$\epsilon_{si} = 1035{,}45\,\mathrm{fFcm}^{-1}$
$[F] = [C]/[V] \quad [A] = [C]/[s]$

$n_i = \sqrt{n_0 \cdot p_0} = [cm^{-3}] \quad (n_0 = p_0 = n_i$ intríns..)

$$= 2\left(\frac{2\pi \cdot \sqrt{m_n^* \cdot m_p^*} \cdot kT}{h^2}\right)^{3/2} \exp\left(\frac{-Eg}{2kT}\right)$$

$$n_0 = \frac{N_D - N_A}{2} + \sqrt{\left(\frac{N_D - N_A}{2}\right)^2 + n_i^2}$$

↑ para p_0 cambiar los D y A

$v_{th} = \sqrt{\frac{kT}{m^*}}$ vel term| $v^a_{p/n} = \pm\mu_{p/n}\vec{E}$

$J = \frac{I}{A} = n \cdot q \cdot v^a \quad R = \frac{L \cdot \rho}{A} = \frac{L}{A \cdot \sigma}$

$J^a_{n/p} = n/p_0 q\mu_{n/p}\vec{E} \qquad J^d_{n/p} = \pm qD_{n/p}\frac{dn/p(x)}{dx}$

$J^a = J^a_n + J^a_p = \sigma \cdot \vec{E} \qquad \sigma = q \cdot (n\mu_n + p\mu_p)$

$D_{p/n} = \frac{\lambda^2}{2\tau_c} = \mu_{p/n}V_{th} \qquad J_n = J^a_n + J^d_n = 0$

$V_{th} = (kT)/q \approx 25{,}9\,\mathrm{mV} \quad \rho(x) = q\,[N_D - n_0(x)]$

$\phi(x) = 60\,\mathrm{mV} \cdot \log_{10}(n(x)/n_i)$

Rel Boltzman $\phi_{n/p} = \pm V_{th} \cdot \ln\frac{n/p_0}{n_i}$

PN

Zona P/N $\rho = \mp qN_{A/D} \quad N_A x_{p_0} = N_D x_{n_0}$

Zona P/N $E(x) = \mp\frac{qN_{A/D}}{\epsilon_{si}}(x \pm x_{p/n_0})$

$\phi_B = \phi_n - \phi_p = V_{th} \cdot \ln\left(N_A \cdot N_D/n_i^2\right)$

SCR-P/N $\phi(x) = \phi_{p/n} \pm \frac{qN_{A/D}}{2\epsilon_{si}}(x \pm x_{p/x_0})^2$

Limites región de vaciamiento || $\vec{E}$ en juntura

$x_{n/p_0} = \sqrt{(2\epsilon_{si}\phi_B N_{A/D})/(q(N_A + N_D)N_{D/A})}$

$|E_0| = \sqrt{(2q\phi_B N_A N_D)/(\epsilon_{si}(N_A + N_D))}$

$x_{d_0} = x_{n_0} + x_{p_0} = \sqrt{2\epsilon_{si}\phi_B(N_A + N_D)/qN_A N_D}$

$[x_n, x_p, x_d, |E|] = [x_n, x_p, x_d, |E|]_0\sqrt{1 - (V/\phi_B)}$

Capacidad de Juntura $C_j(V) = C'_j \cdot A$

$$C'_j = \sqrt{\frac{q\epsilon_{si}N_A N_D}{2(\phi_B - \mathbf{V})(N_A + N_D)}} = \frac{C'_{j_0}}{\sqrt{1 - (\mathbf{V}/\phi_B)}}$$

Diodo PN $V > 0 \Rightarrow |E_{SCR}| \downarrow \Rightarrow |J_a| \downarrow < |J_d|$

$$n(-x_p) = \frac{n_i^2}{N_A}\exp\left(\frac{V}{V_{th}}\right); p(x_n) = \frac{n_i^2}{N_D}\exp\left(\frac{V}{V_{th}}\right)$$

$$J_{n/p} = q\frac{n_i^2}{N_{A/D}}\frac{D_{n/p}}{W_{p/n} - x_{p/n}}\left(\exp\left(\frac{V}{V_{th}}\right) - 1\right)$$

Directa: $V_D = V_{D(on)} \quad I_D > 0 \quad C_{dif} \gg C_j;\ r_d \downarrow$

Inver:$V_D \neq V_{D(on)}; I_D \simeq -I_0; r_d \to \infty; C_{dif} \to 0$

$$I_D = I_0\left(\exp\left(\frac{V}{n \cdot V_{th}}\right) - 1\right) \quad I_{0(gen)} = \frac{qAn_i x_d(V)}{\tau_g}$$

$$I_0 = qAn_i^2\left(\frac{D_n}{N_A(W_p - x_p)} + \frac{D_p}{N_D(W_n - x_n)}\right)$$

$v_D(t) = V_D + v_d(t) \quad i_D(t) = I_D + g_d \cdot v_d(t)$

$g_d = (I_D + I_0)/V_{th} \quad C_{dif} = \tau_T \cdot g_d$

$$\tau_{T_{p/n}} = \frac{(W_{n/p} - x_{n/p})^2}{2D_{p/n}} \quad \tau_T = \frac{\tau_{T_p}I_{D_p} + \tau_{T_n}I_{D_n}}{I_D}$$

Juntura MOS

$sustP: V_T > 0 \quad gateN^{++}: V_{FB} < 0$

$\phi_B + V_{GB} = \Delta V_{ox} + \Delta V_{bulk} \quad (N/P)^{++}\phi_G = \pm 550\,\mathrm{mV}$

$C'_{ox} = \epsilon_{ox}/t_{ox} \quad C_{vac} = \epsilon_{si}/x_d$

Vaciamiento: $Q'_G = -Q'_{bulk} = qN_{bulk}x_d(V_{GB})$

$x_d(V) = \epsilon_{sc}\left(\sqrt{1 + 4(\phi_B - V)\gamma^{-2}} - 1\right)/C'_{ox}$

$\gamma = \sqrt{2\epsilon_{si}qN_{bulk}}/C'_{ox} \quad \Delta V_{bulk} = qN_{bulk}x_d^2(V_{GB})/2\epsilon_{sc}$

$\Delta V_{ox} = Q_G/C'_{ox} = qN_{bulk}t_{ox}x_d(V_{GB})/\epsilon_{ox}$

Flatband: $V_{GB} = -\phi_B = V_{FB}$

$\vec{E} = \phi(x) = \Delta V_{bulk} = \Delta V_{ox} = x_d = 0$

Acumulacion $Q'_{ac} = -Q'_{gate} = -C'_{ox}\Delta V_{ox}$

$x_d = \Delta V_{bulk} = 0 \quad \Delta V_{ox} = V_{GB} - V_{FB}$

Tensión Umbral(V_T) $\Delta V_{bulk} = -2\phi_p$

$\Delta V_{ox} = \gamma\sqrt{-2\phi_p} = 2\phi_B + V_{GB} - \Delta V_{bulk}$

Inversión $Q'_{gate} = -Q'_{bulk} - Q'_{inv} =$

$= qN_A x_d(V_T) + C'_{ox}(V_{GB} - V_T)$

Capacidad de MOS $C'_{GB} = C'_{ox}$ acu/inv

$$C'_{GB} = \frac{C'_{vac}C'_{ox}}{C'_{vac} + C'_{ox}} = \frac{C'_{ox}}{\sqrt{1 + \frac{4(\phi_B + V_{GB})}{\gamma^2}}}\text{vac.}$$

Transistor MOSFET (N/P)

$V_{DS_{sat}} = V_{GS} - V_T \quad k = (\mu_n C'_{ox}W)/(2L)$

Corte:$V_{GS} \lesseqgtr V_T \qquad I_D = 0$

Saturación:$V_{GS} \gtreqless V_T \quad V_{DS} \gtreqless V_{DS_{sat}}$

$I_D = \pm k(V_{GS} - V_T)^2[1 \pm \lambda V_{DS}]$

Triodo:$V_{GS} \gtreqless V_T \quad V_{DS} \lesseqgtr V_{DS_{sat}}$

$I_D = \pm 2k\left(V_{GS} - V_T - (V_{DS})/2\right)V_{DS}[1 \pm \lambda V_{DS}]$

-Back: $V_T = V_{FB} - 2\phi_{p/n} \pm \gamma\sqrt{\mp(2\phi_{p/n} + \cancel{V_{BS}})}$

MPS: $i_D = k(V_{GS} - V_T)^2 + 2k(V_{GS} - V_T) \cdot v_{gs}(t)$

$g_m = 2k(V_{GS} - V_T) \quad r_0 = 1/2k(V_{GS} - V_T)^2\lambda$

$g_{mb} = g_m(\gamma/2\sqrt{-2\phi_B - V_{BS}}) \quad C_{gd} = WC_{ov}$

$C_{gs} = (2/3)WLC'_{ox} + C_{gd} \quad C_{sb/db} = A_{s/d}C'_j$