Answer on Question #43569 – Physics - Solid State Physics

Fermi level of p-type and n-type semiconductor with description.

Solution:

The **Fermi level** is the total chemical potential for electrons (or electrochemical potential for electrons) and is usually denoted by µ or E_F. The Fermi level of a body is a thermodynamic quantity, and its significance is the thermodynamic work required to add one electron to the body (not counting the work required to remove the electron from wherever it came from). A precise understanding of the Fermi level—how it relates to electronic band structure in determining electronic properties, how it relates to the voltage and flow of charge in an electronic circuit—is essential to an understanding of solid-state physics.

Fermi Level in n-type Semiconductor

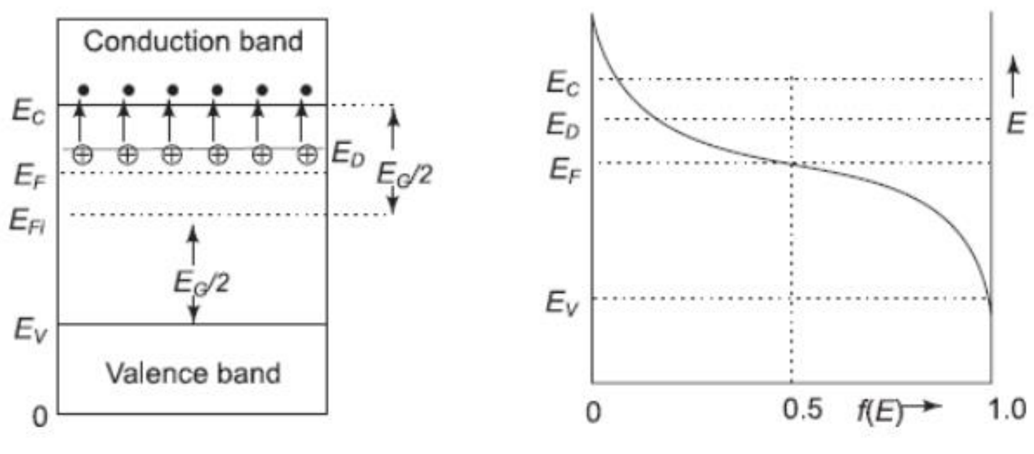
We assume that all donor atoms of an n-type semiconductor get ionized at a given temperature to get estimation of Fermi level. Now the first $\mathrm{N_D}$ states in conduction band will be filled. It becomes difficult for the valence band electrons to bridge the energy gap by thermal agitation due to these filled states. We can say that the number of electron hole-pairs thermally generated at that temperature is reduced. We know that Fermi level is a measure of the probability of occupancy of the allowed energy states. Hence, the Fermi level must move closer to the conduction band to indicate that many energy states in that band are filled by the donor electrons and fewer holes exist in valence band. This situation is shown in Figure.

The n-type semiconductor is almost entirely due to extrinsically supplied electrons from the donors. Hence, $\mathrm{n = N_D}$ is the concentration of donor atoms. $\mathrm{n = N_D = N_C e^{-\left(\frac{E_C - E_F}{KT}\right)}}$

$$\mathrm{\ln N_D = \ln N_C - \frac{E_c - E_F}{KT}}$$

$$\mathrm{E_C - E_F = KT\{\ln N_C - \ln N_D\} = KT \ln\left(\frac{N_C}{N_D}\right)}$$

Band diagram and Fermi level in n-type semiconductor:

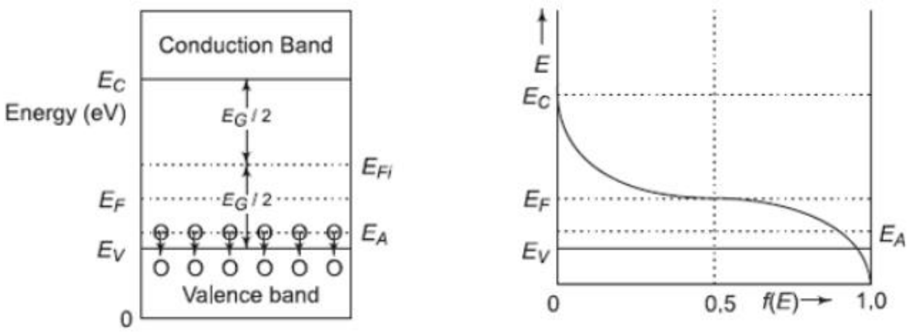


Fermi Level in p-type Semiconductor

Following assumptions must hold good for calculating the Fermi level in p-type semiconductor:

- The density of acceptor atoms far exceeds the density of donor atoms.
- Every acceptor atom has accepted one electron from the valence band.
- The density of electrons in the conduction band is much smaller than that of the holes in the valence band.

Similar arguments as in n-type semiconductor leads to the conclusion that the Fermi level must move from the centre of the forbidden gap closer to the valence band for a p-type material. The situation is shown in Figure.



In this case,

$$n = N_A = N_V e^{-\left(\frac{E_F - E_V}{KT}\right)}$$

$$E_F = E_V + KT \ln\left(\frac{N_C}{N_D}\right)$$