

LEARNING MATERIAL
OF
ELECTRICAL ENGINEERING
MATERIAL (3RD SEM)



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BHUBANESWAR

→ Electrical Engineering material:-

Resistance:- oppose the flow.

conductors are those materials that allow the flow of current to them.

Resistor:- those substances that oppose the flow of flow of electric current. Resistor, the above phenomena is called resistance.

→ conductors are divided into

- ① low resistivity materials.
- ② High resistivity materials.

Resistivity and factors affecting Resistivity:-

Resistivity =

According to ohm's law.

$V = IR$ where.

(V) V = voltage across the terminals of the conductor.

(A) I = current through the conductor.

(R) R = Resistance of the conductor.

→ Resistance of a material is

$R = \frac{\rho L}{a}$

where R = Resistance of the material in ohm (Ω)

ρ = Resistivity or specific Resistance in (Ω.m)

L = Length of the material in meter.

α - area of cross.

Factors affecting resistivity:

① Temperature.

② Alloying.

③ Mechanical stressing.

Effect of temperature on Resistivity:

→ Resistance of conducting material increases with temperature.

→ The change in resistance of the material per Ω per degree change in temp. is called temperature co-efficient of resistance.

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② According to the law resistance of a conductor changes with temp.

$$R_t = R_0 (1 + \alpha t) \quad \text{--- (I)}$$

where R_t = Resistance of the conductor at $t^\circ\text{C}$.

R_0 = resistance of the conductor at 0°C .

α = temp co-efficient of resistance.

t = temperature.

→ According to the above law resistance of the conductor at any temperature of $t_1^\circ\text{C}$.

then $R_{t_1} = R_0 (1 + \alpha t_1) \quad \text{--- (II)}$

Dividing R_{t_1} by R_t , we get

$$\frac{R_{t_1}}{R_t} = \frac{R_0 (1 + \alpha t_1)}{R_0 (1 + \alpha t)} = \frac{1 + \alpha t_1}{1 + \alpha t}$$

Adding & subtracting αt in the Nr

$$\frac{R_{t_1}}{R_t} = \frac{1 + \alpha t_1 + \alpha t - \alpha t}{1 + \alpha t}$$

$$= \frac{1 + \alpha t + \alpha(t_1 - t) - \alpha t}{1 + \alpha t}$$

$$= \frac{1 + \alpha t + \alpha(t_1 - t)}{1 + \alpha t}$$

$$= \frac{1 + \alpha t}{1 + \alpha t} + \frac{\alpha(t_1 - t)}{1 + \alpha t}$$

$$= 1 + \frac{\alpha(t_1 - t)}{1 + \alpha t}$$

$$R_{t_1} = R_t \left[1 + \alpha \frac{(t_1 - t)}{1 + \alpha t} \right] \text{--- (iii)}$$

It means that the resistance at any temp t_1 can be calculated if the resistance at t is known. It helps the designer of electrical equipment to determine by calculation of the I^2R loss in the windings of motor transformer etc.

Effect of alloying on Resistivity Alloying :-

- Adding some impurities (a small percentage) or some other material to a metal.
 - By alloying resistivity of a metal can be increased.
 - Alloys have high resistivity than the base metal.
- For ex - when copper is alloyed with zinc it is called Brass (Copper - 60% Zinc - 40%)

Effect of mechanical stressing on Resistivity :-

- Resistivity of a material changes under the influence of mechanical treatment.
 - The fabrication of the conductor from the ingot to the final stage comprise initially hot working and finally cold-drawing.
 - This hardens the material increase its tensile strength resistivity.
- For ex - overhead conductor.

classification on conducting materials:-

- ① Low Resistivity materials.
- ② High Resistivity materials.

① Low resistivity material:-

→ Low resistivity materials should cover following properties.

- ① low value of resistivity.
- ② low temperature co-efficient (It means change in resistance with change in temperature, should be low). It is required to variation in voltage drop & power loss with change in temperature.

$$\begin{aligned} \text{Voltage drop} &= IR \\ \text{power loss} &= I^2R \\ \text{heat loss} & \end{aligned}$$

② Sufficient mechanical strength:-

The conductor having low resistivity must have sufficient mechanical strength it is required for the conductors used for transmission and distribution of the electrical power because they are subjected to stresses due to wind and their weight.

③ Ductility

It is the property of a material which allows it to be drawn out into a wire.

→ conductors are required in different sizes.

④ Solderability:-

conductors are required to be jointed. The joint should offer minimum contact resistance. So minimum contact resistance means the joint is soldered.

⑤ Resistance to corrosion:-

The conducting material should not corrode when used in out door atmosphere.

② High Resistivity materials:-

High resistivity materials should possess following properties.

① Low temperature co-efficient:-

High resistivity material are used in electrical measuring instruments. For each application, the material should have low temp co-efficient.

② High melting point:-

We expect the material should be able to which stand high temp. for a long time without melting.

③ Low tendency for oxidation:-

materials used as high resistance elements in heating appliances should be able to which stand high temp. for a long time with out oxidation. because if an oxide layer formed on the heating element the amount of heat radiation will reduce.

④ Ductility:-

These materials are required in different shapes & sizes. For ex- Thick wires are used in ovens, heaters, stoves. Thin wires in cases of precision wire wound resistors.

⑤ High mechanical strength:-

It is used where wire must be thin are required to have high tensile strength.

⑥ Low resistivity materials & their application:-

- ① copper
- ② silver
- ③ gold
- ④ Aluminium.
- ⑤ steel
- ⑥ stranded conductors
- ⑦ Bundle conductors
- ⑧ Brass
- ⑨ Bronze
- ⑩ Beryllium copper alloy.

Copper

Properties:-

- ① Reddish in colour
- ② Non-magnetic metal.
- ③ Copper is available in hard drawn, copper and annealed copper.
- ④ Low resistivity.
- ⑤ copper is available in hard drawn, copper and annealed copper.

Annealed copper:-

→ Annealed copper means heating it with an oxygen acetylene torch and rapidly cooling in water.

→ Annealed copper:-

- (i) Soft.
- (ii) Less tensile strength than hard drawn copper.
- (iii) It has higher conductivity than hard drawn copper.
- (iv) Resistivity of annealed copper = $1.72 \times 10^{-8} \Omega \cdot m$
- (v) It is used for insulated conductors in low voltage power cables, winding wires for electrical machines and tram trolley flexible wires.

Hard drawn copper:-

It is cold worked or worked because work hardened or strain hardened.

properties:-

- Its tensile strength is high.
- Its conductivity is less than that of annealed copper.

Limitation:- It is very scarce in India hence used copper is limited.

Application of copper:-

(1) used as a contact materials for central release motor structure top changes etc.

(2) Silver:-

- Pure silver has high electrical conductors.
- corrosion resistance

application:-

- used in commutator segment of small D.C motor (by alloying of 40% copper to silver)
- used in brushes and called in dc motor (alloy of silver by small % of graphite)

(3) Gold:-

- It is best electrical conductor.
- It is not in sufficient quantity to make it economical.
- It is malleable.
- It is ductile.
- It is corrosion resistance.

Application:

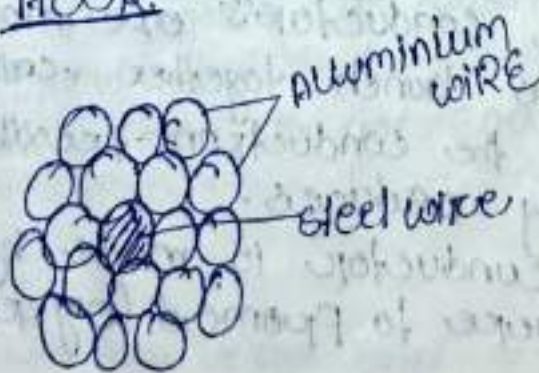
→ used as alloy to make coins & jewellery.

Aluminium:

- It is widely in India.
- It is used in the field of electrical engineering.
- It is the next best conductor copper.
- Resistivity $\rho = 2.8 \times 10^{-8} \Omega \cdot m$
- It is lighter than copper.
- It is easily rolled and hard drawn.
- It can be drawn into the wires.
- Aluminium is a soft metal.
- When aluminium is alloyed with other material like mg, si or fe its mechanical strength increase.
- It will be useful for overhead line conductors.
- Aluminium forms an oxide layer when exposed to atmosphere.
- It prevents the material from further oxidation.
- It acts as a resistance layer to corrosion.

Application:

- It is used in the overhead line conductors bus-bar.
- squirrel cage motor rotor bar.
- winding of electrical machine as a transformer.
- For overhead transmission lines are made of aluminium conductors with steel reinforcement called ACSR.



ACSR conductor

Steel

- Steel reinforcement is made for giving higher strength to the overhead conductor.
- It contains iron with small percentage of carbon added to it.
- Iron itself is not very strong.
- When carbon is added to iron, its mechanical properties are very good.
- It increases tensile strength of steel.
- Its ductility decreases.
- When carbon content is too high in iron, steel, becomes brittle.
- Steels are classified in to:
 - mild steel (carbon about 0.25%)
 - medium steel (carbon about 0.45%)
 - high carbon steel (carbon about 0.7% and above)
- When zinc coating is provided on its surface it is called galvanized.

Application

- galvanized steel wire is used as overhead telephone wire and as earth wires.

Stranded conductor

- a single conductor has large cross-section it is rigid in construction.
- it is liable to break while handling.
- To avoid this, this conductor is made of a no. of thin wires bunch together called strands.
- stranding makes the conductor flexible.
- Risk of breaking reduces.
- A stranded conductor is made by twisting the wire together to form layers.



a. cross section of a wire
stranded circular conductor
Having 1 wire at the centre,
6 wires in the 1st layer
and 12 wires in the 2nd
layer.



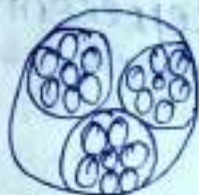
b. A stranded circular
conductor showing how wires
are twisted together.



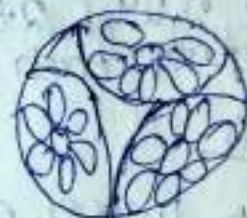
(a) circular stranded
conductor.



(b) compact circular stranded
conductor.



(a) Typical three



circular conductors
made sector shaped.

- A stranded stranding consist of 6 wires around one then 12 wires around the previous six, 18 wires around the 12, 24 wires around the 18 and show up.
- number of layers will depends upon no of wire to be provided.
- central wire is not counted as a wire.

Number of wires in the centre	1 wire $6n$	3 wires $3+6n$	4 wires $4+6n$
Number of wires in the n th layer from centre	$1+3n(1+n)$ $6n$	$3(1+n)^2$ $3+6n$	$(4+3n)(1+n)$ $4+6n$
Total number of wires in a stranded conductor having n layers	$1+3n(1+n)$	$3(1+n)^2$	$(4+3n)(1+n)$
Diameter over the n th layer in centimetres, where d indicates the diameter of each wire in centimetres	$(1+2n)d$	$(2.155+2n)d$	$(2.414+2n)d$

→ Stranded conductor size expressed as

$$7/2.24, 19/2.50, 37/2.06$$

1st no. 7, 19, 37 indicate total no of wires in the stranded conductor.

2nd no 2.24, 2.50, 2.06 etc represent the diameter of each wire in millimeter.

37/2.06

It has 1 wire at the centre

6 wire in the 1st layer

12 wire in the 2nd layer and 18 wires in the third layer.

No of layers is $n=3$ total no of wires

$$\text{equal to} = 1 + 3n(1+n)$$

$$= 1 + 3 \times 3(1+3) = 37$$

$$= 1 + 9 \times 4$$

$$= 1 + 36$$

$$= 37$$

Bundle conductors:-

Date-13.11.2021

- It is used in extra high tension power transmission
- It is used where high current carrying capacity is required to be transmitted.
- here voltage stress is reduced.
- corona loss is smaller.
- it is less liable to cause radio interference.

Low Resistivity copper alloying

→ Alloying of copper is done to make it mechanically hard, so there are 3 types.

- ① Brass
- ② Bronze
- ③ Beryllium copper alloy

Brass

- when copper is alloyed with zinc (60% Cu / 40% Zn) it is called brass.
- Brass has high tensile strength.
- It has lower conductivity than copper.
- It is resistant to corrosion.

Application:-

- plug points
- cricket outlet
- switches
- lamp holder
- fuses etc

Bronze

- when is copper alloying with tin (8% to 16%) and a very small percentage of a third element - cadmium, beryllium, phosphorus, silicon etc is called Bronze.
- when the third element is phosphorus it called phosphor bronze
- if the 3rd element is silicon and cadmium is it called silicon bronze or cadmium bronze.
- Bronze has high mechanical strength.
- It has lower conductivity.

→ It is more free from corrosion.

Application

current carry, spring, sliding contact, knife switch
blade

Beryllium copper alloyed.

→ when copper alloyed contains beryllium it is called bronze.

→ It has high conductivity and high mechanical strength.

→ It is hardening and elasticity can be changed by given appropriate heat treatment.

Application

Spring

sliding contact

knife switch blade

Brass = Cu + Zn
60% 40%

Bronze = Cu + Sn + third element.

High resistivity materials and their application:

- ① Tungsten.
- ② carbon.
- ③ platinum
- ④ mercury.

① Tungsten

→ It is a very hard metal.

→ Resistivity of tungsten is too high that of aluminium.

→ Its melting point is the highest of all metal. (3300°C)

→ It can be drawn in to very thin wires which is required for making filament.

→ Thinner the tungsten wire greater is its tensile strength.

Application

- incandescent lamps.
- Heaters in electronic tubes.



STRAIGHT
FILAMENT



coiled
FILAMENT

- Tungsten doesn't become brittle at high temp.
- Tungsten is used in atmosphere of inert gas like N, Argon, etc or in vacuum.
- it can reliably work at temp. like 2000°C and even higher.

Carbon-

- it is manufactured from graphite and coal etc.
- its manufacturing process include under water grinding of the raw carbon material.

→ molting of the powder carbon with a binding agent like cold-chap.

→ moulding of the component last baking them.

→ To increase the conductivity of carbon it is mix to it different additives like Cu or Bronze.

Characteristics of carbon

- It is high value of resistivity.
- -ve temp coefficient.
- pressure sensitive. Resistance increases with the decrease in pressure.
- low surface friction.

Application

- Brushes for electrical machine.
- electrode for electric furnace.

→ Non wire resistor, membranes etc for telecommu-
nication equipment.

Battery shell element -

→ Acc. - clane.

→ Acc. - welding etc.

Platinum -

→ It is greyish white metal.

→ It is non corrosive.

→ It is malleable.

→ It is ductile.

→ It is resistance to hot chemical.

→ It is of heavy metal.

Application

→ It is used as the heating element in laboratory
ovens and furnaces.

→ It is used as electrical contact material.

Mercury -

→ It is the heavy silver white metal.

→ It is the only metal which is liquid at room
temperature.

→ Mercury is poisonous.

Uses

→ Mercury are rectifier.

→ Gas filled tubes.

→ As a liquid contact material in electrical switches.

→ It is used for making and breaking contact in
Buchholz relay used for transformer protection.

Super conductivity.

- We know that resistivity of some metals increases with the increase in temperature and vice versa.
- There are some metals or compounds whose resistivity becomes zero when their temp. is brought near 0° kelvin (-273°C). At this stage the metals or compound are said to attend super conductivity.

For example - mercury it becomes supercon ducting at approximately 4.2 kelvin.

* Transition temperature:

- The temperature at which the transition takes place from the state of normal conductivity to that of super conductivity, that called transition temperature.

- There are two types of super conductors

a. Type 1 super conductor.

b. Type 2 super conductor.

a. Type 1 super conductor -

- These are soft conductors metals they are usually pure elements like metals.
- They have very little use technical application.

b. Type 2 super conductor

- They are hard super conductors.
- They are usually alloys of metals with high values of resistivity in normal state.
- They are very useful.

* Super conducting materials -

- They are Tin, lead, lead and tantalum. At present about 30 superconductor metals and more than 600 superconductor alloys are already known.
- The highest temp at which superconductivity are observed 20K .

For ex - Aluminium, Germanium, Niobium, etc.

Application

→ Electrical machines -

- Efforts are made to develop electrical machines and transformers utilizing superconductivity.
- It will increase the efficiency by 99.9% it will reduce the size.

power cables -

- if it is used for power cable, it will enable transmission of power over long distance by reducing the voltage drop or power loss.

Electro Magnet -

- super conducting solenoids don't produce any heat during operations.

Future prospects -

- In case of super conductor scientists are forcing change to keep the conductor at 0 kelvin.
- only He is used to achieve low temperature required for super conductivity.
- He is an expensive gas.
- Efforts are made to make helium available in cheap.

Date - 06/12/2021

Chapter - 2

Semiconducting materials -

Atom - out of the total volume of an atom most of the volume is an occupied space by electrons.

- Q → what in an atom holds it together?
- why an atom doesn't collapse?

Ans → The atoms held together by the attraction of negatively charged electrons to the positively charged nucleus in their respective orbits. It exercises a centrifugal force which is exactly counter balanced the attractive forces of the nucleus.

② Since nucleus contains protons which have +ve charges.
→ Hence like charges repel with each other.

③ The nucleus should fly apart but it doesn't why?
→ Repelling forces in the nucleus is counter balanced by a force of attraction in the nucleus which is yet not understood by the scientist.

Conductors & Insulators:-

→ All matter are classified into

- (i) conductors.
- (ii) semi conductors.
- (iii) Insulators.

This classification based on the outermost orbit of the atom.

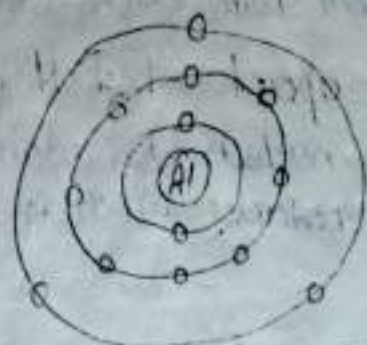
→ When voltage is applied across the material the orbiting electron in the outermost orbit experiences a force of attraction towards the +ve terminal of the applied voltage.

→ Hence the depending upon the distance betn valency & from the nucleus and the no. of e^- in the valency ring the valency electrons may or may not be pulled out of orbits under pressure of the externally applied voltage.

→ Example: silver 47

Copper - 29





- smaller the no^o of valency electrons, greater is the tendency to leave the parent atom.
- more no^o of orbits means more is complex is the atoms.
- when the orbit is full with all 8 electrons, very high voltage has to be applied to cause the valency e⁻ to leave their orbits.
- The best conductors are those which are more complex and have less no^o of valency electrons.

Ag > copper > aluminium.

- Good conductors usually have 1, 2 or 3 valency electrons.
- when voltage is applied across a conductor electron flow is easily created.
- EX - silver, gold, Ag, Aluminium, graphite, ionic compound dissolved in water.

on insulator's

- insulators are materials that oppose the free flow of electron from atom to atom and molecule to molecule.
- insulator does not allow free flow of e⁻ when voltage is applied.
- Best insulators have valency rings continuous 8 electrons.
- Example of insulators: wood, plastic, glass, paper.

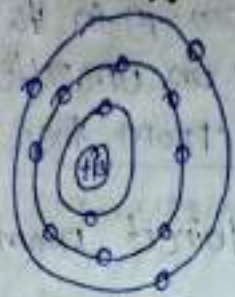
Semiconductor

A semiconductor neither a good conductor nor a good insulator.

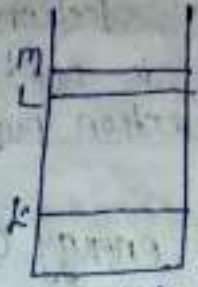
Ex: Germanium, Silicon.

(Valency electron is 4 for both.)

Electron energy and energy band theory -



Bohr model of AL



Simplified energy level Representation of the shell.

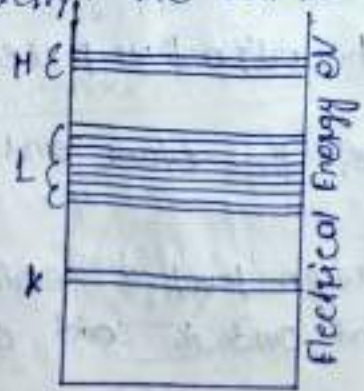
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* Energy level of electron total energy -

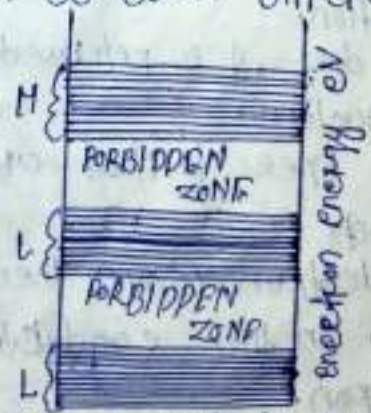
Defn: An electron revolving around the nucleus of an atom has potential energy, centrifugal energy, rotational energy & magnetic energy, all of which together determine the total energy of the energy level of an electron. This value is measured in electron volts, commonly expressed as eV.

→ It is defined as that amount of energy gained or lost when an electron moves with or against a potential difference of one volt.

→ The larger the orbit in which an electron revolves the greater is its energy. Electrons with least energy are on with the K level it is nearest with the no. of electron exactly the same orbit. So each different electron.



(a) Energy levels of a Typical Atom



(b) Energy levels Grouped as Bands

So in the diagram have been energy levels have group into energy band.

FORBIDDEN ZONE

→ The area between one called energy gap FORBIDDEN ZONE. Here ~~lets~~ No of electron can have an energy.

Excitation of atoms.

→ when each electron in an atom is in its normal orbit, the atom is said to be in an unexcited state

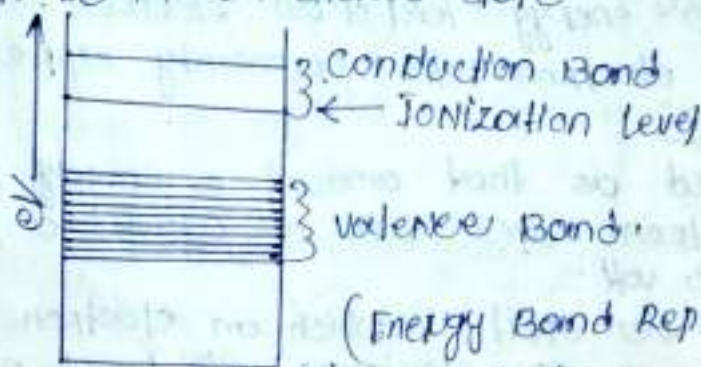
→ To move an electron further away from the electron its an energy.

* The additional energy can be obtained from any of the following -

- ① Light.
- ② Heat.
- ③ Electrostatic.
- ④ Magnetic.
- ⑤ kinetic.

→ If a required amount of heat energy is absorbed by electron it will jump to a higher energy level.

→ when the electron is in the higher energy level, the atom is said to be in an excited state.



(Energy Band Representation of Ionization)

→ when required it ~~also~~ absorbed by a valence electron it will leave the valence band and may ~~upto~~ by the ionization.

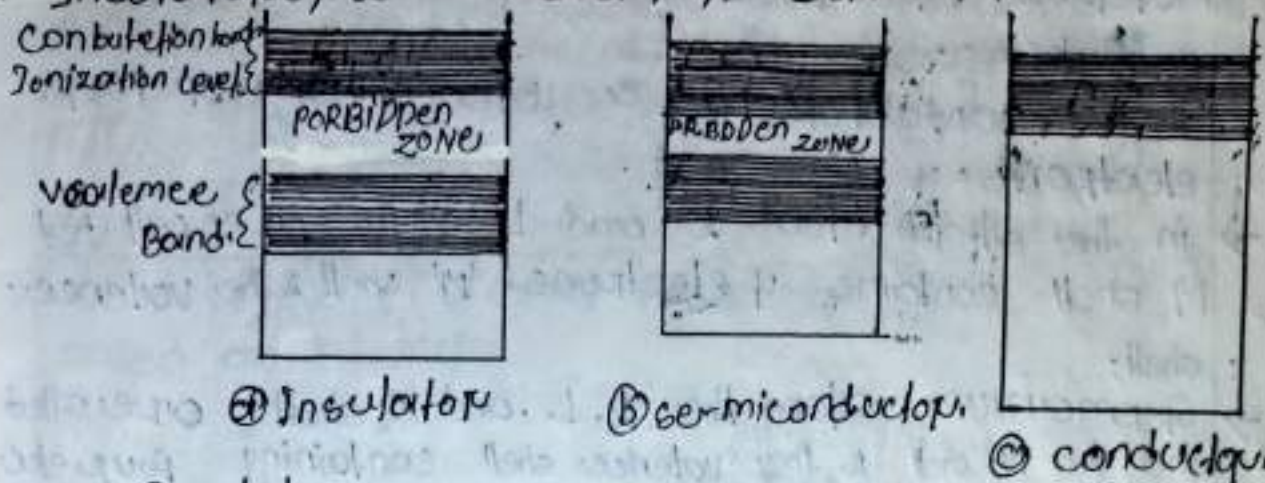
→ If it does, it is released from the attractive forces of the nucleus.

→ it is free to float around betⁿ the atom and to conduct.

→ An electron above the ionization level is said to be in the conduction band and is said a free electron.

→ Ionization means when an electron of the valence valence band, the remaining atom is no longer but has a positive charge and is called a positive ion.

* Insulators, semiconductor, & conductors:



(a) Insulator

(b) Semiconductor

(c) conductor

or. Ppt. Insulator-

- Forbidden zone betⁿ the valence band the conduction band its in quite large.
- This indicates that electrons in the valence band require large amount of additional energy to move upto the end conduction become free.
- As long as the valence electrons are unable ~~states that~~ in the case of semiconductors to move upto the conduction band there can be no electron flow.

* Conductor

- In a conductor.
- In the better conductor may overlap.
- Electrons from the valence ring may be moved into the conduction zone by a small amount of energy.

* Semi-conductors

- In case of semi-conductors forbidden zone is reduced.
- Hence the valence electron required less energy to free them selfs from attractio. of the nucleus.

Semiconductors materials -



(Si)



(Ge)



→ The shell arrangements for (a) Silicon and Germanium (b) simplified Si and Ge atoms

→ The electrical characteristics of semiconductor materials fall between those of insulators and conductors.

→ A semiconductor has a valence ring of four electrons.

→ In the silicon atom K and L shells are full but M shell contains 4 electrons. 'M' shell is the valence shell.

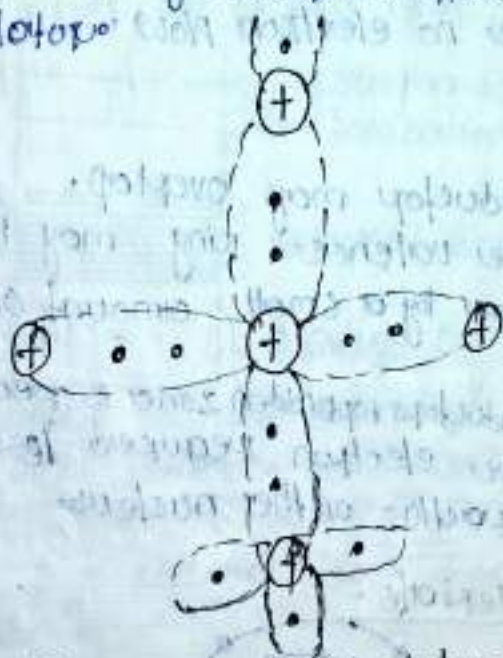
→ Germanium atom the K, L, and M shell are filled and the N shell is the valence shell containing four electrons. shell is the 'N' shell.

COVALENT BONDS

When each atom shares electrons to fill its valency ring with 8 electrons is called covalent bond.

→ Each bond with 2 electrons in an electron pair bond.

→ When atoms enter into covalent bonding each atom in effect has 8 valency electrons hence it makes it a good insulator.



[sets of covalent sharing]

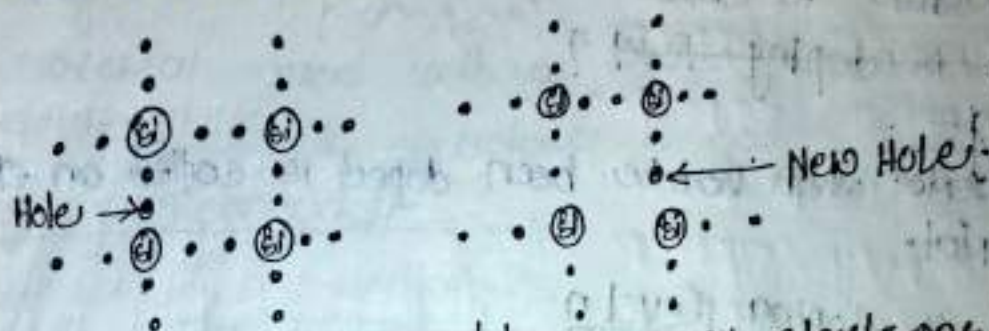
① Covalent bonding leads to the development of a polycrystal or several individual crystals held together perfectly.

The extra atoms are not properly locked in place and there are missing atoms in some parts of the structure.

- (ii) Due to impurities, there may be extra electrons which can't lock into the covalent bond structure. So, materials having covalent bonds doesn't have a perfect crystal structure & is not a good insulator but a poor insulator. It is called semi-conductors.

Intrinsic Semiconductors - (Silicon, Germanium)

→ If a crystal contains only one type of atom it is called an intrinsic



Hole movement caused by valency electrons.

When temperature is less than or equal to 0°C this intrinsic material will act as a good insulator.

- When intrinsic semiconductor operate in a room temperature, valency electrons produces which makes it conductor.
- When an electron is freed from the atom of an intrinsic material it breaks a covalent bond leaves a vacancy called Hole.
- The free electron and the hole form an electron hole pair.
- Higher the temperature, greater the free electrons and greater the no. of holes.

(a) → What is hole?

- It means loss of an electron & it is +vely charged.
- When voltage is applied to an intrinsic material it acts as a conductor.
- The free electrons move from -ve terminal to +ve terminal of the voltage source. The holes created by free ones.

fixed and don't move they appear to move from the +ve terminal.

→ current flow in a semiconductor is composed of free e⁻ movement & hole movement.

Extrinsic semiconductor -

- Intrinsic semiconductor have less applications.
- To make a material function as a semiconductor some impurities are added in a controlled manner.
- This addition of impurities to an intrinsic semiconductor is called.

~~Imp = what is doping level?~~

doping -

→ A material which has been doped is called an extrinsic material.

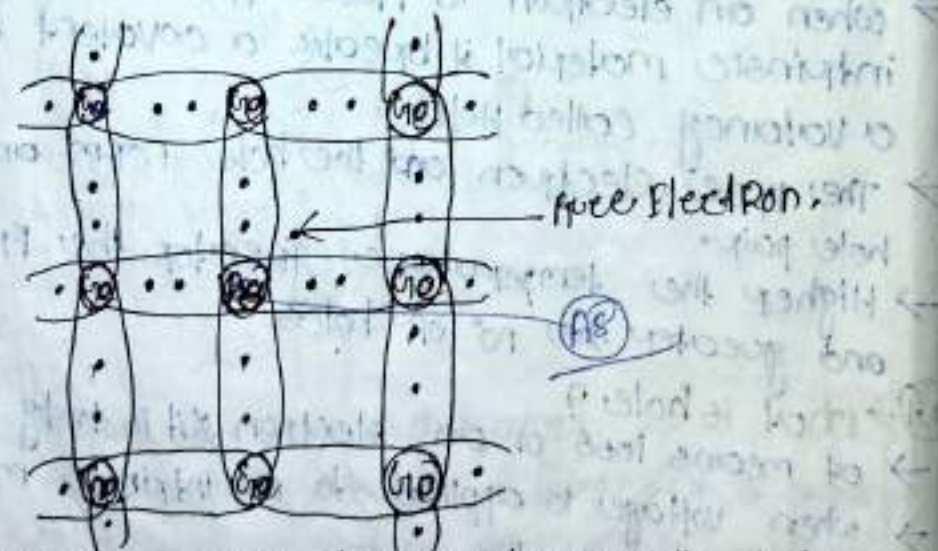
~~Imp = what is doping level?~~

→ The extent to which the impurity has been added is called doping level.

→ Extrinsic semiconductors are of two types -

- ① N-type semiconductor.
- ② p-type semiconductor.

① N-type semiconductor.



(Arsenic Impurity Atom provides a Fifth Electron that cannot enter the covalent Bond structure)

→ Those impurities that have 5 valency electrons is called pentavalent impurities.

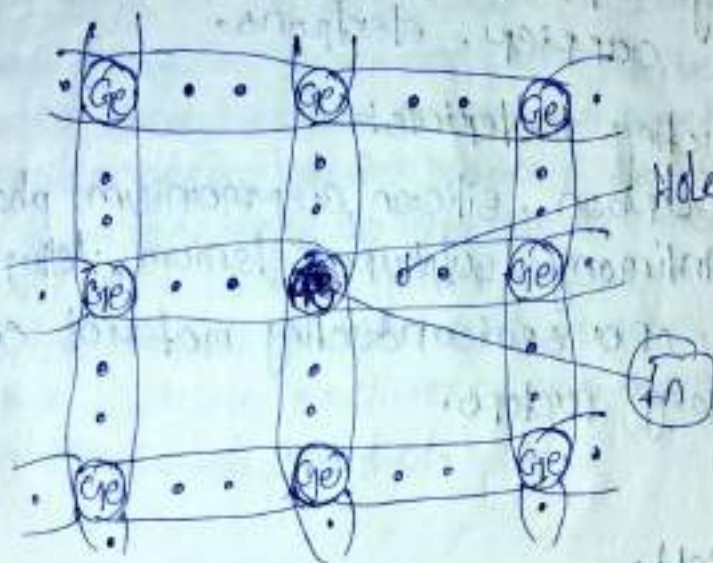
Ex: Antimony, Arsenic, phosphorus.

→ when a pentavalent impurities added to an intrinsic material, only 4 of its valency electrons go into covalent bond.

→ 5th valency electron of the impurity atom is free to wander through the crystal. since pentavalent atom don't an extra electron atom, they are called donor impurity.

→ A material doped with a donor impurity has excess of electron in its structure is called N-type material.

p-type semiconductor-



(In p-type material, an Indium impurity atom creates a hole in the covalent bond structure to provide an attraction for an electron.)

→ Those impurities that have three valency electrons are called equivalent groups.

Ex - Aluminium, Gallium, Indium.

→ when added to intrinsic materials, they lock into the crystal structure.

→ Since the impurities has 3 valency electrons there is a hole in the covalent bond due to lack of an electron. Since there is lack of electron and it accepts electron, from known as this type of impurities are Accepted.

→ Intrinsic materials doped with a trivalent impurities i.e called positive or p-type semiconductor.

Majority & Minority carriers-

n-type material-

Majority carrier - electrons.

Minority carrier - holes.

p-type material-

Majority carrier - holes.

Minority carrier - electrons.

Semiconducting materials:-

Boron, carbon, silicon, germanium, phosphorus, Arsenic, Antimony, sulphur, selenium, tellurium, Iodine.

→ Resistance of a semiconducting material can be control by the following factors.

① Illumination

② voltage.

③ electric field.

Semiconductors can be classified as

① mono-crystals-

Ex- carbon, silicon, germanium.

② poly-crystals-

Ex- selenium, tellurium, Antimony, Arsenic, phosphorus oxides & or such metals such as copper, zinc, titanium, tungsten, molybdenum.

→ sulphides, selenides & tellurides of lead, copper, cadmium & other elements.

→ chemical compounds of certain elements like aluminium, gallium, indium.

Applications of semiconductor materials -

① Rectifiers -

Germanium & Silicon Rectifiers -

A p-type & N-type material are joined together to form a junction called p-n junction. When an external voltage is applied across the two materials a flow of currents if the +ve & -ve terminals of the voltage source are connected to the extrinsic or p & n type material.

voltage applied in this way is called forward bias.

→ The applied voltage is reversed. the positive of the supply voltage is connected to the N-side. the negative of the supply voltage is connected to the P-side & the -ve of the supply voltage is connected to the p-side. there is no flow of current this is called reverse biasing.

→ Thus semiconductors can be used as rectifiers.

→ Modern p-n junction rectifiers use germanium or silicon as the semiconductor material.

- surface resistance depends upon humidity.
- Effect of various factors on insulation resistance-
- Insulation resistance is affected by temp. variations.
- Exposed to moisture decreases insulation resistance.
- It is affected by voltage
- insulation decreases with ageing.

Dielectric strength

- when operating voltage increases gradually of some value of voltage the insulation property will damage or break down, so the property which attributes to such type of breakdown, so, property with damage or break down, so which attributes to such type of breakdown is called dielectrical strength.
- Di-electric strength is the maximum potential difference that the material can withstand.
- its unit is volt per unit thickness of the insulating material.

Factors affecting di-electric strength

- Di-electric strength decrease with increase in temp.
- humidity decrease dielectric strength.

Dielectric constant:-

We know that $Q = CV$

where Q = storing charge
 V = voltage
 C = capacitance.

- capacitance is different for different materials.
- The property of insulating material that causes the difference in the value of capacitance, physical dimensions remaining same is called the dielectric constant, permittivity.

$$C = \frac{A}{d}$$

$$C = \epsilon \frac{A}{d}$$

Where:

$C =$ Capacitance.

$A =$ surface area of insulation.

$d =$ distance betn two plates.

$\epsilon =$ permittivity / dielectric constant.

$$\epsilon = \epsilon_0 \epsilon_r$$

$\epsilon =$ permittivity.

$\epsilon_0 =$ " in vacuume.

$\epsilon_r =$ " of material.

Visual properties:-

→ visual properties are:

① appearance ② colour.

③ crystallinity.

Mechanical properties:-

→ mechanical strength - mechanical strength of an insulating material depends upon a number.

1. Temp rise -

Temp rise gives

$$C = \frac{\epsilon_0 \epsilon_r A}{d}$$

where $\epsilon_0 =$ permittivity of free space

$\epsilon_r =$ relative permittivity

$A =$ area of plates

$d =$ distance between plates

$C =$ capacitance

the product of insulating material that causes the difference in the value of capacitance. physical dimension remaining same is called as dielectric constant.

relative permittivity.

$$C = \frac{\epsilon_0 \epsilon_r A}{d}$$

$$C = \frac{\epsilon_0 \epsilon_r A}{d}$$