One Donor and One Acceptor for p-type semiconductor

Since the hole concentration $p(T)$ is described as

$$p(T) = \frac{N_{\mathrm{A}}}{1 + g\exp\left(\frac{\Delta E_{\mathrm{A}} - \Delta E_{\mathrm{F}}}{kT}\right)} - N_{\mathrm{D}} ,$$

(1)

the following relation is obtained:

$$\frac{p(T) + N_{\mathrm{D}}}{N_{\mathrm{A}} - [p(T) + N_{D}]} = \frac{1}{g}\exp\left(-\frac{\Delta E_{\mathrm{A}}}{kT}\right)\exp\left(\frac{\Delta E_{\mathrm{F}}}{kT}\right). \quad (2)$$

On the other hand, since

$$p(T) = N_{\mathrm{V}}(T)\exp\left(-\frac{\Delta E_{\mathrm{F}}}{kT}\right), \quad (3)$$

the following relation is obtained:

$$\exp\left(\frac{\Delta E_{F}}{kT}\right) = \frac{N_{\mathrm{V}}(T)}{p(T)}. \quad (4)$$

Therefore, substituting Eq. (4) to Eq. (2) gives

$$\frac{p(T)[p(T) + N_{\mathrm{D}}]}{N_{\mathrm{A}} - [p(T) + N_{\mathrm{D}}]} = \frac{N_{\mathrm{V}}(T)}{g}\exp\left(-\frac{\Delta E_{\mathrm{A}}}{kT}\right). \quad (5)$$

Since

$$N_{\mathrm{V}}(T) = 2\left(\frac{2\pi m^{*}kT}{h^{2}}\right)^{3/2}, \quad (6)$$

we obtain the following relationship:

$$\frac{1}{T^{3/2}} \cdot \frac{p(T)[p(T) + N_{\mathrm{D}}]}{N_{\mathrm{A}} - [p(T) + N_{\mathrm{D}}]} = \frac{1}{g}\left[2\left(\frac{2\pi m^{*}k}{h^{2}}\right)^{3/2}\right]\exp\left(-\frac{\Delta E_{\mathrm{A}}}{kT}\right). \quad (7)$$