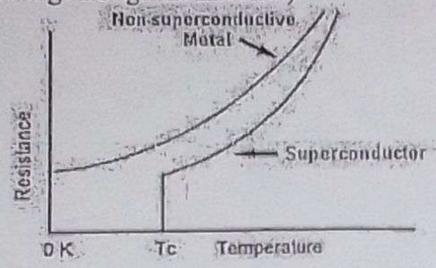
Introduction

In traditional conductors like copper and aluminium the electrical conductivity or passage of current is associated with the wastage of energy due to resistance drop. Copper wire generators are only 50% efficient in generating electricity. Because of this there is a loss of money (billions of dollars).

Some metals and alloys carry current without energy loss and with no resistance at low temperature close to absolute zero and are called as superconducting materials. In these materials electrical resistance disappears suddenly and completely near absolute zero temperature. The temperature at which superconductivity occurs in metallic materials is called critical temperature or superconducting transition temperature, T_c and is in the range 0.01 – 10K.

We can also have high temperature superconductors, which are specially prepared ceramics close to 125K. Eg: $Bi_2(CaSr)_4Cu_3O_{10}$ it has superconductor character at 110K. Superconductivity above the B.P. of N_2 is called high- temperature superconductivity.

Definition of superconductivity: —Superconductivity is the ability of certain Materials to conduct electrical current with no loss of energyl. (Resistance is undesirable because it produces losses in the energy flowing through the material)

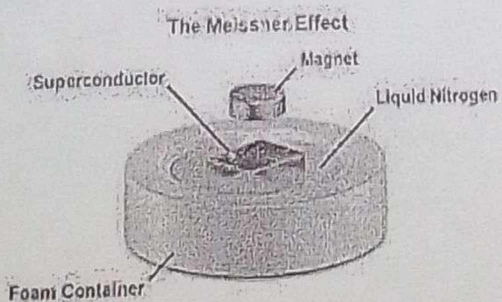


At superconductivity state the materials become diamagnetic and are repelled by magnets or magnetic lines of force is repelled.

T_c values for some superconductors

Material	T_c(K)
Hg	4.2
La	6.0
Mo_2BC	7.0
Nb	9.5
La_3In	10.4
$C_{60}K_x$	18.0

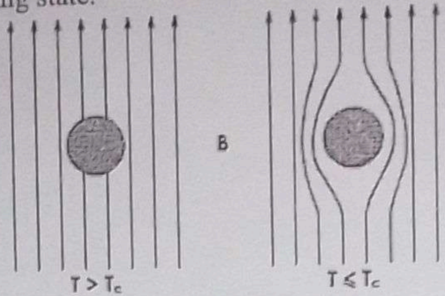
Material	T_c(K)
Nb_3Ge	23.2
La_2CuO_4	35.0
$TlSrLaCuO_5$	40.0
$YBa_2Cu_3O_7$	90.0
$Tl_2Ca_2Ba_2Cu_3O_{10}$	125.0
$HgCa_2Ba_2Cu_3O_8$	135.0



Meissner effect

Meissner effect is the expulsion of a magnetic-field from a superconductor during its transition to the superconducting state. If a conductor is cooled in a magnetic field below the transition temperature T_c, then at transition the lines of induction B (magnetic flux lines) are pushed out. So, superconductors in the Meissner state exhibit perfect diamagnetism or super diamagnetism, meaning that the total magnetic field is very close to zero, deep inside them.

Since diamagnetic materials have negative magnetic susceptibility the specimen becomes an ideal diamagnetic in superconducting state.



If a specimen (Eg: Hg) of superconductor is placed in a very strong magnetic field, the specimen loses its property of superconductivity and becomes normal metal.

Types of Superconductors

Superconductors are divided into two types, Type-I and Type-II based on their magnetic response.

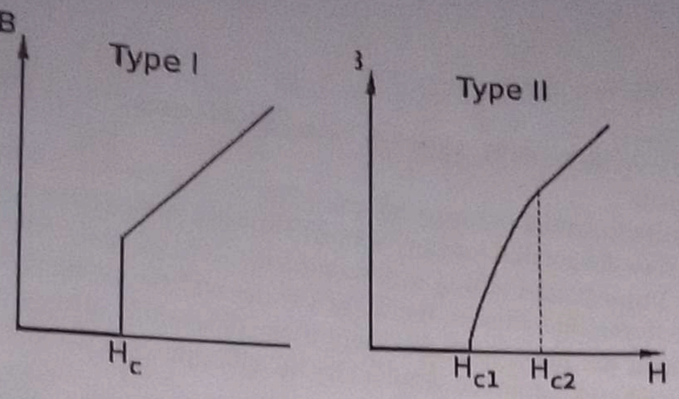
Type-I Superconductors: Very pure samples of lead, mercury and tin are examples of this type. These have zero electrical resistivity below a critical temperature, T_c, zero internal magnetic field (Meissner effect), and a critical magnetic field, H_c above which superconductivity ceases. These have limited practical usefulness since the critical magnetic fields, H_c are very small and superconducting state disappears suddenly at that H_c. Type-I superconductors are sometimes called _soft' superconductors.

Type-II Superconductors: These are also known as the _hard' superconductors. These differ from Type I in that their transition from a normal to a superconducting state is gradual across a region of mixed state behavior. The ideal behavior is seen up to a lower critical field, H_{c_1}, beyond which the magnetization gradually changes and attains zero at an upper critical field, H_{c_2}. The region between H_{c_1} and H_{c_2} is known as _Vertex' region and the Meissner effect is incomplete in this region. Beyond H_{c_2}, the normal behavior is seen.

Some type-II superconductors are metallic compounds and alloys. Recently discovered is Pyrovskites i.e. metal-oxide ceramics. Some examples of superconductors are La_3In, Na_3Ge.

Type-I Vs Type-II Semiconductors

Type-I	Type-II
1. Sudden loss of magnetization.	1. Gradual loss of magnetization.
2. Exhibit Meissner effect.	2. Does not exhibit complete Meissner effect.
3. One $H_c = 0.1$ Tesla	3. Two H_cs: H_{c_1} and H_{c_2} (≈ 30 Tesla).
4. No mixed state.	4. Mixed state present.
5. Soft superconductor	5. Hard superconductor
6. Eg: Pure metals like Pb, Sn, Hg.	6. Eg: Alloys like Nb-Sn, Nb-Ti.



Variation of internal magnetic field (B) wit plied external magnetic field (H) for Type I and Type perconductors

Properties of superconductors

1. They possess greater resistivity than other e nts at room temperature.
2. The T_c for different isotopes of a supercond e element decreases with the atomic mass of the isotope.
3. On adding impurity to a superconducting e nt, T_c is lowered.
4. Superconductivity is more concerned with onduction of electrons than the atoms of element itself.
5. During transition, neither thermal expansio elastic properties change.
6. In superconductivity state, all electromagn ffects disappear.
7. Application of a sufficient strong magnetic f a super conductor below its T_c causes destruction of its superconducting property.
8. When a not too strong magnetic field i lied to a superconductor and is cooled to low temperature below its T_c, then the superco or expels all magnetic flux from its interior. This is known as Meissner effect. In other ds, if the magnetic field is applied after the superconductor has been cooled below then the magnetic flux is excluded from the superconductor.

Applications of superconductors

The potential of superconductors is incredib their applications are practically innumerable.

1. Superconducting magnets capable of gen ng high fields with low power consumptions are being employed in scientific tests and resear uipments.
2. Magnetic-levitation is an application whe perconductors perform extremely well. Transport vehicles such as trains can be made to t on strong superconducting magnets, virtually eliminating friction between the train its tracks. The Japanese Mag-Lev train had superconducting magnets on the cars thems , inducing currents in the rails, and creating a

Thermal Expansion

repulsive force to levitate the train. Mag-Lev trains should be much safer than traditional trains at high speeds.

3. An area where superconductors can perform a life saving function is in the field of biomagnetism. As a diagnostic tool any abnormalities in body tissues and organs can be detected. By impinging a strong superconductor derived magnetic field into the body, hydrogen atoms that exist in the body's water and fat molecules are forced to accept energy from the magneticfield. They then release this energy at a frequency that can be detected and displayed graphically by a computer. That graph is known as Magnetic Resonance Imagining (MRI).
4. Chemical analysis of body tissues is possible by using Magnetic Resonance Spectroscopy (MRS).
5. Electrical power transmission through superconducting materials-power loss is extremely low and equipment operates atlow voltage levels.
6. In magneto hydrodynamic (MHD) power generators to maintain plasma. These superconducting materials are smaller in size and consume less energy.
7. For amplifying very small direct current [illegible] voltages.
8. More powerful magnets can be made wit[illegible] help of superconductors, which are likely to enhance the probability of laboratory n[illegible] fusion reactions.
9. Superconductors are used as electronic [illegible] rs. These are used in cellular telephone systems, where it would allow more rem[illegible] eas to be accessed.
10. High energy particle research hinges on [illegible] able to accelerate sub-atomic particles to nearly the speed of light. Superconduc[illegible] magnets make this possible. Fermi lab is currently using superconducting electro[illegible] ets.
11. Using superconducting bearings and su[illegible] onducting coils, it is possible to get close to a 100% efficient motor, since virtua[illegible] dissipative friction or resistance occurs.
12. The most ignominious military us[illegible] superconductors may come with the development of e-bombs. These are d[illegible] s that make use of strong, superconductor derived magnetic fields to create a fast, h[illegible] intensity Electro Magnetic Pulse (EMP) to disable an enemy's electronic equipme[illegible]

SUPER APACITOR

1. Super Capacitor is a electrochemical capacitor that has an very ʼh power density as compared to comm capacitors, about 100times greater.
2. Super capacitor is o known as electric double layer capaci [EDLC] or ultra capacitor.
3. The capacitance ra is from 100 Farad to 5K Farad.

CONS UCTION

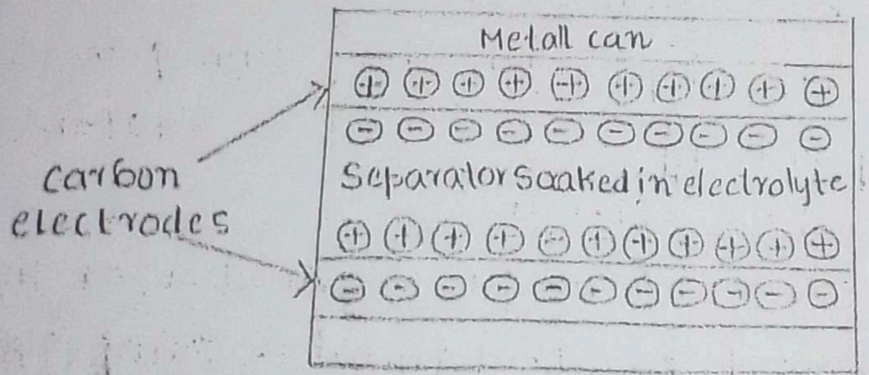
1. Super capacitors ar onstructed with two metal foils, each ated with an electrode material such as tivated carbon.
2. The electrode are t apart by anion permeable membrane [Separato used as an insulator to protect the short ircuits.
3. The construction is ubsequently rolled or folded into a cylindrical r rectangular shape and packed in an a ninium can.

1. Positive electrode
2. Negative electrode
3. Separator
4. Aluminium can

5. Positive Pole
6. Separator
7. Carbon electrode
8. Collector
9. Carbon electrode
10. Negative pole

WORKING OF SUPERCAPACITOR

In a Super capacitor, there is no conventional dielectric. Both plates are Soaked in an electrolyte and Separated by a very thin insulator. When the plates are charged, an opposite charge forms on either side of the Separator, creating what's called an electric double layer. This is why super capacitors are often referred to as double-layer capacitors.

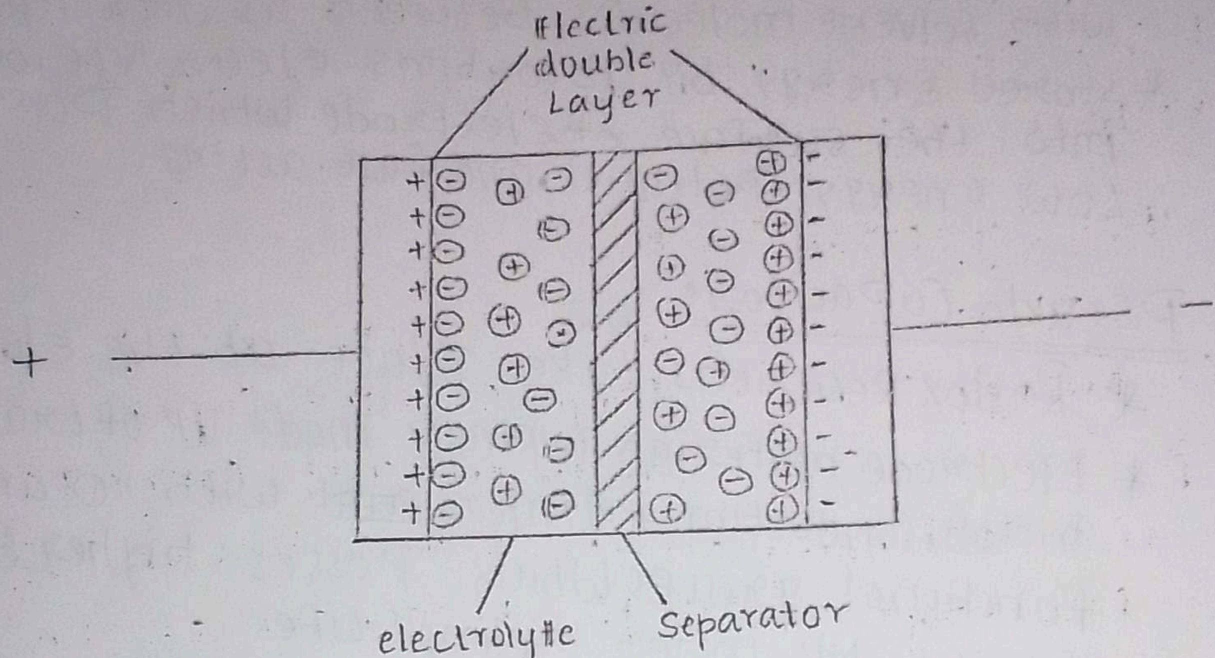


Double Layer capacitor

Electric Double Layer

Electrochemical capacitor has two electrodes, separated by a separator, which are electrically connected to each other via the electrolyte.

When voltage is applied, and plates get charged, an opposite charge forms on the either side of the separator creating a electric double layer.



FEATURES

1. Stores high amount of energy.
2. Have high capacitance.
3. High rates of charge and discharge
4. Low toxicity.
5. High cycle efficiency [95%]

APPLICA ONS

1. In start up mechanism or automobiles.
2. Used in diesel engine art up in sub marines & tanks.
3. Backup power system i missiles.
4. Power source for lapto , ash in cameras.
5. Voltage stabilizer.

Super Capacitor Buses

It is a new form of electric bus powered via energy store in ca onboard super-capacitors. A connector n the roof connects to the stationary elec cal installation when the bus stops to let t passenger on to the bus.

- Electric bus technology
  - Super/outer capaci s [Energy storage device].
  - collector [fitted on top].

Super capacitors can e charged much faster than batteries but hold less energy [at the current tir].

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ADVANTAGES

1. High energy storage.
2. Wide working temperature [-40°C to 60°C].
3. Eco-friendly.
4. Quick charging time.
5. Maximum life cycle.
6. High cycle efficiency [95%].
7. High specific power up to 17 kW/kg.
8. Extremely low internal resistance.
9. Safe.

DISADVANTAGES

1. Low energy density.
2. The voltage varies with the energy stored.
3. Have high self-discharge rate.
4. Requires expert electronic control.
5. Cannot be used in AC and high frequency circuits.
6. High cost.

CONCLUSION

1. Super capacitors may be used where high power or energy storage is required.
2. Super capacitors can be used widely because of their long life & short charging time.
3. On the other hand it has limitations due to its high cost, self discharge, packaging problems etc.

The semiconductors fall somewhere midway between conductors and insulators.

Properties of Semiconductors

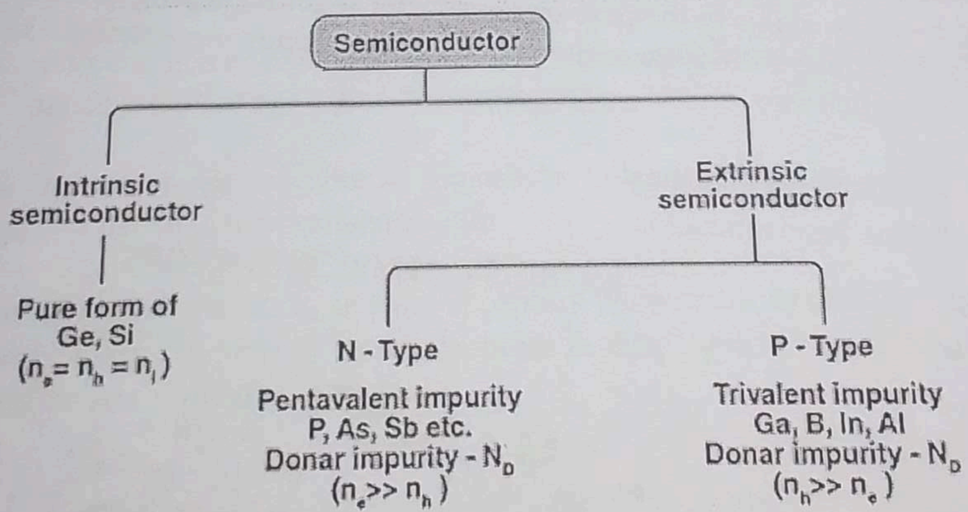
Semiconductors can conduct electricity under preferable conditions or circumstances. This unique property makes it an excellent material to conduct electricity in a controlled manner as required.

- **Resistivity:** 10^{-5} to 10^{6} Ωm
- **Conductivity:** 10^{5} to 10^{-6} mho/m
- **Temperature coefficient of resistance:** Negative
- **Current Flow:** Due to electrons and holes
- Semiconductor acts like an insulator at Zero Kelvin. On increasing the temperature, it works as a conductor.
- Due to their exceptional electrical properties, semiconductors can be modified by doping to make semiconductor devices suitable for energy conversion, switches, and amplifiers.
- Lesser power losses.

Examples of Semiconductors: Gallium arsenide, germanium, and silicon are some of the most commonly used semiconductors. Silicon is used in electronic circuit fabrication and gallium arsenide is used in solar cells, laser diodes, etc.

Types of Semiconductors
Semiconductors can be classified as

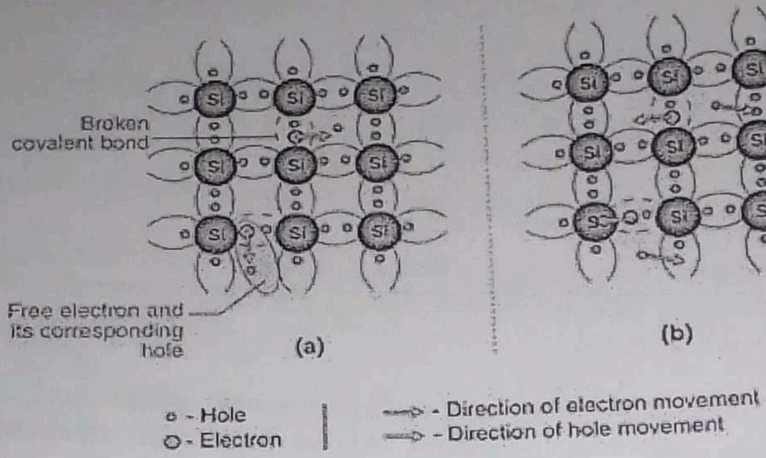
- Intrinsic Semiconductor
- Extrinsic Semiconductor



Intrinsic Semiconductor: An intrinsic type of semiconductor material is made to be very pure chemically. It is made up of only a single type of element. Germanium (Ge) and Silicon (Si) are the most common type of intrinsic semiconductor elements. They have four valence electrons (tetravalent). They are bound to the atom by covalent bond at absolute zero temperature.

At absolute zero kelvin temperature: At this temperature, the covalent bonds are very• strong and there are no free electrons and the semiconductor behaves as a perfect insulator.

Above absolute temperature: With the increase in temperature few valence electrons• jump into the conduction band and hence it behaves like a poor conductor.

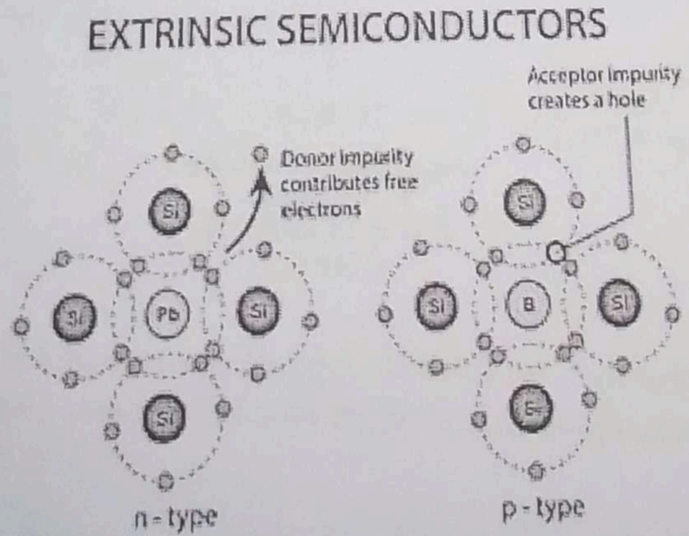


Conduction Mechanism in Case of Intrinsic Semiconductors

a. In absence of electric field
b. In presence of electric Field

Extrinsic Semiconductor: The conductivity of semiconductors can be greatly improved by introducing a small number of suitable replacement atoms called **impurities.** The process of adding impurity atoms to the pure semiconductor is called **doping.** Usually, only 1 atom in 107 is replaced by a dopant atom in the doped semiconductor. An **extrinsic semiconductor** can be further classified into

- N-type Semiconductor
- P-type Semiconductor



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N-Type Semiconductor

- Mainly due to electrons
- Entirely neutral
- I = Ih and nh >> ne
- Majority – Electrons and Minority – Holes

When a pure semiconductor (Silicon or **Germanium**) is doped by pentavalent impurity (P, As, Sb, Bi) then, four electrons out of five valence electrons bonds with the four electrons of Ge or Si.

The fifth electron of the dopant is set free. Thus the impurity atom donates a free electron for conduction in the lattice and is called **"Donar"**.
Since the number of free electron increases by the addition of an impurity, the negative charge carriers increase. Hence it is called n-type semiconductor.

Crystal as a whole is neutral, but the donor atom becomes an immobile positive ion. As conduction is due to a large number of free electrons, the electrons in the n-type semiconductor are the **majority** CARRIERS and holes are the **minority carriers.**

P-Type Semiconductor

- Mainly due to holes
- Entirely neutral
- $I = I_h$ and $n_h >> n_e$
- Majority – Holes and Minority – Electrons

When a pure semiconductor is doped with a trivalent impurity (B, Al, In, Ga) then, the three valence electrons of the impurity bonds with three of the four valence electrons of the semiconductor.

This leaves an absence of electron (hole) in the impurity. These impurity atoms which are ready to accept bonded electrons are called **"Acceptors"**.

With the increase in the number of impurities, holes (the positive charge carriers) are increased. Hence, it is called p-type semiconductor.

Crystal as a whole is neutral, but the acceptors become an immobile negative ion. As conduction is due to a large number of holes, the holes in the p-type semiconductor are **majority carriers** and electrons are **minority carriers.**

Industrial Uses of Semiconductors

The physical and chemical properties of semiconductors make them capable of designing technological wonders like microchips, transistors, LEDs, solar cells, etc.

The microprocessor used for controlling the operation of space vehicles, trains, robots, etc is made up of transistors and other controlling devices which are manufactured by semiconductor materials.

Importance of Semiconductors

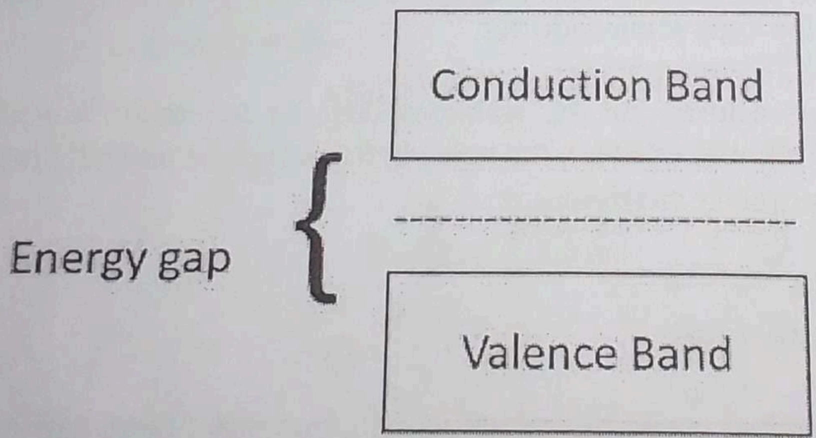
Here we have discussed some advantages of semiconductors which makes them highly useful everywhere.

- They are highly portable due to the smaller size
- They require less input power
- Semiconductor devices are shockproof
- They have a longer lifespan
- They are noise-free while operating

mobile phones, digital cameras.
t.v, washing machines etc.

Band Theory of Solids.

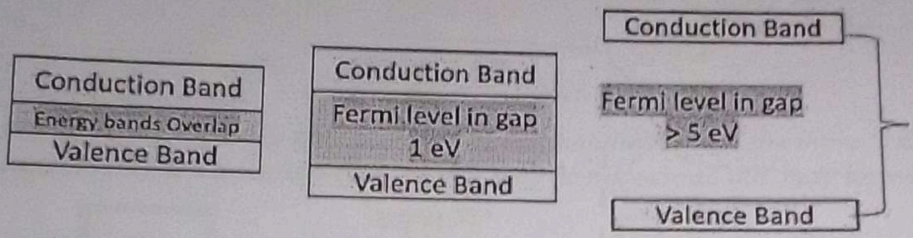
- The solids can be classified into conductors, insulators, and semiconductors depending on the distribution of electron energies in each atom.
- As an outcome of the small distances between atoms, the resulting interaction amongst electrons, and Pauli's exclusion principle, energy bands are formed in the solids.
- In metals, the conduction band, and valence band overlap. However, in a semiconductor or an insulator, there is a gap between the bottom of the conduction band and the top of the valence band. This is called the energy gap or bandgap.



(a) Energy bands for a typical solid

For metals, the valence band, and the conduction band overlap, and there is no band gap as shown in figure (b). Therefore, electrons can easily gain electrical energy when an external electric field is applied and are easily available for conduction.

- Insulators, on the contrary, have a wide gap between the valence band and conduction band of the order of 5 eV (for diamond) as shown in figure (d). Therefore, electrons find it very difficult to gain sufficient energy to occupy energy levels in the conduction band.
- Thus, an energy band gap plays an important role in classifying solids into conductors, insulators, and semiconductors based on the band theory of solids.

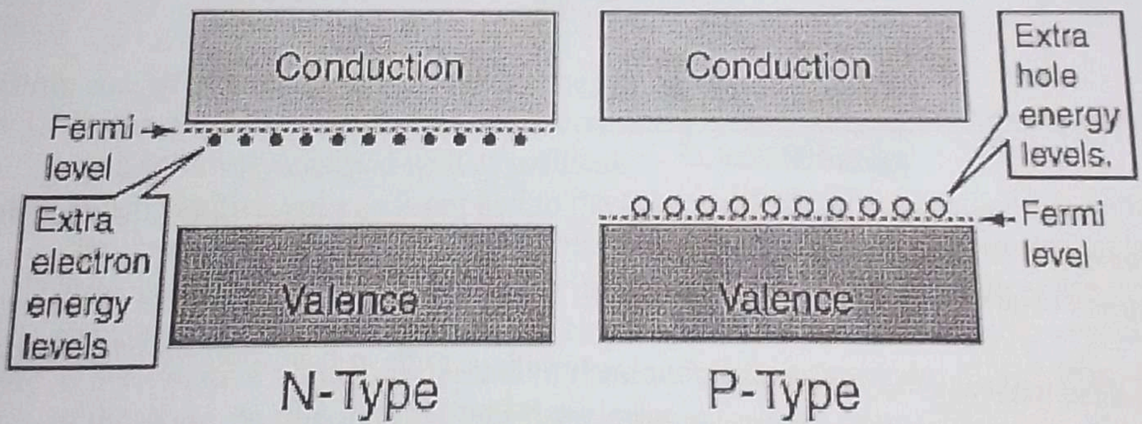


b) Metal   c) Semi Conductor   d) Insulator

- **Band Structure**

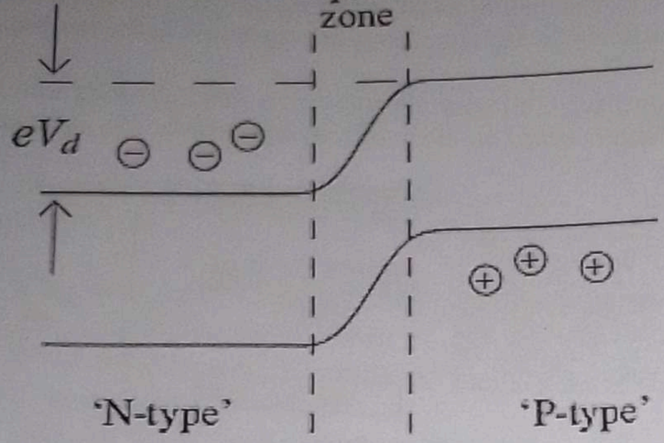
Semiconductors are the materials which have a conductivity and resistivity in between conductors (generally metals) and non-conductors or insulators (such ceramics). Semiconductors can be compounds such as gallium arsenide or pure elements, such as germanium or silicon.

P-N Junction diode: We create a p-n junction by joining together two pieces of semiconductor, one doped n-type, the other p-type.

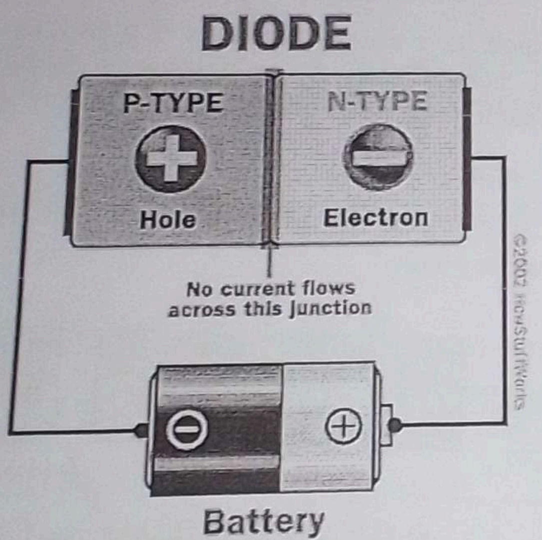


In the n-type region there are extra electrons and in the p-type region, there are holes from the acceptor impurities.

When a p-n junction is formed, some of the electrons from the n-region which have reached the conduction band are free to diffuse across the junction and combine with holes.



This causes a depletion zone to form around the junction (the join) between the two materials.
This zone controls the behavior of the diode

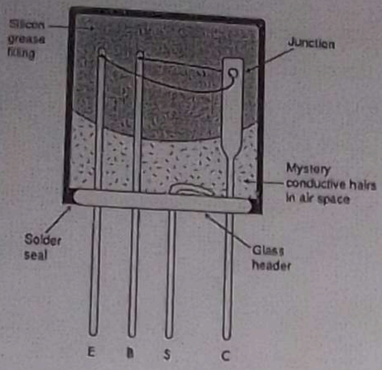


Forward Biasing: Forward biasing the p-n junction drives holes to the junction from the p-type material and electrons to the junction from the n-type material.

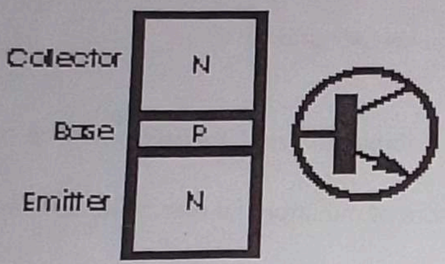
Reverse Biasing : *The application of a reverse voltage to the p-n junction will cause a transient current to flow as both electrons and holes are pulled away from the junction.*

Transistor : *A transistor is a semiconductor device commonly used to amplify or switch electronic signals*

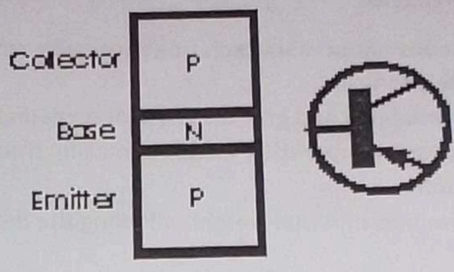
The transistor is a three terminal device and consists of three distinct layers.



Two of them are doped to give one type of semiconductor and the there is the opposite type, i.e. two may be n-type and one p-type, or two may be p-type and one may be n-type.



NPN Transistor



PNP Transistor

They are designated either P-N-P (PNP) types of N-P-N (NPN).

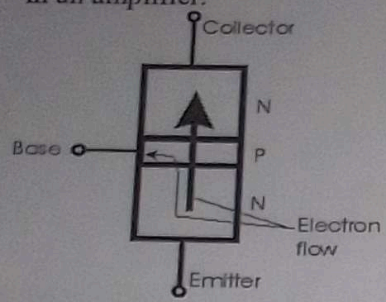
Transistors consist of three terminals: the source, the gate, and the drain.

1. In the n-type transistor, both the source and the drain are negatively charged and sit on a positively charged well of p-silicon.
2. When positive voltage is applied to the gate, electrons in the p-silicon are attracted to the area under the gate, forming an electron channel between the source and the drain.
3. When positive voltage is applied to the gate, electrons in the p-silicon are attracted to the area under the gate, forming an electron channel between the source and the drain.
4. When positive voltage is applied to the drain, the electrons are pulled from the source to the drain. In this state the transistor is on.
5. If the voltage at the gate is removed, electrons aren't attracted to the area between the source and drain. The pathway is broken and the transistor is turned off.

Transistors are composed of three parts – a base, a collector, and an emitter.
The base is the gate controller device for the larger electrical supply.

The collector is the larger electrical supply, and the emitter is the outlet for that supply. By sending varying levels of current from the base, the amount of current flowing through the gate from the collector may be regulated.

In this way, a very small amount of current may be used to control a large amount of current, as in an amplifier.



Transistor Advantages:

1. Highly automated manufacturing processes, resulting in low per-unit cost.
2. Extremely long life.
3. Higher reliability and greater physical ruggedness
4. Lower possible operating voltages, making transistors suitable for small, battery-powered applications.
5. Small size and minimal weight, allowing the development of miniaturized electronic devices.

Rectifiers:

The most popular application of the diode.

Most electronics need a direct current to function, but the standard form of electricity that is transmitted to homes is alternating current

Rectifiers are needed to change the alternating current into direct current inside the electronics so that they can function correctly.

Rectification is the conversion of alternating current (AC) to direct current (DC).

Rectifiers This involves a device that only allows one-way flow of electrons, which is exactly what a semiconductor diode does.

Half-Wave Rectifiers: The simplest kind of rectifier circuit is the half-wave rectifier.

It only allows one half of an AC waveform to pass through to the load.

Half-wave rectification is a very simple way to reduce power to a resistive load Some two-position lamp dimmer switches apply full AC power to the lamp filament for "full" brightness and then half-wave rectify it for a lesser light output.

A full wave rectifier is defined as a rectifier that converts the complete cycle of alternating current into pulsating DC

Bridge Rectifiers: For most electrical demands, a bridge rectifier is used. A rectifier bridge is four diodes configured so that the output always has the same polarity regardless of the polarity of the input. Rectifier bridges are most often used to convert alternating current into full-wave direct current for power supplies and throttles

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nano materials =.

Nano materials:-

Nano materials are defined as a set of substances where atleast one dimension is less than approximately hundred nano meters. Therefore 1 nano meter is 1 millionth of a millimeter approximately 1 lakh times smaller than the diameter of a human hair.

or

the particles that have size range in from 10 to 100 nanometers. 1 nanometer $= 10^{-9}$ meters. these are usually particles at the atomic or molecular size.

Depending upon the size the materials are classified into three types

~~materials~~

macroscopic particles (or) Bulk particles

Nano particles (or) mesoscopic particles

microscopic particles (or) atomic particles

Based on composition
- → organic nanomaterials
- → inorganic nanomaterials
- → hybrid nanomaterials

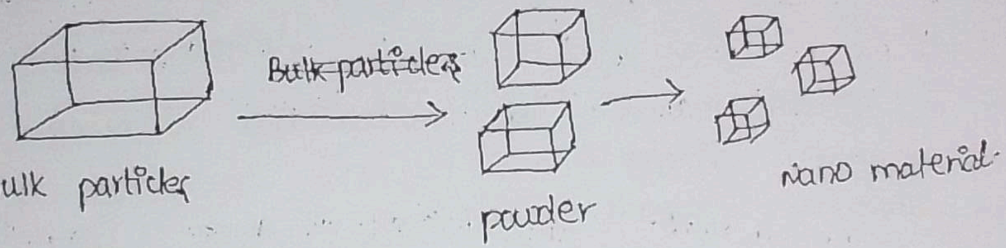
Based on dimensions
- → zero
- → 1D
- → 2D
- → 3D

Preparation of nano material :-

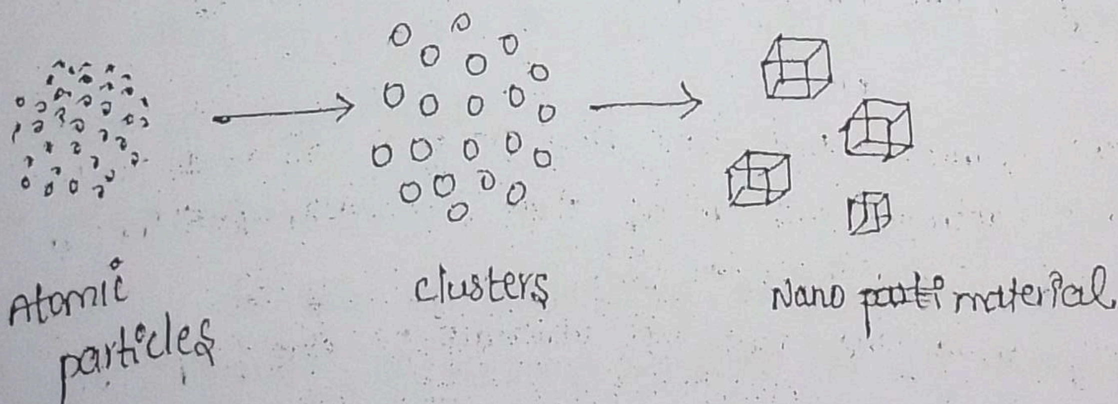
(1) Top down approach method

(2) Bottom up approach method.

(1) Top down approach method —



(2) Bottom up approach method —



These are divided into two types
(1) Based on composition
(2) Based on dimension

(1) Based on composition:-

→ organic nano material
* it composed of carbon
* They exist in diff. forms
Ex:- carbon nanotubes, fullerenes, Graphines

applications:-
They are used in water purification process and as electrodes for solar cells.

→ Inorganic nanomaterial
* it composed of metal and metaloxide nanomaterials.
* They exist in diff. forms.
Ex:- metal nanomaterials (silver N.m, Gold N.m, copper N.m)
metal oxide N.m (zinc oxide, Iron oxide, magnesium oxide, titanium dioxide)

applications:-
They can be used as anti bacterial agents in fuel cells, for medical diagnosis and testing

→ Hybrid nano materials
* They exist in combination like, organic-organic
organic - inorganic
inorganic - inorganic etc.,

Ex:- polymer, liposomes

applications:-
They can be used in dental fillings and coatings.

(2) Based on dimensions:-

→ Zero dimension
* In this all dimensions reduced to nanorings
* movement of electrons restricted to all three directions i.e. x, y, z directions.
Ex:- Quantum dots, nanoparticles

(v) Bio - medical applications.

(vi) mechanical related applications.

Fullerenes:

Fullerenes are proposed by richards smalley in 1985. He also got Nobel price in 1996 for his explination in fullarene. His reasearch was completed in Rice university USA.

Name coined to buckminster fullerene to by buckminster fuller and also explained by structure. C_{60} molecule is fuller.

fullerence, diamond, graphite are allotropy of carbon element

Allotrophy:

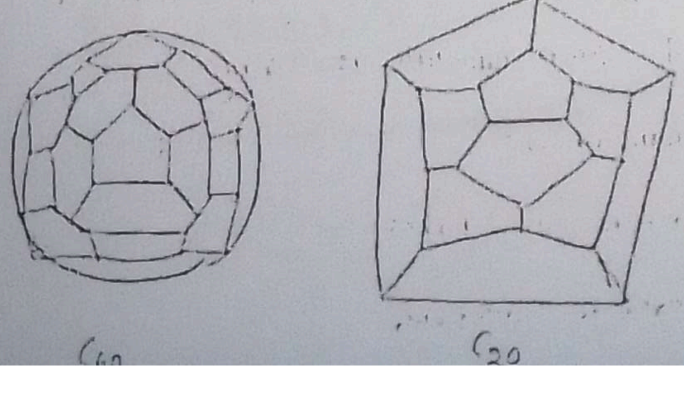
It consists of same elements, but different physical properties.

The molecule which is allotrophy of carbon elements in the form of hallotube sperical and ellipsoid structure is known as "fullerence".

Types of fullerences:

1. Buck Minister fullerene (C_{60}). Truncated Iso hedron (Ісосаhedron)(Topic note)
2. Carbon nano tubes. Hallow tube (single walls, multi walls).
3. Mega tubes. Large dimension's
4. polymers. Two dimensional chain polymers
5. Nano onions. multi layer in its structure
6. Boron Bucky balls Instead of carbon elements

Buckminster fullerene has 12 pentagonal rings & 20 hexagonal rings. And the shape is.



C_{60} C_{20}

Properties of Fullerene:

* Fullerenes are stable, but not totally unreactive
* It's behaviour and structure depend on the temperature. As the temperature is increased fullerene gets converted into the C_{70}.
* Fullerene structure can change under different pressures.
* In chemical reactions, fullerene can act as an electrophile.
* It acts as an electron - accepting group and is characterized as an oxidizing agent.
* Fullerenes when doped or crystallized with alkali or alkaline earth metals it show cases super conductivity properties.
* Fullerene is ferromagnetic.

organic solvents such as
toluene, chlorobenzene, & 1,2,3 trichloropropane

Uses of Fullerenes:

✓ Buckyballs and carbon nanotubes have been used as building blocks for a great variety of derivatives and larger structures.

* Fullerenes are used in the medical field as light-activated antimicrobial agents.

* It is also used in several biomedical applications including the design of high performance MRI contrast agents, X-ray imaging contrast agents, photodynamic therapy and drug and gene delivery.

* Buckminsterfullerene is used in drug delivery systems, in lubricants, and as a catalyst.

* It is also used as a conductor.

* Some types of fullerenes can be used as an absorbent for gases.

* It is used in making cosmetic product.

* C_{60} based films are used for photovoltaic applications.

* Fullerenes are used in making carbon nanotubes based fabrics and fibres.

carbon Nanotube is a cylindrical hollow tube made up of nanoparticles. It is represented as CNT. These are cylindrical fullerene, also called as Buckytubes. It is an 1-D Nanomaterial. It can be classified into two types: single-walled carbon nanotube(SWCN) or multi-walled carbon nanotube (MWCN)

Properties of CNT:

1. carbon Nanotubes are very stiff as stiff as diamond.
2. weight of CNT is very low.
3. The density of carbon nanotubes is one-fourth of that of steel.
4. CNT's have high terminal capacity, generally, it is twenty-two times stronger than steel. Therefore, it does not expand on heating like that of steel.
5. These are good conductors of heat.
6. CNT have very good electrical conductivity.
7. CNT's are 10 times stronger than steel.
8. These are elastic in nature.
9. CNT's are chemically inert. so they are chemically stable. Therefore they resist corrosion

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Applications of CNTs:

① carbon nanotubes are used to destroy cancer tumours. These are also used in drug-delivery system. * It is used in space Elevators.

② CNTS are used in the wind mill blades because of their low weight. * It is used in making paper battery.

③ These are used to make bullet-proof jackets, aircraft to spacecraft bodies

④ These are used in making electrodes because of their excellent electrical properties.

⑤ These are used to make biosensors and electrochemical sensors.

⑥ These are used in making transistors because of their semi-conducting properties * It is Used in solar cells.

⑦ CNTS are used as catalyst in semi chemical reactions. * It is Used in antibacterial fabric.

⑧ CNT's are used in filters media in filtration process to seperate particals of size greater than the dia of CNT.

Graphene:

Graphene is an allotrope of carbon that exist as two dimensional (2D) planner sheet It is a single atomic graphite layer.

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Properties of Graphene:

The most outstanding properties of graphene are.

① High thermal conductivity.
② High electrical conductivity.
③ High electricity and flexibility.
④ High hardness, resistance : Graphene is ~ 200 times stronger than steel, similar to diamond resistance, but much lighter
⑤ Able to generate electricity by exposure to light

* Transparancy
* Scattering
* High mobility

⑥ Transparent material.
⑦ An Antimicrobial effect. Bacteria are not able to grow on it.
⑧ Low electricity consumption compared to other compounds.

Applications of Graphene:

Graphene is called the "wonder material" has taken it's place among the global rush industry. It's application are virtually unlimited and promise to revolutinize many fields, From electronics and computing to construction on even health.

1. In energy industry, graphene is used in solar cells, Graphene enhanced Li-ion batteries, super capacitors, fuel cells, nuclear power plants etc..

In medical field graphene is used in drug delivery, Gene delivery, cancer treatment, photothermal therapy, Dialysis, Bone & teeth implantation, HIV diagnosis, etc.

In the field of electronics, graphene is used in super transistors, super conductors, waterproof electronics, wearable electronics, Hard drives & memories, Elastic robots, optical Sensors, etc.

Graphene is the world's strongest material and can be used to enhance the strength of other materials. Graphene-enhanced composite materials can find uses in aerospace, building materials, mobile devices and many other applications.

In the field of sports, graphene is used in Helmets, in shoes, Graphene clothes, Graphene Rackets etc.

In Military protective equipment, graphene is used in making helmets, bulletproof vests & many more accessories.

Graphene can be used as anti-corrosion coatings and paints. With high transparency and high chemical inertness graphene can be used as a promising coating material for the protection of glass.