Solid State Equations

by: Author

Constants

Physical

q	Elementary Charge	1.602×10^{-19}	C
m_0	Electron Mass	9.11×10^{-19}	kg
ϵ_0	Permittivity of Free Space	8.854×10^{-14}	F/cm
μ_0	Permeability of Free Space	1.257×10^{-8}	H/cm
k	Boltzmann's Constant	1.38×10^{-23}	J/K
k	Boltzmann's Constant	8.62×10^{-5}	eV/K
h	Planck Constant	6.626×10^{-34}	J s
h	Planck Constant	4.136×10^{-15}	eV s
$\hbar$	Reduced Planck Constant	1.055×10^{-34}	J s
$\hbar$	Reduced Planck Constant	6.582×10^{-16}	eV s

Material

		Si	GaAs	Ge
ϵ_r		11.7	13.1	16.0
E_g	eV	1.12	1.42	0.66
χ	V	4.01	4.07	4.13
N_c	cm^{-3}	2.8×10^{19}	4.7×10^{17}	1.04×10^{19}
N_v	cm^{-3}	1.04×10^{19}	7.0×10^{18}	6.0×10^{18}
n_i	cm^{-3}	1.5×10^{10}	1.8×10^{6}	2.4×10^{13}

Equations

Carrier Concentration and Fermi Level

$$n_0 = \frac{N_D - N_A}{2} + \left[\frac{N_D - N_A}{2} + n_i^2\right]^{1/2}$$

$$p_0 = \frac{N_A - N_D}{2} + \left[\frac{N_A - N_D}{2} + n_i^2\right]^{1/2}$$

$$N_c = 2\left[\frac{m_n^* kT}{2\pi\hbar^2}\right]^{3/2} \qquad N_v = 2\left[\frac{m_p^* kT}{2\pi\hbar^2}\right]^{3/2}$$

$$n_0 = n_i \exp\left[\frac{E_F - E_i}{kT}\right] \qquad p_0 = n_i \exp\left[\frac{E_i - E_F}{kT}\right]$$

$$n_0 = N_c \exp\left[\frac{-(E_c - E_F)}{kT}\right] \qquad p_0 = N_v \exp\left[\frac{-(E_F - E_v)}{kT}\right]$$

$$E_c - E_F = -kT \ln\frac{N_D}{N_c} \qquad E_F - E_v = -kT \ln\frac{N_A}{N_v}$$

$$R - G_t = \frac{np - n_i^2}{\tau_n(n + n_t) + \tau_p(p + p_t)}$$

$$n_t = n_i \exp\left(\frac{E_t - E_i}{kT}\right) \qquad p_t = n_i \exp\left(\frac{E_i - E_t}{kT}\right)$$

Carrier Transport

$$J_{\text{drift}} = \rho_p v_{dp} - \rho_n v_{dn}$$

$$v_{dp} = \mu_p \mathcal{E} \qquad v_{dn} = -\mu_n \mathcal{E}$$

$$\rho_p = qp \qquad \rho_n = -qn$$

$$J_{\text{drift}} = q(\mu_n n + \mu_p p)\mathcal{E} = \sigma\mathcal{E}$$

$$\frac{1}{2} m^* v_{sat}^2 = \frac{3}{2} kT$$

$$J_{\text{diff}} = -q\left(D_p \frac{dp}{dx} - D_n \frac{dn}{dx}\right) = -kT\left(\mu_p \frac{dp}{dx} - \mu_n \frac{dn}{dx}\right)$$

p-n Junctions

$$V_{bi} = |\phi_{Fp}| + |\phi_{Fn}| = \frac{kT}{q} \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

$$W = \left[\frac{2\epsilon_s(V_{bi} - V_a)}{q}\left(\frac{N_A + N_D}{N_A N_D}\right)\right]^{1/2}$$

$$x_p = \left[\frac{2\epsilon_s(V_{bi} - V_a)}{q}\left(\frac{N_D}{N_A}\right)\frac{1}{N_A + N_D}\right]^{1/2}$$

$$x_n = \left[\frac{2\epsilon_s(V_{bi} - V_a)}{q}\left(\frac{N_A}{N_D}\right)\frac{1}{N_A + N_D}\right]^{1/2}$$

$$\mathcal{E}_{max} = \frac{-qN_D x_n}{\epsilon_s} = \frac{-qN_A x_p}{\epsilon_s}$$

$$\mathcal{E}_{max} = \frac{-2(V_{bi} - V_a)}{W}$$

$$np = n_i^2 \exp\left(\frac{qV_a}{kT}\right)$$

Schottky Junction

$$V_{bi} = \phi_m - \chi - \underbrace{kT\ln(N_c/N_d)}_{\phi_n}$$

$$x_n = \left[\frac{2\epsilon_s(V_{bi} - V_a)}{qN_D}\right]^{1/2}$$

MOS Capacitors

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