Annex C: Overview of textbook expressions on charge carrier statistics in thermal equilibrium

Taken from R. F. Pierret, Semiconductor Device Fundamentals, Addison Wesley, 1996.

Table 2.4 Carrier Modeling Equation Summary.

Density of States and Fermi Function

$$g_c(E) = \frac{m_n^*\sqrt{2m_n^*(E - E_c)}}{\pi^2\hbar^3}, \quad E \geq E_c$$

$$g_v(E) = \frac{m_p^*\sqrt{2m_p^*(E_v - E)}}{\pi^2\hbar^3}, \quad E \leq E_v$$

$$f(E) = \frac{1}{1 + e^{(E-E_F)/kT}}$$

n, p, and Fermi Level Computational Relationships

$$n = \frac{N_D - N_A}{2} + \left[\left(\frac{N_D - N_A}{2}\right)^2 + n_i^2\right]^{1/2}$$

$$E_i = \frac{E_c + E_v}{2} + \frac{3}{4}kT\ln\left(\frac{m_p^*}{m_n^*}\right)$$

$$n \simeq N_D, \quad p \simeq n_i^2/N_D \qquad N_D \gg N_A, N_D \gg n_i$$

$$E_F - E_i = kT\ln(n/n_i) = -kT\ln(p/n_i)$$

$$p \simeq N_A, \quad n \simeq n_i^2/N_A \qquad N_A \gg N_D, N_A \gg n_i$$

$$E_F - E_i = kT\ln(N_D/n_i) \quad N_D \gg N_A, N_D \gg n_i$$

$$E_i - E_F = kT\ln(N_A/n_i) \quad N_A \gg N_D, N_A \gg n_i$$

Carrier Concentration Relationships

$$n = N_C \frac{2}{\sqrt{\pi}} F_{1/2}(\eta_c) \qquad N_C = 2\left[\frac{m_n^* kT}{2\pi\hbar^2}\right]^{3/2}$$

$$p = N_V \frac{2}{\sqrt{\pi}} F_{1/2}(\eta_v) \qquad N_V = 2\left[\frac{m_p^* kT}{2\pi\hbar^2}\right]^{3/2}$$

$$n = N_C e^{(E_F - E_c)/kT}$$

$$p = N_V e^{(E_v - E_F)/kT}$$

$$n = n_i e^{(E_F - E_i)/kT}$$

$$p = n_i e^{(E_i - E_F)/kT}$$

n_i, np-Product, and Charge Neutrality

$$n_i = \sqrt{N_C N_V}\, e^{-E_G/2kT} \qquad np = n_i^2 \qquad p - n + N_D - N_A = 0$$