ENERGY BANDS OF SOLIDS OR BAND THEORY OF SOLIDS

The following are the energy bands in solids.

Valence Band

- This band contains valence electrons. This band may be partially or completely filled with electrons. This band is never empty. Electrons in this band do not contribute to electric current.

Conduction Band

- In this band, electrons are rarely present. This band is either empty or partially filled.
- Electrons in the conduction band are known as free electrons. These electrons contribute to the electric current.

Forbidden Energy Gap or Forbidden Band

- The energy gap between the valence band and conduction band is known as forbidden energy gap or forbidden band. No electrons are present in this gap. It is a measure of energy band gap.
- The minimum energy required for shifting electrons from valence band to conduction band is known as energy band gap.
- If λ is the wavelength of radiation used in shifting the electrons from valence band to conduction band, then energy band gap is

  $$E_g = h\upsilon = \frac{hc}{\lambda}$$

  where h is called Planck's constant and c is the speed of light.
- The forbidden energy gap E_g in a semiconductor depends upon temperature.

  For silicon, $E_g(T) = 1.21 - 3.60 \times 10^{-4}T$

  At room temperature (300 K), $E_g = 1.1$ eV

  For germanium,

  $$E_g(T) = 0.785 - 2.23 \times 10^{-4}T$$

  At room temperature (300 K), $E_g = 0.72$ eV

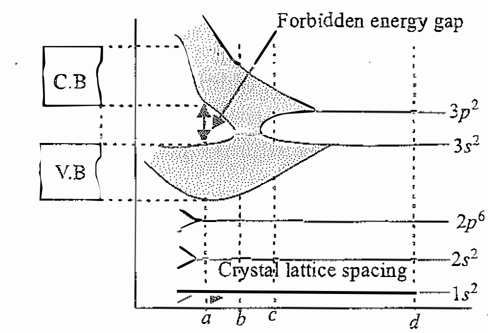
Formation of Energy Bands

Let us consider a single crystal of Si. Each atom has electronic configuration

$$_{14}\text{Si} = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$$

Now assume that surrounding 10^{23} atoms are brought closer to Si atom, by mutual interaction the outermost energy level filled *i.e.*, $3s^1$, $3s^2$, $3p^1$, $3p^2$ and unfilled *i.e.*, $3p^3$, $3p^4$, $3p^5$, $3p^6$ each splits in 10^{23} possibilities each and the splitting widens as the surrounding atoms are brought closer.

- **At separation '*d*':** All the energy levels are sharp and no splitting has started.



Formation of energy bands in silicon.

- **At separation '*c*':** All the filled energy levels and unfilled energy levels splits into 10^{23} each and widening also take place of splitted forms.
- **At separation '*b*':** The widening become so much that all the splitted forms overlapped.
- **At separation '*a*':** A redistribution take place such that all filled energy levels $3s^1$, $3s^2$, $3p^1$, $3p^2$ and splitted forms makes the valence band and all unfilled energy levels $3p^3$, $3p^4$, $3p^5$, $3p^6$ and splitted forms makes the conduction band. Separation between valence band and conduction band is called forbidden energy gap.

INTRINSIC SEMICONDUCTOR

A pure semiconductor which is free from every impurity is known as intrinsic semiconductor. Germanium (Ge) and silicon (Si) are the important examples of intrinsic semiconductors.

- In intrinsic semiconductor, $n_E = n_H = n_I$

  where n_E, n_H are number density of electrons in conduction band and number density of holes in valence band, n_I is the intrinsic carrier concentration.
- When an electric field is applied across an intrinsic semiconductor, electrons and holes move in opposite directions so that total current (I) through the pure semiconductor is given by

  $$I = I_E + I_H$$

  where I_E is the free electron current and I_H is the hole current.