# THE SOLID STATE

# ELECTRICAL PROPERTIES

## PROPERTIES OF SOLIDS: -

(i) Electrical Properties

(ii) Magnetic Properties

### (i) Electrical Properties: -

Solids exhibit an amazing range of electrical conductivities, the range of electrical conductivities from $10^{-20}$ to $10^{7}$ $ohm^{-1}\ m^{-1}$. Solids can be classified into three types on the basis of their conductivities.

**(1) Conductors:** Metals are goods conductors and have conductivities in the order $10^{7}\ (\Omega m)^{-1}$

**(2) Insulators:** Those solids which have very low conductivities ranging from $10^{-20}$ to $10^{-10}\ (\Omega m)^{-1}$ are electrical insulators e.g.;

MnO, CoO; NiO, CuO, $Fe_2O_3$ , $TiO_2$ .

**(3) Semiconductors:** Those solids which have intermediate conductivities generally from $10^{-6}$ to $10^{4}\ (\Omega m)^{-1}$ are termed as semiconductors.

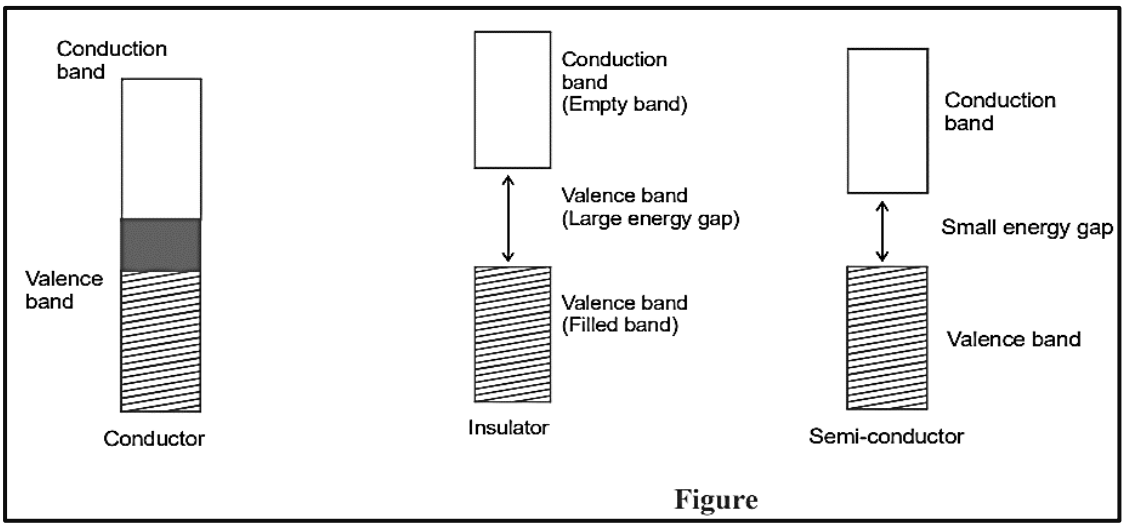
### Intrinsic Semiconductors:

The conduction by pure substances such as silicon and germanium are called intrinsic conduction and these pure substances exhibiting electrical conductivity are called intrinsic semiconductors.

### Causes of Conductance in Solids

1. In most of the solids, conduction is through electron movement under an electric field.
2. In ionic solids conduction is by movement of ions in molten state.
3. The magnitude of electrical conductivity strongly depends upon the number of electrons available to take part in conduction process.
4. In metals, conductivity strongly depends upon the number of electrons available per atom. The atomic orbitals form molecular orbitals which are too close in energy to each other so as to form a band.

5. If conduction band is not completely filled or it lies very close to a higher unoccupied band, then electrons can flow easily under an electric field thereby showing conductivity.
6. In case of insulators, the gap between valence band conduction band is too large, so electrons cannot jump from valence band to conduction band and very small conductivity is observed.
7. In case of semiconductors, the gap between valence band and conduction band is small and therefore some of the electrons may jump from valence band to conduction and some conductivity is observed.
8. Electrical conductivity of semiconductors increases, with increase in temperature. This is due to the fact that with increase in temperature, large number of valence electrons from the valence band can jump to conduction band. Pure substances like silicon and germanium that exhibit this type of conducting behaviour are called intrinsic semiconductors.
9. For particle purpose, the conductivity of pure silicon and germanium is too low at room temperature, therefore, there is need to increase the conductance by doping.




**Figure**

## Type of Semiconductors

### (1) n-Type Semiconductors:

Metal excess compounds conduct electricity through normal electron conduction mechanism and are therefore n-type semiconductors.

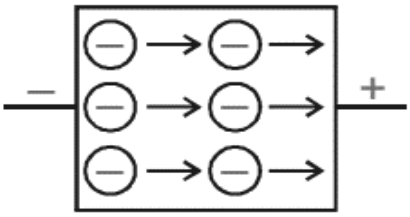
### Creation n-Type Semiconductor

1. When silicon is doped with small amount of group -15 elements such as P, As or Sb, its electrical conductivity increases sharply.

2. In pure silicon each silicon atom uses its four valence electrons for the formation of four covalent bonds with the neighbouring silicon atoms.

3. When silicon is doped with some group-15 element, the some of the positions in the lattice are substituted by atoms of groups -15 elements have five valence electrons. After forming the four covalent bonds with silicon (or another group-14 element such as germanium). One excess electron is left on them.

4. Since this electron is not involved in bonding it becomes delocalized and contribute to electrical conduction. Silicon doped with group 15 element behaves as a n-type semiconductor.




n-type semiconductor

## (2) p-Type Semiconductors:

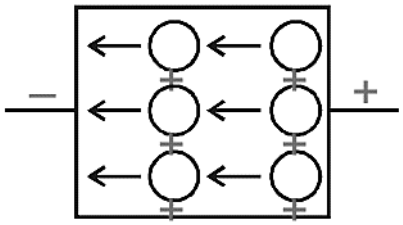
Metal deficient compounds conduct electricity through positive hole conduction mechanism and are therefore p-type semiconductors.

### Creation p-Type Semiconductor

1. Electrical conductivity of silicon or germanium can also be increases by doping with some group-13 element such as B, Al or Ga.

2. Goup-13 elements have only three valence electrons. The combine with group-14 elements to form an electron deficient bond or electron vacancy or a hole. These holes can move though the crystal like a positive charge giving rise to electrical conductivity.

3. Gorup-14 elements doped with group-13 elements behave as p-type semiconductors. In the presence of electrical field the holes move in direction opposite to that of electrons.




p-Type Semiconductors