EE Formula sheet

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- $\frac{1}{\rho} = \sigma = \frac{q^2 n\tau}{m*}$; Fermi distribution:$f(E) = \frac{1}{e^{\frac{E-E_F}{kT}}+1}$
- When $E_F < E_C - 3kT$, $n = N_E e^{-\frac{E_C - E_F}{kT}}; N_C = 2\left(\frac{2\pi m_n * kT}{h^2}\right)^{\frac{3}{2}}$.
- When $E_F > E_V + 3kT$, $p = N_V e^{-\frac{E_F - E_V}{kT}}; N_V = 2\left(\frac{2\pi m_p * kT}{h^2}\right)^{\frac{3}{2}}$. N_C, N_V are effective DOSes in the two bands.
- Drift velocity$=\mu\vec{E}$, $\mu = \frac{e\tau}{m*}$, $J = -env = \sigma E$
- Where $\sigma = e(n\mu_e + p\mu_h)$
- Diffusion: $\Phi(flux) = -Dd_x\eta$ thus $J_{p,diff} = -eDd_xp$, same for n.
- $J_n = en(x)\mu_n V(x) + ED_n \frac{\mathrm{d}n(x)}{\mathrm{d}x}$, same for p with opposite sign for second term.
- Einstein: $\frac{D_n}{\mu_n} = \frac{kT}{q}$ at equilibrium for non uniform doping
- $E_F = E_i + kT \ln \frac{n_0}{n_i}$. Same formula for p, with a minus sign
- $n_0 + N_A = p_D + N_D$
- Continuity equation: $\frac{\partial n}{\partial x} = \frac{1}{q}\frac{\partial J}{\partial x} + \frac{\partial n}{\partial x}\Big|_{thermal,R-G,light}$. Same for p with first term negative
- Built in potential $V_{bi} = \frac{1}{q}((E_i - E_F)_p - (E_i - E_F)_n)$
- Equilibrium in PN junction: $\frac{p_{p0}}{p_{n0}} = e^{eV_{bi}/kT}$; with potential $p_n = p_{n0}e^{eV_A/kT}$
- Minority carrier diffusion: $\frac{\partial \Delta n_p}{\partial t} = D_n \frac{\partial^2 \Delta n_p}{\partial x^2} - \frac{\Delta n_p}{\tau_n} + G_L$, same for p_n
- Poisson's eqn: $\nabla^2\phi = -\frac{\rho}{\epsilon} = \frac{q}{\epsilon}((n_0 - p_0) - (N_A - N_D))$
- Depletion width $W = \sqrt{\frac{2\epsilon}{q}\frac{N_A + N_D}{N_A N_D} V_{bi}}$
- Concentration gradient of minority holes $\delta p(x_n) = p_{n0}(e^{eV/kT} - 1)e^{-x_n/L_p}$
- $J_p(x_n) = \frac{eD_p}{L_p}\delta p$
- Schockley: $J = \left(\frac{qD_p}{L_p}p_{n0} + \frac{qD_n}{L_n}n_{p0}\right)(e^{qV_A/kT} - 1) = J_0(e^{\cdots} - 1)$. J_0 is reverse saturation current.
- $R = \frac{dV}{dJ} = \frac{kt}{qJ}$
- $V_{BR} \propto N_B^{-1}$, where N_B is doping of lightly doped side
- Schottky: $e\Phi_B = e\Phi_m - e\chi_s$ (χ_s is EA of semiconductor)
- Current $J - J_s\left(e^{\frac{qV}{kT}} - 1\right)$. $E_{max} = \sqrt{\frac{2eN_D}{\epsilon}(V_D - V)}$
- $\alpha = I_C/I_E, \beta = I_C/I_B$
- Emitter efficiency $\gamma \simeq i - \frac{I_{E_n}}{I_{E_p}}$
- Bl
- MOSFET $I_{D,sat} = \frac{W}{2L}\mu_n C_{ox}(V_{GS} - V_T)^2$
- Saturation discipline: $V_0 > Vi - V_T, V_i > V_T, V_0 \geq \sqrt{\frac{i_{DS}}{k}}$