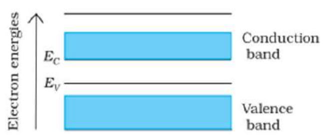
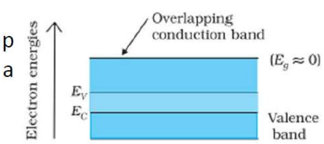
Module:7 Optoelectronic Devices & Applications of Optical fibers

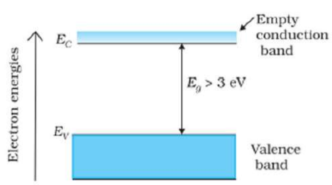
Dr Rajeshkumar Mohanraman
Assistant Professor Grade 1
School of Advanced Sciences
VIT Vellore



$E_c \rightarrow$ lowest energy level of the C.B. and $E_v \rightarrow$ highest energy level of the V.B. In a solid where the valence band is partially empty, electrons from the lower energy levels can move to the higher levels making conduction possible.

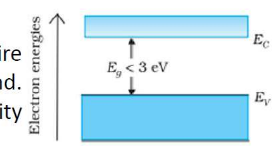
$E_g \rightarrow$ energy gap. If in a solid the conduction and valence bands overlap each other, electrons can easily move from the VB to the CB. This makes a large number of electrons available for conduction.



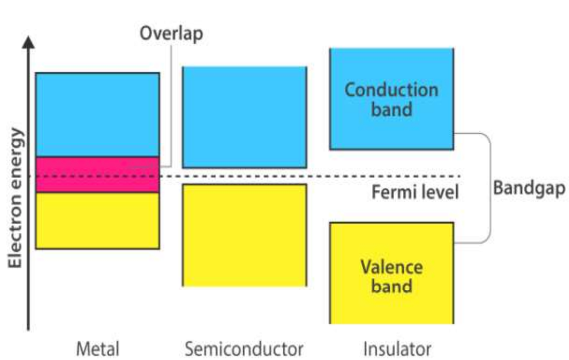


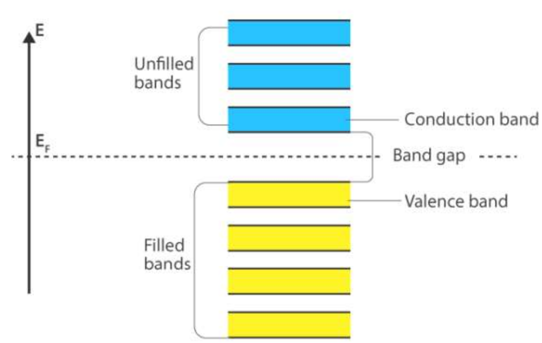
E_g is very large (>3 eV). Due to this large gap, electrons cannot be excited to move from the valence to the conduction band by thermal excitation, there are no free electrons in the conduction band and no conductivity. These are insulators.

If energy gap is small (< 3 eV). Since the gap is small, some electrons acquire enough energy even at room temperature and enter the conduction band. These electrons can move in the conduction band increasing the conductivity of the solid. These are semiconductors.

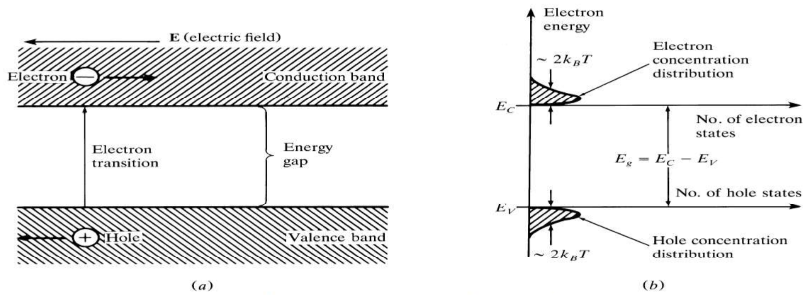


Band Theory of Solids





Basic Semiconductor Physics



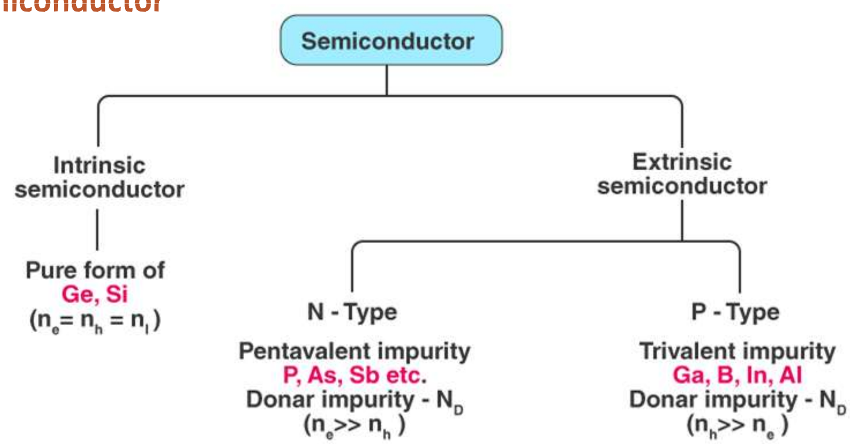
Boltzmann's constant $k_B = 1.38 \times 10^{-23}$ JK^{-1}

a) Energy level diagrams showing the excitation of an electron from the valence band to the conduction band. The resultant free electron can freely move under the application of electric field.

b) Equal electron & hole concentrations in an intrinsic semiconductor created by the thermal excitation of electrons across the band gap

Types of Semiconductors

- ❑ **Intrinsic Semiconductor**
- ❑ **Extrinsic Semiconductor**

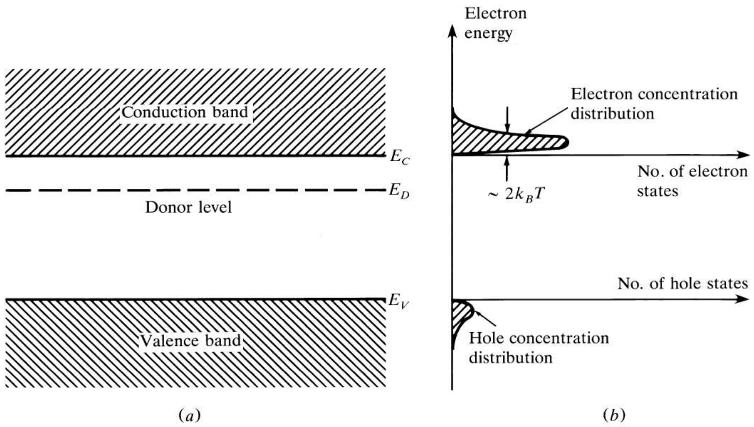


•**Intrinsic Semiconductor (Pure semiconductor):** An intrinsic semiconductor is made up a very pure form of semiconductor material. It's conductivity is solely determined by the thermally generated carriers.

• **Extrinsic Semiconductor (Doped semiconductor):** When an impurity atom is added with a pure semiconductor, then it is called extrinsic semiconductor. The process of adding impurity to a semiconductor is called doping. The added impurity is called dopant.

❑**Majority carriers**: electrons in *n*-type or holes in *p*-type.
❑**Minority carriers**: holes in *n*-type or electrons in *p*-type.
❑The operation of semiconductor devices is essentially based on the **injection** and **extraction** of minority carriers.

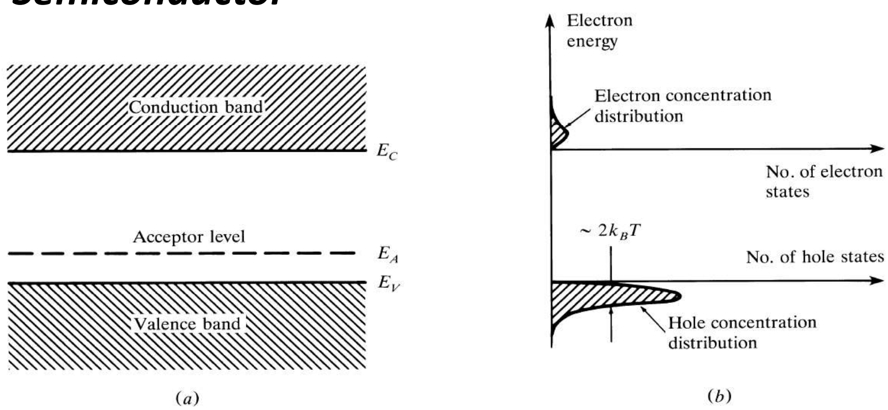
n-Type Semiconductor



Number of free electrons >> number of holes in n-type semiconductor. That is why free electrons are called majority carriers, and holes are called minority carriers in the **n-type semiconductor**.

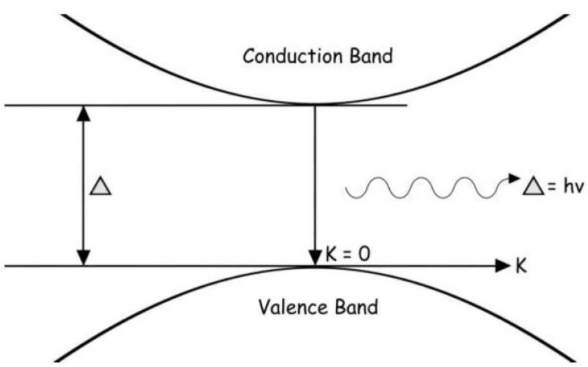
a) Donor level in an *n*-type semiconductor.
b) The ionization of donor impurities creates an increased electron concentration distribution

p-Type Semiconductor



a) Acceptor level in an *p*-type semiconductor.
b) The ionization of acceptor impurities creates an increased hole concentration distribution

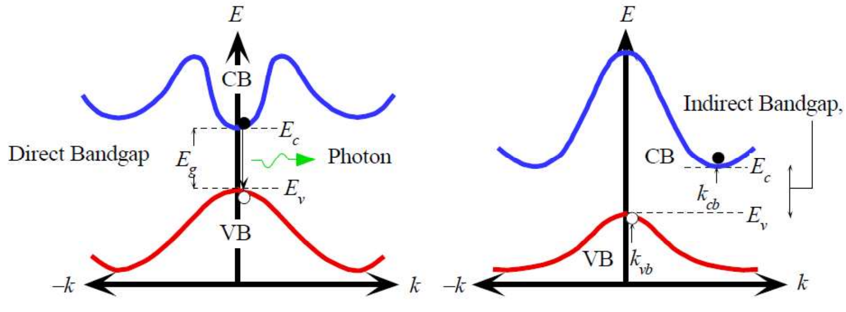
Direct Band Gap Semiconductors



- Those semiconductor materials which have a direct band gap are the ones that emit photons.
- Example of material which has direct band gap is Gallium Arsenide(GaAs).

In a direct bandgap material, the bottom of the energy level of conduction band lies directly above the topmost energy level of the valence band on the Energy vs Momentum (wave vector 'k') diagram. When electrons and hole recombine, energy E = hν corresponding to the energy gap △ (eV) is escaped in the form of light energy or photons where h is the Planck's constant and ν is the frequency of light.

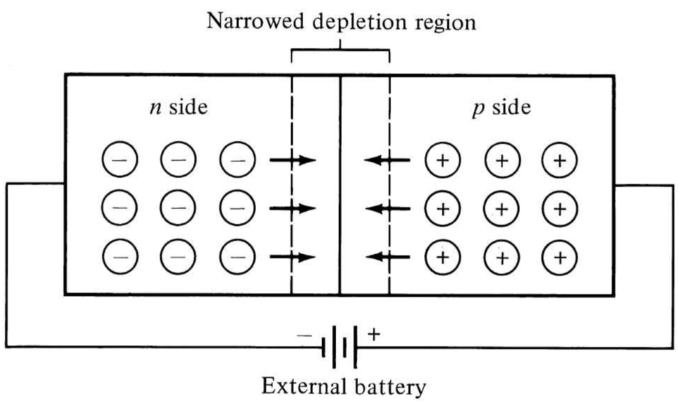
Indirect Band Gap Semiconductors



(a) GaAs (b) Si

(a) In GaAs the minimum of the CB is directly above the maximum of the VB. GaAs is therefore a direct bandgap semiconductor. (b) In Si, the minimum of the CB is displaced from the maximum of the VB and Si is an indirect bandgap semiconductor.

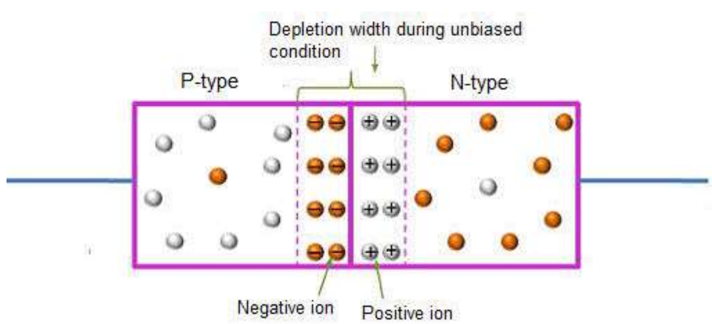
Forward-biased *PN* Junction



Lowering the barrier potential with a forward bias allows majority carriers to diffuse across the junction.

The PN Junction

Zero Bias



- No external voltage is applied to the P-N junction.
- The electrons diffuse to the P-side and simultaneously holes diffuse towards the N side through the junction, and then combine with each other.
- Due to this an electric field is generated by these charge carriers. Electric field opposes further diffusion of charged carriers so that there is no movement in the middle region. This region is known as depletion width or space charge.

Reversed-biased *PN* Junction

Connecting the *p-type* region to the *negative* terminal of the battery and the *n-type* region to the *positive* terminal corresponds to reverse bias. It will increase the junction barrier and thereby offer a high resistance to the current flow through the junction. This type of bias is known as reverse bias