UNIT II

SEMICONDUCTING MATERIALS

CONTENTS

2.5.P type semi-conductor

When a trivalent impurity is added with the pure semiconductor it is called p type semi conductor

A trivalent impurity (Boron) having three valance electrons is added to a pure semiconducting material having four valance electrons (germanium).

The three valance electrons of the impurity atoms bond with three valance electrons of the semiconductor atom and remaining position of the semi conductor forms an empty space which is called a hole.

Therefore number of holes increases, then they are the majority charge carrier in p –type semiconductor and electrons are the minority charge carriers.

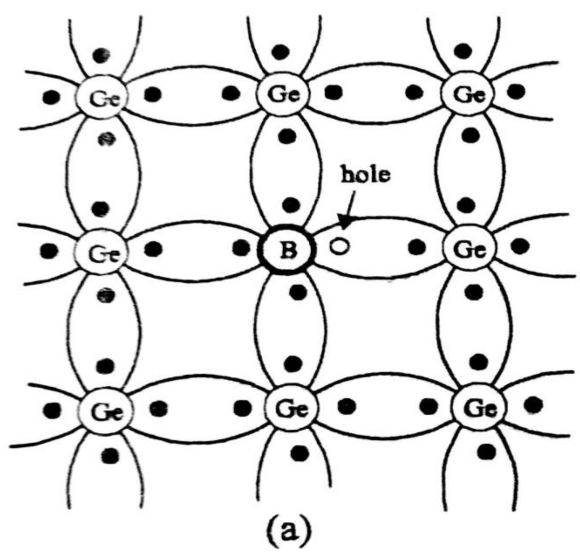

Fig 2.5.1 Crystal structure of P type semiconductor

2.5.1 CARRIER CONCENTRATION IN P–TYPE SEMICONDUCTOR

Density of holes in valence band

$$p = 2\frac{(2\pi m_h^* kT)^{\frac{3}{2}}}{(h^2)^{3/2}} e^{\frac{Ev-Ef}{kT}} ------(1)$$

Electrons are moving from valence band to acceptor level when a trivalent element is added with the pure semiconductor as shown in fig

Therefore

The number of electrons in acceptor level is equal to the number of holes in valence band

Let N_a be the number of acceptor energy levels

Density of electrons in acceptor level $= N_a \left(\frac{1}{1+e^{\frac{Ea-Ef}{KT}}}\right)$

(Since Ea>>Ef

$$Ea - Ef \gg KT$$

$$1 + e^{\frac{Ea-Ef}{KT}} \approx e^{\frac{Ea-Ef}{KT}}$$

$Density\ of\ electrons\ in\ acceptor\ level = N_a e^{\frac{Ef-Ea}{KT}}$-----------------(2)

At equilibrium condition

Number of electrons in acceptor level =Number of holes in valence band

$$2\frac{(2\pi m_h^* kT)^{\frac{3}{2}}}{(h^2)^{3/2}} e^{\frac{Ev-Ef}{kT}} = N_a e^{\frac{Ef-Ea}{KT}}$$

$$\frac{e^{((Ev-Ef/kT)})}{e^{((Ef-Ea)/kT}} = \frac{N_a}{2\frac{(2\pi m_h^* kT)^{\frac{3}{2}}}{(h^2)^{3/2}}}$$

$$\frac{-2E_F + Ev + Ea}{kT} = \log \frac{a}{2\frac{(2\pi m_h^* KT)^{\frac{3}{2}}}{(h^2)^{3/2}}}$$

$$E_F = \frac{Ea+Ev}{2} - \frac{KT}{2} \log \frac{N_a}{2\frac{(2\pi m_h^* KT)^{\frac{3}{2}}}{(h^2)^{3/2}}} \text{----------------(3)}$$

Carrier concentration in n type semi-conductor

$$p = 2\frac{(2\pi m_h^* KT)^{\frac{3}{2}}}{(h^2)^{3/2}} e^{\frac{Ev-EF}{kT}} \text{-------------(4)}$$

$$e^{\frac{Ev-EF}{KT}} = e^{\frac{Ev-\left(\frac{Ea+Ev}{2}-\frac{KT}{2}\log\frac{N_a}{2\frac{\left(2\pi m_h^* KT\right)^{\frac{3}{2}}}{(h^2)^{\frac{3}{2}}}}\right)}{kT}}$$

$$= e^{\frac{\frac{-Ea+Ev}{2}+\frac{KT}{2}\log\frac{N_a}{2\frac{(2\pi m_h^* KT)^{\frac{3}{2}}}{(h^2)^{3/2}}}}{kT}}$$

$$= e^{\frac{-Ea+Ev}{2kT}+\frac{KT}{2KT}\log\frac{N_a}{2\frac{(2\pi m_h^* KT)^{\frac{3}{2}}}{(h^2)^{3/2}}}}$$

$$= e^{\frac{-Ea+Ev}{2kT}+\frac{1}{2}\log\frac{N_a}{2\frac{(2\pi m_h^* KT)^{\frac{3}{2}}}{(h^2)^{3/2}}}}$$

$$= e^{\frac{Ev-Ea}{2kT}} e^{\log\frac{N_a}{2\frac{(2\pi m_h^* KT)^{\frac{3}{2}}}{(h^2)^{3/2}}}}$$

$$\text{Exp}\left(\frac{Ev-Ef}{KT}\right) = e^{\frac{Ev-Ea}{2kT}} \frac{Na^{1/2}}{2^{1/2}\frac{(2\pi m_h^* KT)^{\frac{3}{4}}}{(h^2)^{3/4}}} \text{-------------(5)}$$

Sub this in (4)

$$p = 2\frac{(2\pi m_h^* KT)^{\frac{3}{2}}}{(h^2)^{3/2}} \; e^{\frac{Ev-Ea}{2kT}} \frac{Na^{1/2}}{2^{1/2}\frac{(2\pi m_h^* KT)^{\frac{3}{4}}}{(h^2)^{3/4}}}$$

$$\text{p} = (2Na)^{1/2}\frac{(2\pi m_h^* KT)^{\frac{3}{4}}}{(h^2)^{3/4}} \; e^{\frac{Ev-Ea}{2kT}}$$

This is the expression for the carrier concentration for p type semi-conductor.

2.5.2.Variation of Fermi level with temperature and impurity concentration for P type semi-conductor

Fermi level depends upon the temperature and impurity concentration

Variation with temperature.

$$E_F = \frac{Ea + Ev}{2} - \frac{KT}{2}\log\frac{N_a}{2\frac{(2\pi m_h^* KT)^{\frac{3}{2}}}{(h^2)^{\frac{3}{2}}}}$$

(i) At T = 0K

$$E_F = \frac{Ea + Ev}{2}$$

Fermi level lies half way between the acceptor level and valence band,

(ii) When the temperature is increased, Fermi level shifts upward due to the large ionization of acceptor.

(iii) At very high temperature, the number of electrons moving from valence band electrons exceeds the electrons moving from donor level to conduction band. Thus, Fermi level shifts downward and finally reach the middle of band gap, which is for intrinsic semiconductor.

Variation with Impurity concentration

When the concentration acceptor increases extrinsic behavior increases. However, at very high temperature Fermi level reaches to intrinsic level.

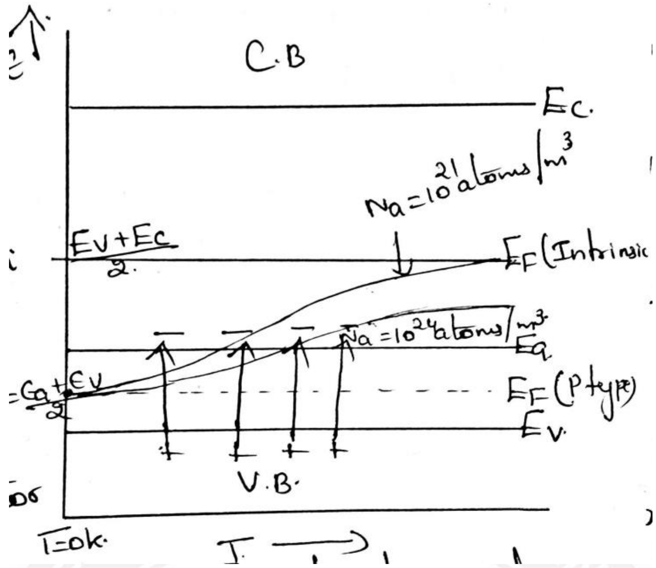

Fig 2.5.2-Variation of Fermi level with temperature for P type semiconductor