Extrinsic Semiconductors

Extrinsic semiconductors are semiconductors formed by adding a small measured amount of chemical impurity to intrinsic semiconductor.

These impurities are called as dopant. And the process of adding the impurities is called doping.

Types of dopants :

Fourth group elements are commonly used to make semiconductors (eg: Si, Ge). They have four valence e^-s (tetravalent), and can be doped with these two kinds of dopants :

1. Pentavalent : They have 5 valence e^-s, and belong to 5^{th} group in periodic table.
   eg: Phosphorous (P), Antimony (Sb), Arsenic (As) etc.

2. Trivalent : They have 3 valence e^-s and belong to 3^{rd} group in periodic table.
   eg: Aluminium (Al), Indium (In), Boron (B) etc.

* 3^{rd} & 5^{th} group elements are close in size to 4^{th} group element ∴ are a good choice of dopants.

Types of extrinsic semi conductor

Extrinsic semiconductors can be classified into two kinds :

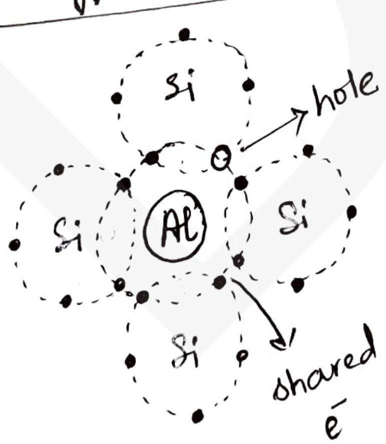
P type semiconductor.

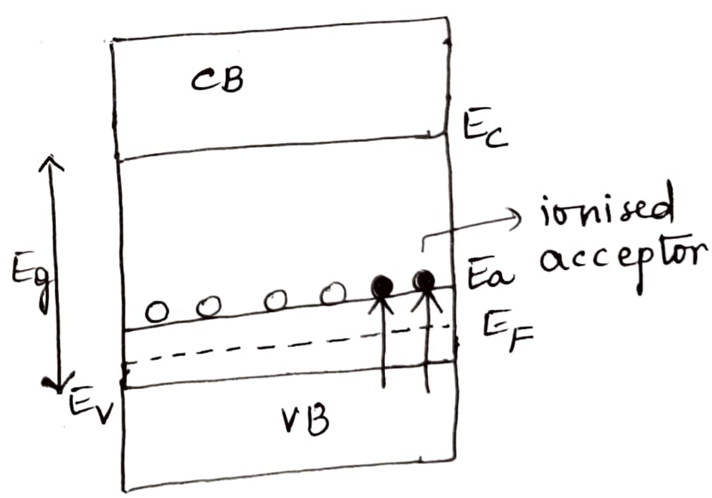
N type ".

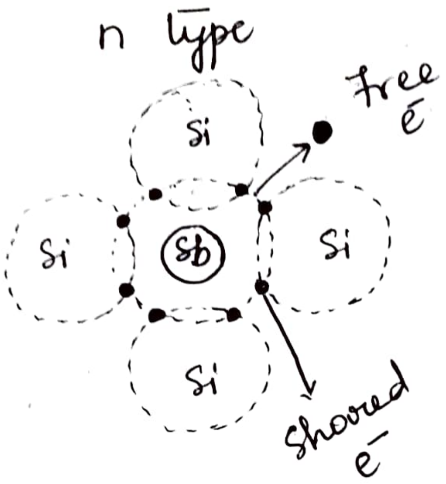
P type semiconductor : When a small amount of trivalent impurity is added to tetravalent semiconductor the resultant is a P type semi conductor.

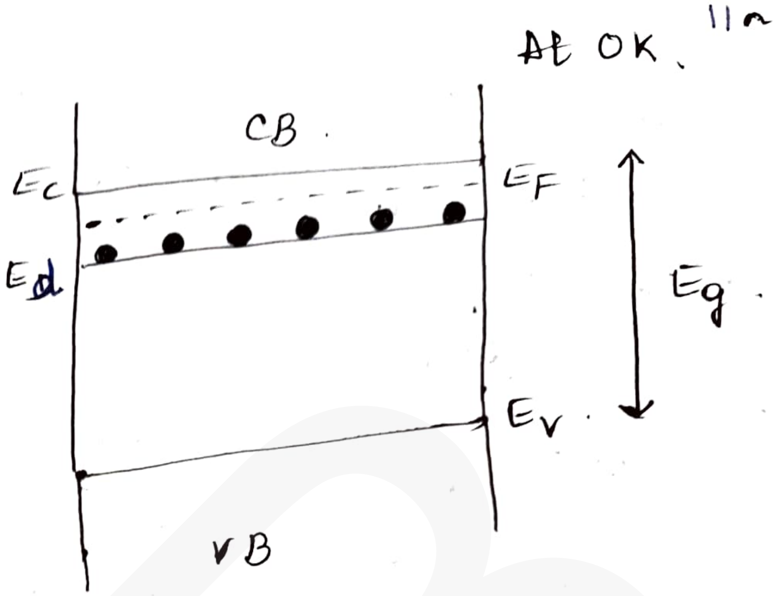
n type semiconductor : When pentavalent impurity is added to the intrinsic semiconductor, n type semi conductors are formed.

P type SC :









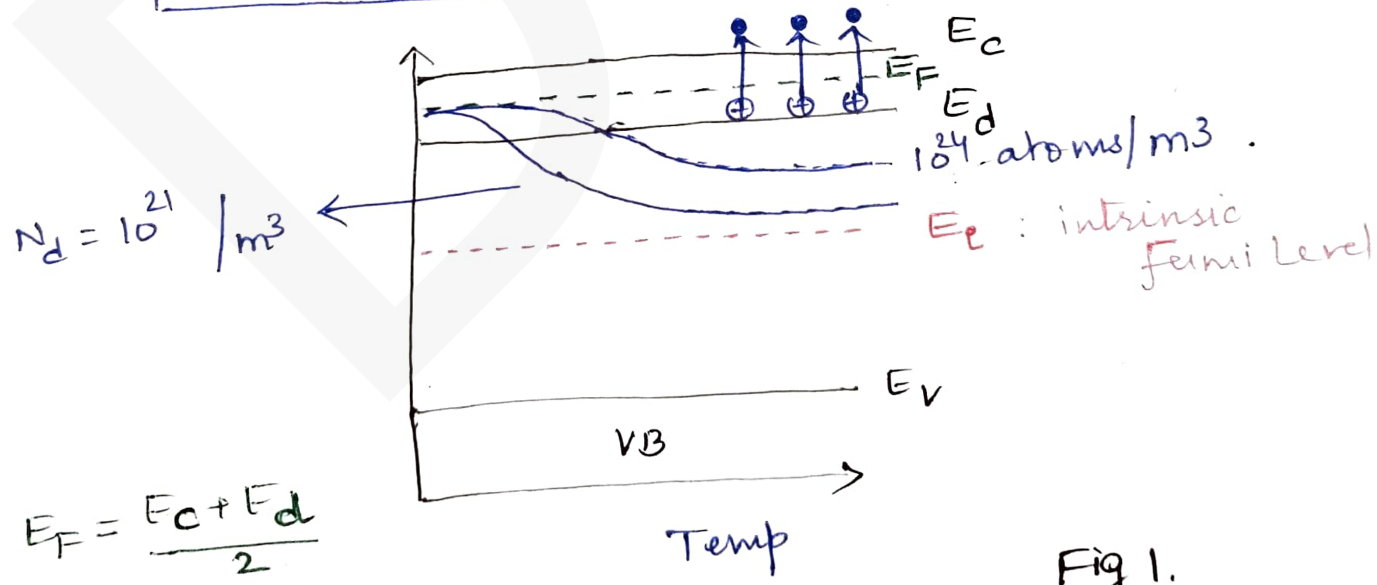
Effect of temperature and concentration (Impurity) on Fermi level of extrinsic semiconductor.

For n type semiconductor Fermi level is given by

$$E_F = \frac{E_d + E_c}{2} + \frac{k_B T}{2} \log_e \left[\frac{N_d}{2\left(\frac{2\pi m_e^* k_B T}{h^2}\right)^{3/2}} \right]$$

at $T = 0$

$$\boxed{E_F = \frac{E_d + E_c}{2}}$$



$$E_F = \frac{E_c + E_d}{2}$$

$$E_i = \frac{E_v + E_c}{2}$$

Fig 1.

i) At 0 K, Fermi level lies exactly in between E_c (bottom of CB) & E_d (donor level).

ii) As temperature increases electrons from donor level shifts to CB.

iii) With further increase of temperature (at very high temperatures), covalent bonds in VB breaks & electrons start moving to CB. The intrinsic carrier dominates the donor. The Fermi level gradually shifts downwards.

iv) Finally E_F moves very close to E_i.

* As the donor concentration is increased the Fermi level starts to move towards CB. In figure 1, it is clearly shown how Fermi level shifts with increase/decrease of donor concentration (impurity).

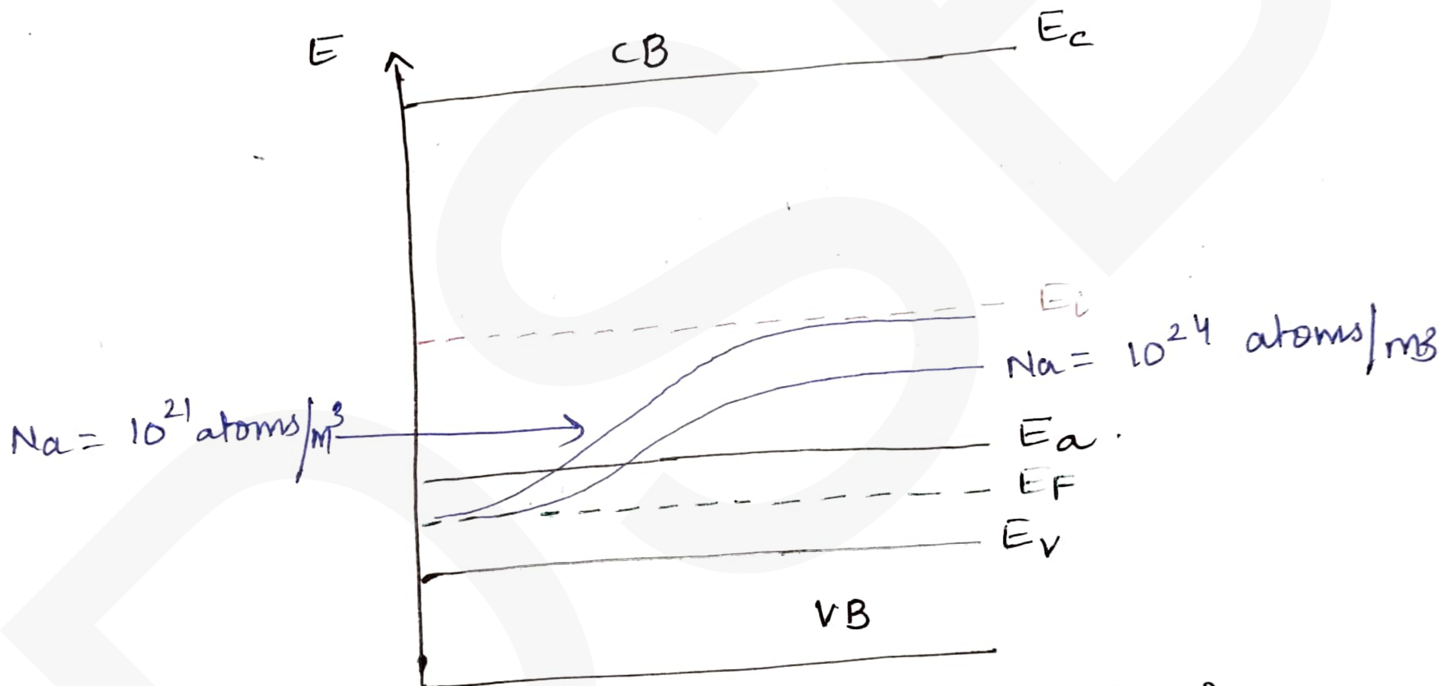
For p type :

For a p type semi conducting material E_F is given by :

$$E_F = \frac{E_a + E_v}{2} - \frac{k_B T}{2} \log_e \left[\frac{N_a}{2\left(\frac{2\pi m_p^* k_B T}{h^2}\right)^{3/2}} \right]$$

at $T = 0$

$$E_F = \frac{E_a + E_v}{2}.$$



$E_i = \frac{E_v + E_c}{2}$,

Fig 2.

* At 0K, Fermi level lies exactly at middle of the E_a (acceptor level) and E_v (top of valence band)

* As Temperature increases, more & more electrons ~~occupy~~ from VB occupies the holes at acceptor level i.e. acceptor are ionised.

* Fermi level starts to move towards E_i (intrinsic Fermi level)

* At a particular temperature when all the acceptors are ionised, Fermi level crosses E_a.

* At very high temp, Fermi level shifts closest to intrinsic Fermi level and p type semi-conductor behaves like an intrinsic semi-conductor.

⊖ At minimal doping concentration, Fermi level is close to E_i. As doping concentration increases Fermi level shifts towards E_a. This is shown in figure 2.