Types of materials:
Based on the levels of conductivity, materials are classified as:
a) Conductors
b) Insulators
c) Semi-conductors.

a) Conductors:
→ Conductor is a type of material which allows the flow of charge due to the presence of free electron.
→ The resistance of a conductor increases with an increase in temperature (Positive coefficient of resistivity).
→ The conductors have very high conductivity (10^{-7} Ω/m) thus they can conduct electrical current easily.
→ There is no or low energy gap between the conduction and valence band, hence does not need extra energy for the conduction.
→ E.g Gold, Copper, Silver, Aluminum, etc.
→ Conductors are used for making electric wires.

b) Semiconductor:
- A semiconductor is a material whose conductivity lies between conductor and insulator.
- The resistance of a semiconductor decrease with increase in temperature (negative coefficient of resistivity)
- It act as an insulator at absolute zero.
- They have intermediate conductivity (10^{-7} Ω/m to 10^{-13} Ω/m) thus they can act as insulator and conductor at different conditions
- The band gap of semiconductor is greater than the

conductor but smaller than an insulator i.e 1ev. Their electron needed little energy for conduction.

→ E.g. Silicon, Germanium, Gallium, etc.

→ Semiconductors are used in electronic devices like cellphone, computer, etc.

c) Insulator

→ An insulator is a material that does not allow the flow of current.

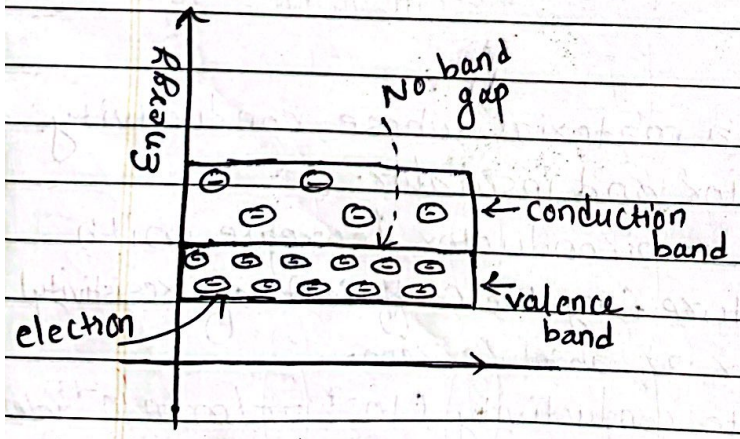
→ Insulator has very high resistance but decrease with temperature. (Negative coefficient of resistivity).

→ They have very low conductivity (10^{-13} ℧/m) thus they do not allow current flow.

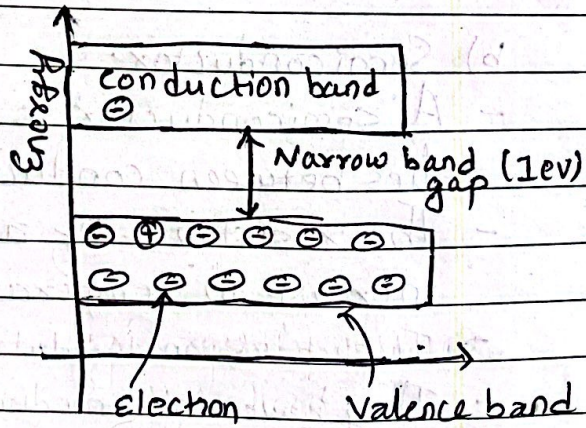
→ The band gap in insulator is huge (+5 ev), which need an enormous amount of energy like lightning to push electrons into the conduction band.

→ E.g Rubber, Glass, Wood, etc.

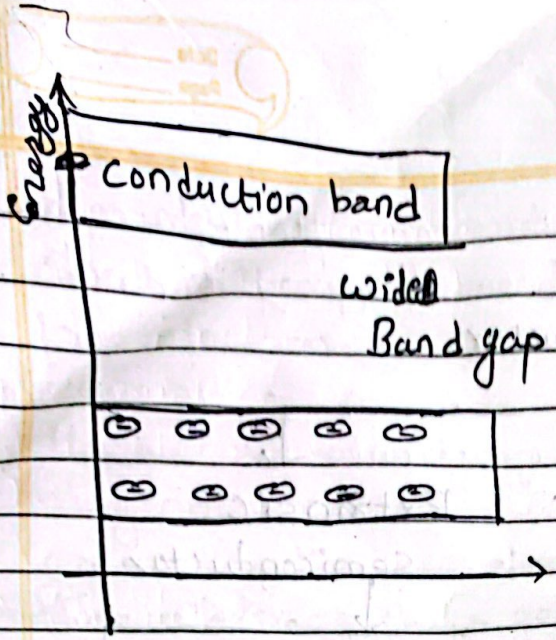
→ The insulators are used for protection against high voltages.



Conductor



Semiconductor.



Insulator:- Doping → Doping is the intentional introduction of impurities into an intrinsic semiconductor for the purpose of modulating its electrical, optical and structural properties. The doped material is known as extinsic semiconductor.

Semiconductors:

Properties of semiconductors

- 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.
- Less power losses.
- Semiconductors are smaller in size and posses less weight.

Types of Semiconductor:

- Semiconductor
  - Intrinsic Semiconductor
  - Extrinsic Semiconductor
    - N-Type Pentavalent impurity
    - P-Type Trivalent impurity

Intrinsic Semiconductor:

Semiconductors which are chemically pure, meaning free of impurities are called intrinsic Semiconductors. The most common intrinsic semiconductor are Silicon and germanium, which belong to group 4 of the periodic table. They have four valence electron and is responsible for the conduction properties of the Semiconductors.

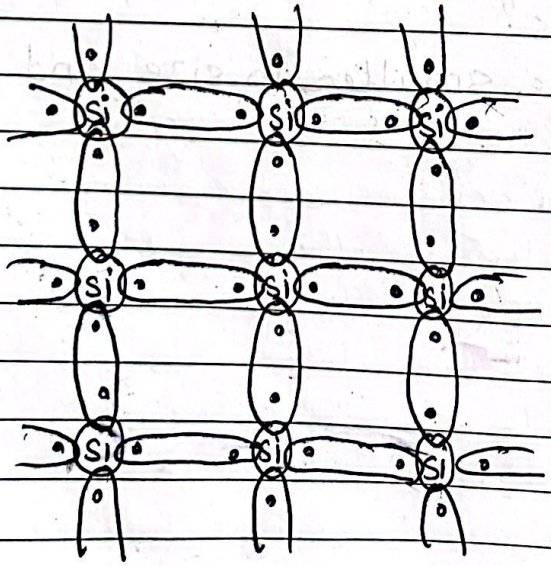


Fig: Crystal structure of Silicon at absolute Zero temp (-273°c)

The intrinsic semiconductor act as insulator at 0 Kelvin temperature due to the absence of free electron.

However at room temperature, the thermal energy may cause a few of the covalent bonds to break, thus generating the free electrons.
The electrons thus generated get excited and move into the conduction band from the valence band, overcoming the energy barrier. During this process each electron leaves behind a hole in the valence band. The electron and holes create in this way are called intrinsic charge carrier and are responsible for the conductive properties exhibited by the intrinsic semiconductor materials.

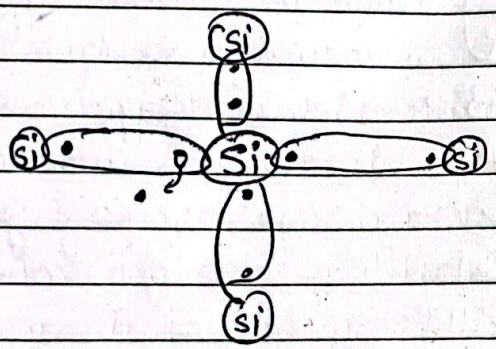


Fig: Schematic model of generation of hole and conduction electron due to thermal energy at moderate temp.

In intrinsic semi-conductor the number of free electrons, n_e is equal to the number of holes n_h
i.e $n_e = n_h = n_i$
where n_i is called intrinsic carrier concentration.

Under the action of an electric field, these hole move towards negative potential giving the hole current I_h.

The total current, I is the sum of the electron current I_e and the hole current I_h.

i.e $I = I_e + I_h$.

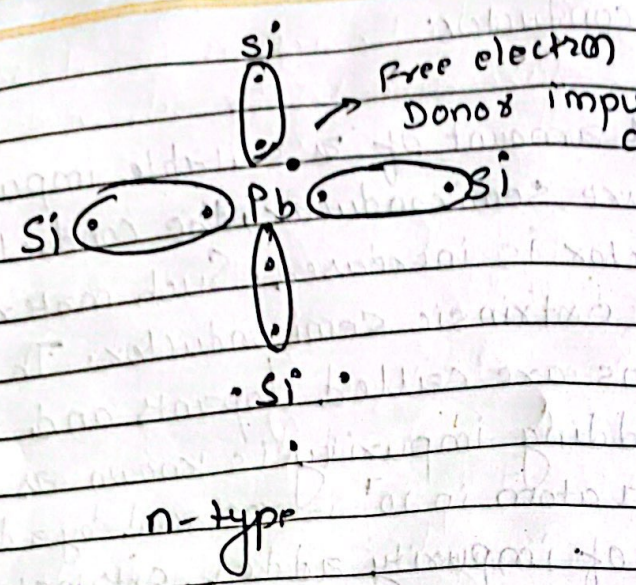
Extrinsic Semiconductor:

When a small amount of a suitable impurity is added to a pure semiconductor, the conductivity of the semiconductor is increased. Such materials are known as extrinsic semiconductor. The impurity atoms are called dopants and the procus of adding impurity is known as doping. Usually, only 1 atom in 10^7 is replaced by a dopant atom. On the basic of impurity added, extrinsic semiconductor are further classified as:

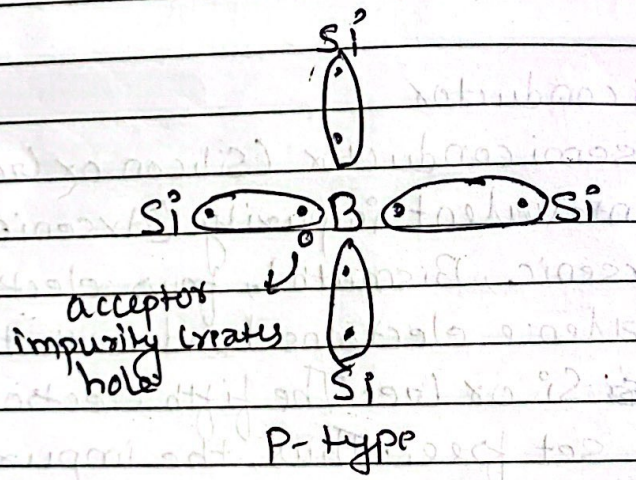
a) N-type semiconductor
b) P-type semiconductor

a) N-type semiconductor

When a pure semiconductor (Silicon or Germanium) is doped by pentavalent impurity (Arsenic, Phosphrous, Arsenic, Bismuth), four electrons out of five valence electrons bonds with the four electrons of Si or Ge. 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 increases. Hence it is called n-type semiconductor. 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



When a pure semiconductor is doped with trivalent impurity (Aluminium, Gallium, Indium, Boron) 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 are increased. Hence it is called P-type semiconductor. As conduction is

due to the large number of holes, the holes in the P-type semiconductor are majority carriers and electrons are minority carriers.

Semi conductor