SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

CLASSIFICATION OF METALS, CONDUCTORS AND SEMICONDUCTORS

On the basis of conductivity

On the basis of the relative values of electrical conductivity (σ) or resistivity

($\rho = 1/\sigma$), the solids are broadly classified as:

(i) Metals: They possess very low resistivity (or high conductivity).

ρ ~ 10–2 – 10–8 W m   or σ ~ 102 – 108 S m–1

(ii) Semiconductors: They have resistivity or conductivity intermediate

to metals and insulators.

ρ ~ 10–5 – 106 W m

σ ~ 105 – 10–6 S m–1

(iii)Insulators: They have high resistivity (or low conductivity).

ρ ~ 1011 – 1019 W m

σ ~ 10–11 – 10–19 S m–1

each electron will have a different energy level.

These different energy levels with continuous energy variation form what are called energy bands.

The energy band which includes the energy levels of the valence electrons is called the valence band.

The energy band above the valence band is called the conduction band.

insulator

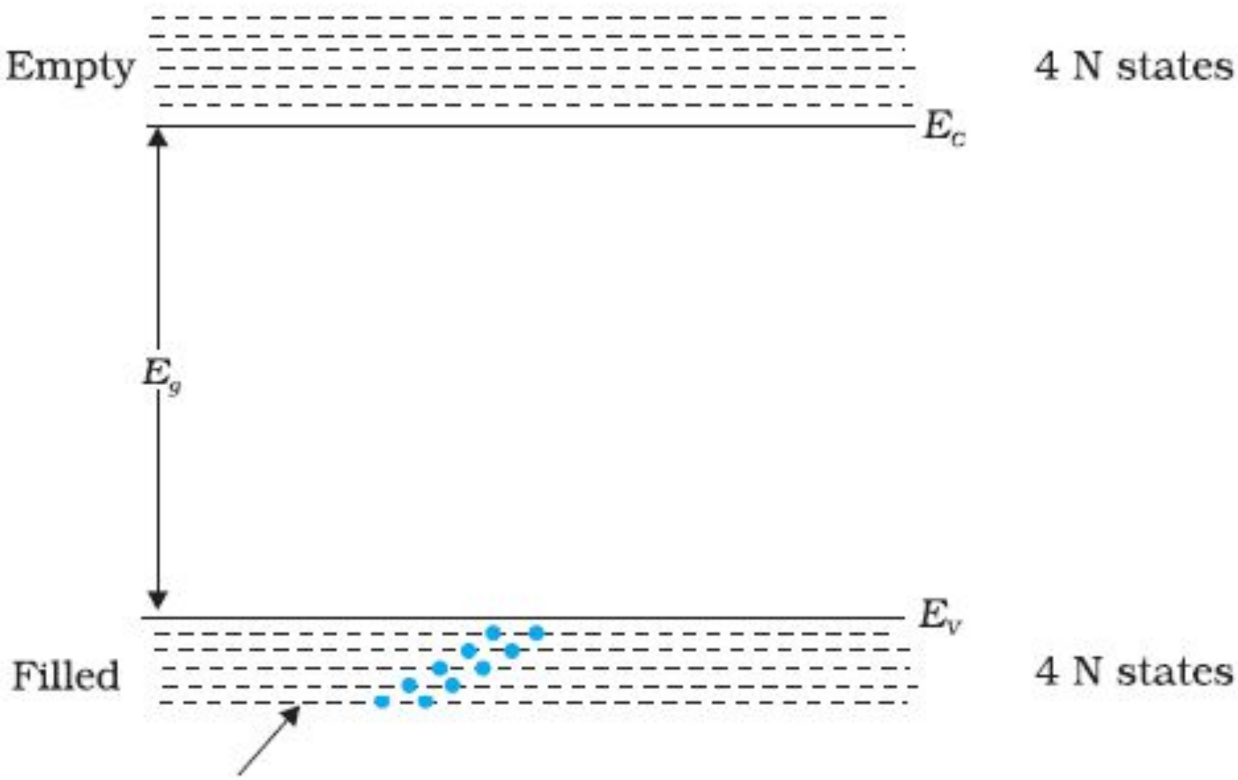
If there is some gap between the conduction band and the valence band, electrons in the valence band all remain bound and no free electrons are available in the conduction band.

This makes the material an insulator

But some of the electrons from the valence band may gain external energy to cross the gap between the conduction band and the valence band. Then these electrons will move into the conduction band.

At the same time they will create vacant energy levels in the valence band where other valence electrons can move.

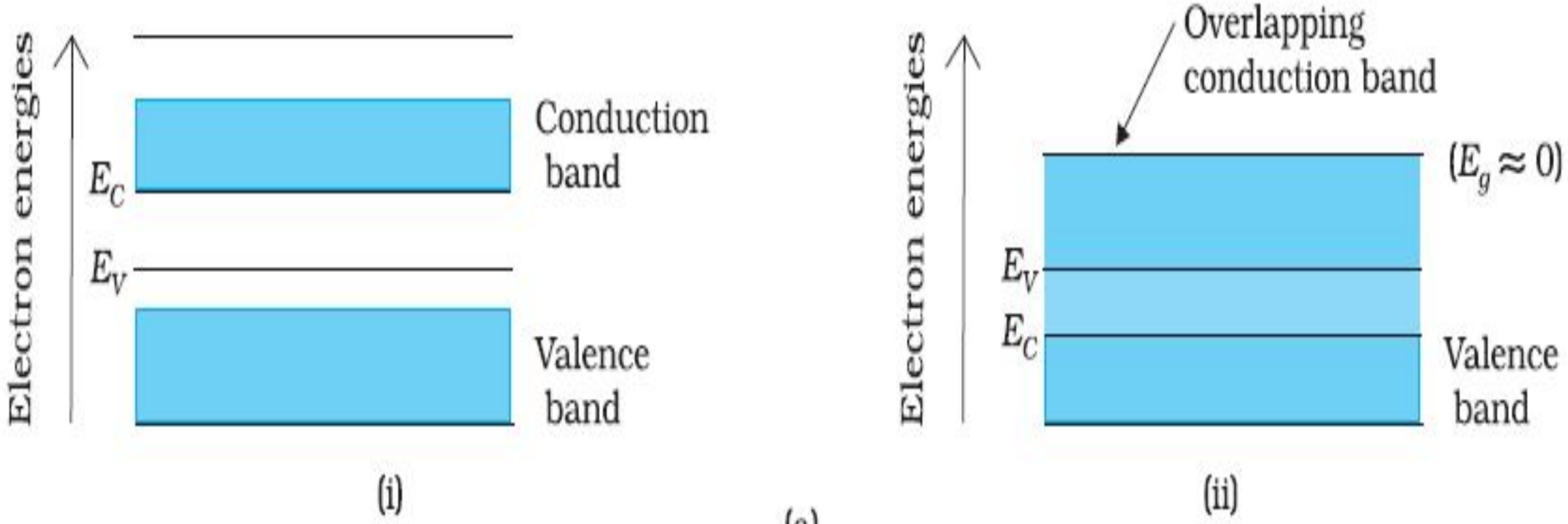
Thus the process creates the possibility of conduction due to electrons in conduction band as well as due to vacancies in the valence band.


Empty
4 N states
E_c
E_g
E_v
Filled
4 N states

The gap between the top of the valence band and bottom of the conduction band is called the energy band gap (Energy gap E_g).

It may be large, small, or zero, depending upon the material

When there is overlap electrons from valence band can easily move into the conduction band.



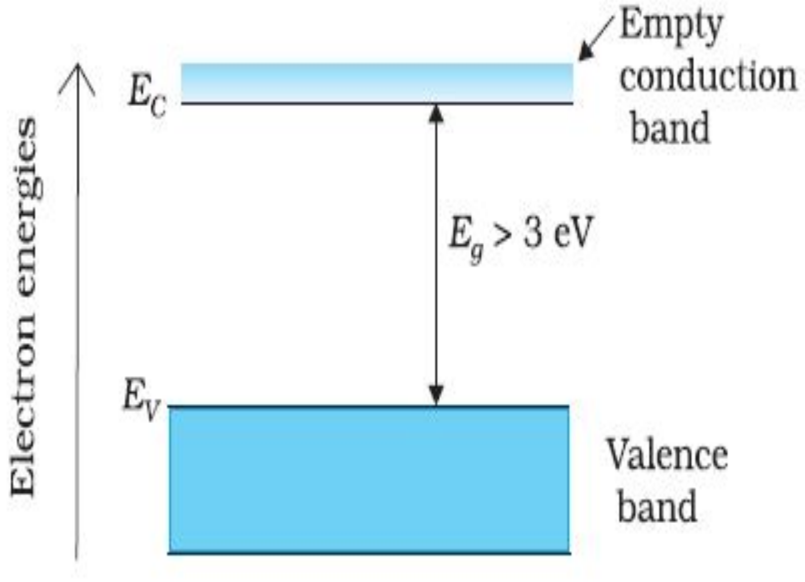
(a)

This situation makes a large number of **electrons** available for electrical conduction.

When the valence band is **partially** empty, electrons from its lower level can move to higher level making **conduction** possible.

Therefore, the **resistance** of such materials is **low** or the **conductivity** is **high**.

In the case, a large band gap Eg exists ($E_g > 3$ eV).



(b)

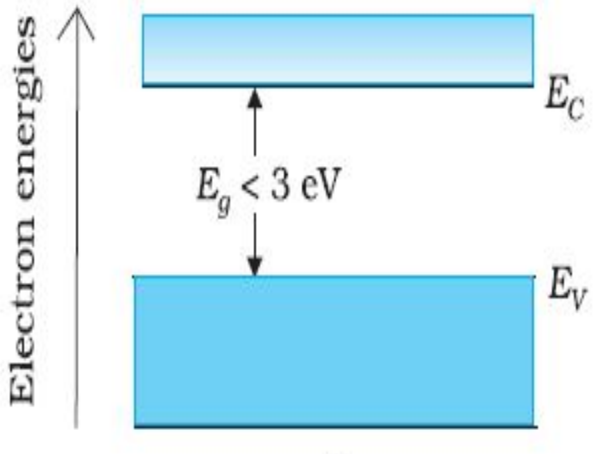
Insulators

There are no electrons in the conduction band, and therefore no electrical conduction is possible.

Note that the energy gap is so large that electrons cannot be excited from the valence band to the conduction band by thermal excitation.

This is the case of insulators

Here a finite but small band gap (Eg < 3 eV) exists.



(c)

semiconductors

Because of the small band gap, at room temperature some electrons from valence band can acquire enough energy to cross the energy gap and enter the conduction band.

These electrons (though small in numbers) can move in the conduction band. Hence, the resistance of semiconductors is not as high as that of the insulators.