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Formula Sheet
ELEC321

Chapter 1:

For FCC $a = 2\sqrt{2}R$, For BCC $a = \frac{4R}{\sqrt{3}}$ and for diamond, $a = \frac{8R}{\sqrt{3}}$

Surface area for cubic crystal, for (100) a^2, for (110) $\sqrt{2}a^2$, and for (111) is $\frac{\sqrt{3}a^2}{2}$

Chapter 2:

$E = h\nu$, $\lambda = \frac{h}{p}$, $\Delta p \Delta x \geq \hbar$, $\Delta E \Delta t \geq \hbar$, and K.E. of a particle = $\frac{mv^2}{2}$.

Time-independent Schrodinger equation, $\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}[E - V(x)]\psi = 0$

Infinite potential well: $E_n = \frac{h^2 n^2}{8ma^2}$, $\psi_n(x) = \sqrt{\frac{2}{a}}\sin\left(\frac{n\pi x}{a}\right)$; $0 \langle x \langle a$

Potential barrier: $T \approx 16\left(\frac{E}{V_0}\right)\left(1 - \frac{E}{V_0}\right)\exp(-2K_2 a)$, and $K_2 = \sqrt{\frac{2m}{\hbar^2}(V_0 - E)}$

Chapter 3:

$m^* = \frac{\hbar^2}{d^2E/dk^2}$, $g(E) = \frac{4\pi(2m^*)^{3/2}}{h^3}\sqrt{E}$, and $f(E) = \frac{1}{1 + \exp\left(\frac{E - E_F}{kT}\right)}$

Chapter 4:

$n_0 = N_c \exp\left[\frac{-(E_C - E_F)}{kT}\right]$, $p_0 = N_v \exp\left[\frac{-(E_F - E_v)}{kT}\right]$, and $N_c = 2\left(\frac{2\pi m_n^* kT}{h^2}\right)^{3/2}$

$n_i = \sqrt{N_c N_v} e^{-E_g/2kT}$, $n_0 = n_i \exp\left[\frac{(E_F - E_{Fi})}{kT}\right]$, and $p_0 = n_i \exp\left[\frac{(E_{Fi} - E_F)}{kT}\right]$

$E_{Fi} = E_{midgap} + \frac{3}{4}kT\ln\left(\frac{m_p^*}{m_n^*}\right)$,

$\frac{n_d}{n_0 + n_d} = \frac{1}{1 + \frac{N_c}{2N_d}\exp\left[\frac{-(E_c - E_d)}{kT}\right]}$, and $\frac{p_a}{p_a + p_0} = \frac{1}{1 + \frac{N_v}{4N_a}\exp\left[\frac{-(E_a - E_v)}{kT}\right]}$

For compensated doping: $n_0 = \frac{N_d - N_a}{2} + \sqrt{\left(\frac{N_d - N_a}{2}\right)^2 + n_i^2}$,

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Chapter 5:

Current densities:
$$J_n = en\mu_n E_x + eD_n \frac{dn}{dx} \rightarrow \textit{Electron current}$$
$$J_p = ep\mu_p E_x - eD_p \frac{dp}{dx} \rightarrow \textit{Hole current}$$

$\mu = \dfrac{e\tau}{m^*}$, $l = v_{th}\tau$, $\sigma = e(n\mu_n + p\mu_p)$ and average Kinetic Energy of carriers, $\frac{1}{2} m^* v_{th}^2 = \frac{3}{2} KT$

Induced Electric field, $E_x = -\dfrac{KT}{e} \cdot \dfrac{1}{n_0(x)} \cdot \dfrac{dn_0(x)}{dx}$, and $\dfrac{D_n}{\mu_n} = \dfrac{D_p}{\mu_p} = \dfrac{kT}{e}$

Hall effect: $p = \dfrac{I_x B_Z}{edV_H}$ and $\mu_p = \dfrac{LI_x}{epV_x Wd}$

Chapter 6:

For n-type semiconductors: $R'_n = R'_p = \dfrac{\delta n(t)}{\tau_{p0}}$,

For direct recombination, $\tau_{p0} = 1/(\alpha_r n_0)$ and for indirect recombination, $\tau_{p0} = \dfrac{1}{C_p N_t}$

Shockley-Read-Hall recombination rate: $R'_n = R'_p \approx \dfrac{C_n C_p N_t \left(np - n_i^2\right)}{C_n (n + n_i) + C_p (p + p_i)}$

Ambipolar transport equation in *p*-type semiconductor: $\dfrac{\partial \delta n}{\partial t} = D_n \dfrac{\partial^2 \delta n}{\partial x^2} + \mu_n E \dfrac{\partial \delta n}{\partial x} + g' - \dfrac{\delta n}{\tau_{n0}}$

Ambipolar transport equation in *n*-type semiconductor: $\dfrac{\partial \delta p}{\partial t} = D_p \dfrac{\partial^2 \delta p}{\partial x^2} - \mu_p E \dfrac{\partial \delta p}{\partial x} + g' - \dfrac{\delta p}{\tau_{p0}}$

Dielectric relaxation time constant, $\tau_d = \dfrac{\varepsilon}{\sigma}$

Quasi-Fermi levels: $n_0 + \delta n = n_i \exp\left(\dfrac{E_{Fn} - E_{Fi}}{kT}\right)$ and $p_0 + \delta p = n_i \exp\left(\dfrac{E_{Fi} - E_{Fp}}{kT}\right)$

Chapter 7:

$$V_{bi} = \frac{kT}{e} \ln\left(\frac{N_a N_d}{n_i^2}\right),\ E_{\max} = \frac{-2V_{bi}}{W} = -\left\{\frac{2eV_{bi}}{\varepsilon_s}\left(\frac{N_a N_d}{N_a + N_d}\right)\right\}^{1/2} = -\frac{eN_d x_n}{\varepsilon_s} = -\frac{eN_a x_p}{\varepsilon_s}$$

$$W = \left\{\frac{2\varepsilon_s V_{bi}}{e}\left(\frac{N_a + N_d}{N_a N_d}\right)\right\}^{1/2},\ x_p = \frac{N_d W}{N_a + N_d} \text{ and } x_n = \frac{N_a W}{N_a + N_d}$$