A2B34ELP Elektronické prvky výběr nejdůležitějších vztahů

Fyzika polovodičů

foton $E = h\nu = \frac{hc}{\lambda}$ $p = \frac{h\nu}{c} = \frac{h}{\lambda}$

elektron $p = m^*v = \hbar k$ $k = \frac{2\pi}{\lambda}$ $E = E_c + E_k$ $E_k = \frac{1}{2}m^*v^2 = \frac{\hbar^2}{2m^*}k^2$ $m^* = \hbar^2\left(\frac{d^2E}{dk^2}\right)^{-1}$

polovodič $f_{FD}(E) = \frac{1}{1+exp\left(\frac{E-E_F}{kT}\right)}$ pro E>4kT $f_{FD} \approx exp\frac{E_F - E}{kT}$ $g(E) = \frac{1}{2\pi^2}\left(\frac{2m}{\hbar^2}\right)^{3/2}(E-E_c)^{1/2}$

$n_0 = N_C \cdot \exp\frac{(E_F - E_C)}{kT}$ $N_c = 2\left(\frac{2\pi m_n^* kT}{h^2}\right)^{3/2}$ $p_0 = N_V \cdot \exp\frac{(E_V - E_F)}{kT}$ $N_v = 2\left(\frac{2\pi m_p^* kT}{h^2}\right)^{3/2}$

$n_0 \cdot p_0 = n_i^2$ $n_i = (N_c N_v)^{1/2}\exp(-\frac{E_g}{2kT})$ $n_0 = n_i \exp(\frac{E_F - E_i}{kT})$ $p_0 = n_i \exp(\frac{E_i - E_F}{kT})$

$p + N_D^+ = n + N_A^-$ $div\ grad\ \phi = \Delta\phi = -\frac{e}{\varepsilon}(p - n + N_D^+ - N_A^-)$

$\frac{\partial n}{\partial t} = \frac{1}{e} div\ \mathbf{j_n} + G - R$ $\frac{\partial p}{\partial t} = -\frac{1}{e} div\ \mathbf{j_p} + G - R$

$J_n = en\mu_n E + eD_n\frac{dn}{dx}$ $J_p = ep\mu_p E - eD_p\frac{dp}{dx}$ $D = \frac{\mu kT}{e}$

Přechod PN

U_{ext}=0 $U_D = \frac{kT}{e}\cdot\ln\left(\frac{n_N}{n_P}\right) = \frac{kT}{e}\cdot\ln\left(\frac{p_P}{p_N}\right) = \frac{kT}{e}\cdot\ln\left(\frac{N_D \cdot N_A}{n_i^2}\right)$

$\frac{x_n}{x_p} = \frac{N_A}{N_D}$ $w_{OPN} = x_N + x_P = \sqrt{\frac{2\varepsilon_s U_D}{e}\left(\frac{N_A + N_D}{N_A N_D}\right)}$

$U_{ext}\neq 0$ $j = j_0\left[\exp\left(\frac{eU}{kT}\right) - 1\right]$ $j_0 = e\left(\frac{D_n n_{P0}}{L_n} + \frac{D_p p_{N0}}{L_p}\right)$ $L_n = \sqrt{D_n\tau_n}$

$w_{OPN} = \sqrt{\frac{2\varepsilon_s(U_R + U_D)}{e}\left(\frac{N_A + N_D}{N_A N_D}\right)}$ $C_J = \varepsilon_S\frac{A}{w_{OPN}}$

Schottkyho přechod

$$j = j_0 \cdot \left(\exp\frac{eU}{kT} - 1\right) = A^* \cdot T^2 \cdot \exp\left(\frac{-e\cdot\phi_{Bn}}{kT}\right)\cdot\left(\exp\frac{eU}{kT} - 1\right)$$

Struktura MIS

substrát P $\varphi_s(inv.) = 2\varphi_F = 2\frac{kT}{q}\ln\frac{N_a}{n_i}$ $W_{OPN} = \left[\frac{2\varepsilon_S\varphi_S(inv)}{eN_A}\right]^{1/2}$

$U_T = -\frac{Q_{OPN}}{C_{ox}} + 2\varphi_F$ ideální $U_T = \Phi_{MS} - \frac{Q_{ef}}{C_{ox}} - \frac{Q_{OPN}}{C_{ox}} + 2\varphi_F$ reálná

Tranzistor MOSFET

"dlouhý kanál N"

$$I_D = \mu_n C_{ox} \frac{W}{L}\left[(U_{GS} - U_T)U_{DS} - \frac{1}{2}U_{DS}^2\right]$$

$$I_D = \mu_n C_{ox} \frac{W}{L}(U_{GS} - U_T)\, U_{DS} \qquad \text{pro } U_{GS}\text{-}U_T >> U_{DS}$$

$$I_D = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(U_{GS} - U_T)^2 \qquad \text{pro } U_{GS}\text{-}U_T \leq U_{DS}$$

"krátký kanál N"

$$I_D = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(U_{GS} - U_T)^2(1 + \lambda U_{DS}) \qquad \text{pro } U_{GS}\text{-}U_T \leq U_{DS} \qquad \lambda = \frac{1}{U_A}$$

$$r_o = \left[\lambda \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(U_{GS} - U_T)^2\right]^{-1} = \frac{U_A + U_{DSP_0}}{I_{DP_0}}$$

Bipolární tranzistor (BJT)

tranzistor NPN

$$I_C = I_S \exp\left(\frac{U_{BE}}{U_T}\right) \qquad I_S = A_E e D_n \frac{n_i^2}{N_A W}$$

$$I_B = I_S \frac{1}{\beta}\exp\left(\frac{eU_{BE}}{kT}\right) = \frac{1}{\beta} I_C \qquad I_B = I_S\left(\frac{D_p}{D_n}\frac{N_A}{N_D}\frac{W}{L_p} + \frac{1}{2}\frac{W^2}{D_n \tau_b}\right)\exp\left(\frac{eU_{BE}}{kT}\right)$$

$$I_E = I_C + I_B = I_C + \frac{I_C}{\beta} = \frac{\beta + 1}{\beta} I_C = \frac{\beta + 1}{\beta} I_S \exp\left(\frac{U_{BE}}{U_T}\right) = \frac{I_S}{\alpha}\exp\left(\frac{U_{BE}}{U_T}\right)$$

Tranzistor JFET

tranzistor JFET(N) v saturaci

$$I_D = I_{DSS}\left(1 + \frac{U_{GS}}{U_P}\right)^2 \qquad U_P = \frac{eN_D a^2}{2\varepsilon_0 \varepsilon_s}$$