Electrical Materials

10/04/2020

Properties of Electrical materials ⇒ ① It should have high Electrical Conductivity ② It should have low Electrical resistivity.

As per Conductivity of material :-

Ag > Cu > Au > Al.

Conductivity $\propto \frac{1}{\text{Resistivity}}$

As per Resistivity of material :-

Ag < Cu < Au < Al

Ag: 1.5×10^{-8} ohm-mt

Cu: 1.7×10^{-8} ohm-mt

Au: 2.2×10^{-8} ohm-mt

Al: 2.8×10^{-8} ohm-mt.

Unit of Resistivity ⇒ ohm-mt.

Unit of Conductivity ⇒ per ohm-mt.

Which materials are suitable for Conductor :-

Materials which have the following properties are suitable for Conductor - ① Low Resistivity ($< 10^{-6}$ ohm-mt) ② Good mechanical strength ③ Good flexibility & ductility ④ Good fabricability ⑤ Good machinability ⑥ Good Corrosion & oxidation resistance.

Based on the Resistivity of the material, it is classified as ① Conductor [where resistivity (ρ) = 10^{-9} — 10^{-3} ohm-mt] ② Insulator [where, (ρ) = 10^{4} — 10^{17} ohm-mt] ③ Semi Conductor [where ρ = 10^{-3} — 10^{3} ohm-mt]

(2)

Example of Conductor — Cu, Ag, AL, Au.
Example of SemiConductor — Silicon, Germanium (Ge)
Example of Insulator — PVC, Glass, SiO_2, Bakelite.

Application of Conductor 1) Electrical transmission line ② Electrical distribution lines ③ For Electrical equipments like Generator, Motor, Transformer etc.

- Cu & AL is mostly used as Conductor
- Aluminium Conductor with steel reinforced (ACSR) Cable is used for high Voltage transmission line.
- oxygen free high conductivity Copper (OFHC) is used for critical application like Busbars & other Energy Conservation purpose.

Resistor

— Resistors is an Electrical Component that reduces the Electrical current.
— primary requirement of Resistor is uniform resistivity & it should have small temperature coefficient of Resistance.
— Example of Resistor 1) Manganin alloy (87% Cu + 13% Mn).
② Constantan (60% Cu + 40% Ni).

— Application of Resistor

~~1) uniform application~~
1) Industrial application where uniform current flow is required.
2) In Electronic Circuit, resistors are used to reduce current flow, divide voltages et

(3)

Heating Elements - Ex - (a) Nichrome (80% Ni + 20% Cr) melting point - 1100°C
(b) Kanthal (69% Fe + Cr + Al + Cu).

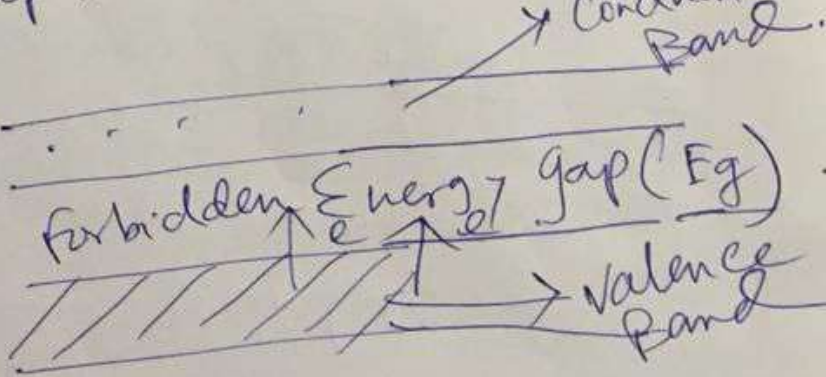
Properties of Heating Elements (1) High melting point (2) High Electrical resistance (3) Good oxidation resistance (4) Low coefficient of thermal Expansion.

Semiconductor ⇒ In between Conductor & Insulator.

Valence Band - It is energy band that consist of valence Electrons present in the outermost shell of atom.

Conduction Band - When sufficient Energy is provided (light or heat Energy), then this valence Electrons changed into free Electrons and moves on to Conduction Band and Causes Conductivity.

Forbidden Energy Gap - valence Band and Conduction Band is separated by a certain Energy gap is known as forbidden Energy Gap.



(**) Based on these Energy Gap (Eg), materials are classified as Conductor, Semiconductor & Insulator.

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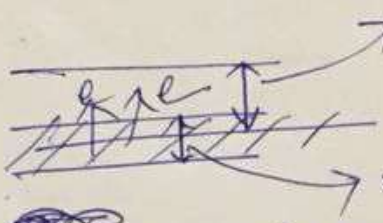
a) Materials with Energy Gap of 2-3 eV ⇒ Semi Conductor

***b) Materials with Energy Gap of > 3 eV ⇒ Insulator

c) Materials with practically no Energy gap ⇒ Conductor.

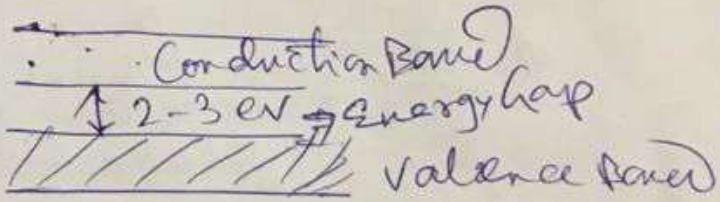
Conductor



- In Conductor either there is no Forbidden Energy gap or there is overlaping of the Conduction & valence Band.
- For Conduction to occur, free Electrons should move from Valence Band To Conduction Band by Crossing the Energy Gap.

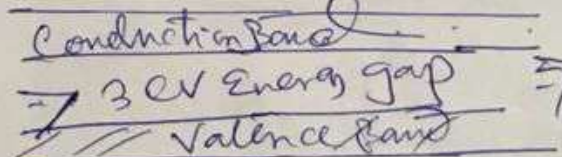
Semi Conductor

Eg - Si, Ge.



Insulator

Ex - Diamond
SiO2
PVC.



⇒ Here Energy gap is so big that electron can not jump in Insulator.

Semiconductor are classified into two Category ① Intrinsic Semiconductor ② Extrinsic Semiconductor, based on doping in it.

Doping - Sometimes impurities materials are ~~used~~ ~~inserted~~ inserted Externally inside the Semiconductor to improve its Conductivity, is known as doping.

Ex - P, As, Sb is dopped in

(5) Intrinsic Semiconductor – ① No impurity or No dopping is done ② Pure crystal of Si & Ge is Intrinsic Semiconductor ③ In Intrinsic semiconductor Conductivity happens due to thermal means.

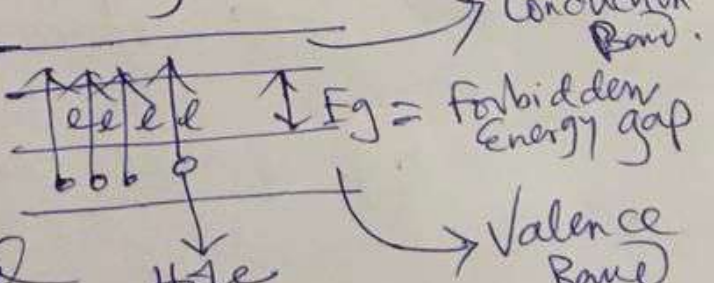
Extrinsic Semiconductor – ① Impurity like P, As, Sb, Sn is dopped in Si ② Conduction happens due to this impurity

Example of Semiconductor
① Silicon (Si) ② Germanium (Ge)
③ GaP (Gallium phosphide).
④ GaAs (Gallium Arsenide).

Application of Semiconductors
ⓐ Solar cell ⓑ Transistors ⓒ Junction rectifiers ⓓ LED's ⓔ TV, Radio Circuit ⓕ Laptop, mobile Circuit.

⊛ Effect of Light & Heat on Intrinsic Semiconductor

— In Intrinsic Semiconductor no dopping is done
— So for conductivity to occur in Intrinsic Semiconductor, heat & light plays a great role.
— there will be thermal Excitation due to application of heat & light, and free Electrons will leave from Valence Band to Conduction by Crossing the Forbidden Energy gap.



— Due to the movement of Electrons, Hole will be Created in Valence Band
— Effect of light & heat is Similar in Intrinsic Semiconductor.

(6) ~~Intrinsic Semiconductor = where~~

— When free Electrons leave the valence Band & goes to Conduction band, then holes are created in Valence Band. Thus free Electrons & holes are created at the same time.

— free Electrons carry negative charge & holes created positive charge.

— once temperature or Intensity of light is increased, more no of free Electrons & holes will be created and Conductivity will increase.

Extrinsic Semiconductor — where dopping is done by External Impurity.

they are classified into (a) n-type (b) p-type Semiconductor

n-type — where doping is done by Electron donor like — P & As.

— In n-type Semiconductor Electrons are majority Carriers.

p-type — where dopping is done by Electron acceptor Elements like — Boron, Gallium (Ga)

In p-type semiconductor, holes are majority Current Carrier.

(7)

Superconductive materials

Superconductivity – It is the ability of certain materials to conduct Electric Current with almost zero or negligible resistance.

** **Properties of Superconductive materials** :–

(a) virtually zero Electrical Resistance
(b) perfect diamagnetic property
(c) Heavy Current effect destroy the Superconductivity properties
(d) For a material to show superconductivity a low temperature is required. Superconductivity occurs when a material is cooled below the critical temp (Tc).
(e) Application of strong magnetic field beyond Critical limit destroy Superconductivity.

** **Classification of Superconductor** :–

1) **By their magnetic properties** – Type-I, Type-II
Type-I – only one critical magnetic field
Type-II – two Critical magnetic field.

2) **By their Critical temperature** –
⇒ **low temp Superconductor** – whose Critical temp is Below 30K.
⇒ **High temp Superconductor** – whose Critical temp > 30K.

3) **By their constituents & Structure** – pure Elements, some allotropes of Carbon, Ceramics.

** **Application of Superconductor** – widely used in (1) production of large permanent magnet (2) logic & storage function of computer.

Example ~~$YBa_2Cu_3O_7$~~, Nb_3Ge