Equações C-V

p-type: $\phi_{ms} = \phi_m - \left(\chi + \frac{E_g}{2.q} + \phi_F\right)$ n-type: $\phi_{ms} = \phi_m - \left(\chi + \frac{E_g}{2.q} - \phi_F\right)$

$\phi_F = u_T.\ln\left(\frac{N_A}{n_i}\right)$ $u_T = \frac{k.T}{q}$ (p.ex. u_T=25mV p/ 20^{o}C)

$$V_G = \phi_{ms} + \psi_{ox} + \psi_s$$

$V_G = \phi_{ms} - \frac{Q_{ox}}{C_{ox}} - \frac{Q_S}{C_{ox}} + \psi_s$ $C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$ $V_{FB} = \phi_{ms} - \frac{Q_{ox}}{C_{ox}}$

$V_G = V_{FB} - \frac{Q_S}{C_{ox}} + \psi_s$ $Q_S = Q_i + Q_D$ $Q_G = -Q_S$

$V_G = V_{FB} - \frac{Q_i}{C_{ox}} - \frac{Q_D}{C_{ox}} + \psi_{s0}$ $\psi_s = \psi_{s0} = 2.\phi_F$

$V_T = V_{FB} - \frac{Q_D}{C_{ox}} + \psi_{s0}$ $V_G - V_T = -\frac{Q_i}{C_{ox}}$

Poisson´s Equation: $\frac{d\mathcal{E}}{dx} = \frac{\rho}{\varepsilon_{si}}$ $\rho = -qN_A$ => $\frac{d\mathcal{E}}{dx} = -\frac{qN_A}{\varepsilon_{si}}$ $\frac{d^2\psi}{dx^2} = \frac{qN_A}{\varepsilon_{si}}$

$x_d = \sqrt{\frac{(2.\varepsilon_{si}.\psi_s)}{q.N_A}}$ $Q_D = -q.N_A.x_d$ $Q_D = -\sqrt{(2.\varepsilon_{si}.q.N_A.\psi_s)}$

$V_T = V_{FB} + \gamma\sqrt{\psi_{s0}} + \psi_{s0}$ $\gamma = \frac{\sqrt{(2.\varepsilon_{si}.q.N_A)}}{C_{ox}}$ $C_d = \frac{\varepsilon_{si}}{x_d} = \sqrt{\frac{(\varepsilon_{si}.q.N_A.)}{2.\psi_s}} = -\frac{dQ_S}{d\psi_s}$

$L_d = \sqrt{\frac{(\varepsilon_{si}.u_T)}{q.N_A}}$ $C_{FB} = \frac{\varepsilon_{si}}{L_d} = \sqrt{\frac{(\varepsilon_{si}.q.N_A.)}{u_T}}$

$$C_G = \frac{dQ_G}{dV_G} = \frac{-dQ_S}{dV_G} = \frac{-dQ_S}{\frac{-dQ_S}{C_{ox}} + d\psi_s} = \frac{1}{\frac{1}{C_{ox}} + \frac{1}{C_d}}$$

Análise C-V Básica

A partir da curva C-V (HF) => C_{HFmax} e C_{HFmin} [F]

1) $C_{ox} = \dfrac{C_{HFmax}}{A}$ [F/cm²] => $t_{ox} = \dfrac{\varepsilon_{ox}}{C_{ox}}$ => $\mathbf{t_{ox}}$ [cm]

$$\frac{1}{C_{HFmin}} = \frac{1}{C_{HFmax}} + \frac{1}{C_{dmin}} \quad => \quad C_{dmin} = \frac{1}{\dfrac{1}{C_{HFmin}} - \dfrac{1}{C_{HFmax}}} \cdot \frac{1}{A} \qquad [\text{F/cm}^2]$$

2) $C_{dmin} = \dfrac{\varepsilon_{si}}{x_{dmax}} = \sqrt{\dfrac{(\varepsilon_{si}.q.N_A.)}{2.\psi_{s0}}}$ => $x_{dmax} = \dfrac{\varepsilon_{si}}{C_{dmin}}$ => $\mathbf{X_{dmax}}$ [cm]

$\psi_s = \psi_{s0} = 2.\phi_F$ e $\phi_F = u_T.\ln\left(\dfrac{N_A}{n_i}\right)$ => $C_{dmin} = \dfrac{\varepsilon_{si}}{x_{dmax}} = \sqrt{\dfrac{(\varepsilon_{si}.q.N_A.)}{4.u_T.\ln\left(\dfrac{N_A}{n_i}\right)}}$

3) $N_A = \dfrac{4.u_T.\ln\left(\dfrac{N_A}{n_i}\right).(C_{dmin})^2}{\varepsilon_{si}.q}$ => $\mathbf{N_A}$ [#/cm³]

=> $L_d = \sqrt{\dfrac{(\varepsilon_{si}.u_T)}{q.N_A}}$ => $C_{FB} = \dfrac{\varepsilon_{si}}{L_d} = \sqrt{\dfrac{(\varepsilon_{si}.q.N_A.)}{u_T}}$ => $\mathbf{C_{FB}}$ [F/cm²]

4) $C_{GFB} = \dfrac{A}{\dfrac{1}{C_{FB}} + \dfrac{1}{C_{ox}}}$ [F] => $\mathbf{V_{FB}}$ [V]

=> $V_{FB} = \phi_{ms} - \dfrac{Q_{ox}}{C_{ox}}$ => $\dfrac{Q_{ox}}{q} = N_{ox}$ [#/cm²] => $\mathbf{N_{ox}}$ [#/cm²]

5) $V_T - V_{FB} = -\dfrac{Q_D}{C_{ox}} + \psi_{s0}$ c/ $Q_D = -\sqrt{(2.\varepsilon_{si}.q.N_A.\psi_{s0})}$ => $\mathbf{V_T}$ [V]

Análise C-V - Perfil de Impurezas

$$C_m = \frac{C_{HFm}}{A} \qquad dQ_G = C_m.dV_G = -q.N(x_d).dx_d = -\varepsilon_{si}.q.N(x_d).d\left(\frac{1}{C_m}\right)$$

$$1 = -\varepsilon_{si}.q.N(x_d).\frac{\left(\frac{1}{C_m}\right).d\left(\frac{1}{C_m}\right)}{dV_G} \quad => \quad N(x_d) = \left(\frac{-2}{\varepsilon_{si}.q}\right)\left[\frac{d\left(\frac{1}{(C_m)^2}\right)}{dV_G}\right]^{-1}$$

$$c/ \quad 2xdx = d(x^2) \quad => \quad x_d = \varepsilon_{si}\left(\frac{1}{C_m} - \frac{1}{C_{ox}}\right)$$

Influência dos “Interface Traps”

$$C_m.dV_G = C_d.d\psi_s \qquad \text{(s/ IT)}$$

$$C_m.dV_G = (C_d + C_i).d\psi_s \qquad \text{(c/ IT)}$$

$$\frac{1}{C_{HF}} = \frac{1}{C_{ox}} + \frac{1}{C_d} \qquad \frac{1}{C_{LF}} = \frac{1}{C_{ox}} + \frac{1}{(C_d + C_i)}$$

$$N(x_d) = \left(\frac{-2}{\varepsilon_{si}.q}\right).\frac{\left(1 - \frac{C_{LF}}{C_{ox}}\right)}{\left(1 - \frac{C_{HF}}{C_{ox}}\right)}.\left[\frac{d\left(\frac{1}{(C_{HF})^2}\right)}{dV_G}\right]^{-1}$$