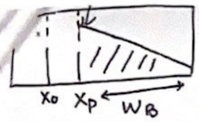
$$\therefore J_0 = \frac{q D_n n_{po}}{W_B} = 3.5\times10^{-12}\ A/cm^2 = \frac{q D_n n_i^2}{W_B \cdot N_A}$$



one-side abrupt junction

$$\frac{1.6\times10^{-19}\cdot 35\cdot(10^{10})^2}{10^{17}\cdot W_B} = 3.5\times10^{-12}$$

$$\frac{D_n}{\mu_n} = \frac{kT}{q},\quad D_n = 0.026\times1350 = 35\ cm^2/s$$

$$W_B = \frac{1.6\times10^{-19}\cdot 35\cdot10^3}{3.5\times10^{-12}} = \frac{1.6\times10^{-15}}{10^{-12}} = 1.6\times10^{-3}\ cm = 16\ \mu m$$

$$\boxed{W_B = 16\ \mu m}$$

(b) $J_{GR} = J_{GR0}\exp\left(\frac{qV_a}{2kT}\right)$

$J_{diff} = J_0\exp\left(\frac{qV_a}{kT}\right)$

$$\frac{J_{GR}}{J_{diff}} = \boxed{\frac{J_{GR0}}{J_0}}^{100}\exp\frac{-qV_a}{2kT} > 1$$

$$\exp\frac{qV_a}{2kT} < 100,\quad \frac{qV_a}{2kT} < \ln(100)$$

$$V_a < 2\frac{kT}{q}\cdot\ln 100 = 4\times\frac{kT}{q}\ln 10 = 240\ mV$$

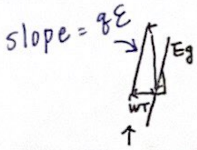
單位:mV

$$\boxed{0 < V_a < 0.24}$$

(c) $\mathcal{E}_{max} = -\frac{dV}{dx} = \frac{1}{q}\frac{dE_c}{dx}$

單位換成eV

$$\frac{E_g}{W_T} = \frac{dE_c}{dx} = q\mathcal{E}_{max} = \frac{8\times10^6\ eV}{cm} = \frac{1.1\ eV}{W_T}$$



$$W_T = \frac{1.1}{10^6}\ cm = 1.1\times10^{-6}\ cm = 11\ nm$$

$$\boxed{W_T = 11\ nm}$$

(d) $C_j = \sqrt{\frac{q\varepsilon_{si}N_A}{2(V_{bi}-V_a)}}$, $\quad V_{bi} = \frac{kT}{q}\ln\frac{\boxed{N_C}N_A}{n_i^2} = 0.026\ln\frac{2.5\times10^{19}\times10^{17}}{10^{20}} = 0.98\ V$

$$= \sqrt{\frac{1.6\times10^{-19}\times11.7\times8.85\times10^{-14}\times1\times10^{17}}{2[0.98-(-1)]}} = \sqrt{42\times10^{-16}} = 6.5\times10^{-8}\ F/cm^2 = 6.5\times10^{-16}\ F/\mu m^2$$

$$= 0.65\ fF/\mu m^2$$

$$\boxed{C_j(V_a=-1V) = 0.65\ fF/\mu m^2}$$

(e) $C_j = \sqrt{\frac{q\varepsilon_{si}\cdot N_A}{2(V_{bi}-V_a)}}$ $\quad V_a = 0.7V$.

$$= \sqrt{\frac{q\varepsilon_{si}\cdot N_A}{2\cdot(0.98-0.7)}} = 1.72\times10^{-7}\ F/cm^2 = 1.72\times10^{-15}\ F/\mu m^2 = 1.7\ fF/\mu m^2$$

$C_{tot} = 48 + 1.7 = 49.7\ fF/\mu m^2$

$$\boxed{C_{tot} \cong 50\ fF/\mu m^2}$$

$$J_{diff} = J_0\cdot\exp\frac{qV_a}{kT} = 3.5\times10^{-12}\cdot\exp\frac{0.7}{0.026} = 1.7\ A/cm^2$$

$$C_{sc} = \frac{dQ_s}{dV} \qquad Q_s = q n_{po}\exp\frac{qV_a}{kT}\cdot W_B$$

$$= q n_{po}\cdot W_B\cdot\frac{q}{kT}\exp\frac{qV_a}{kT} = \frac{qD_n n_{po}}{W_B}\cdot\frac{W_B^2}{D_n}\cdot\frac{1}{V_{th}}\exp\frac{qV_a}{kT} = J_{diff}\cdot\frac{W_B^2}{D_n}\cdot\frac{1}{V_{th}} = G_p$$

($\frac{W_B^2}{D_n} = \tau_n$)

$C_{sc} = G_p\cdot\tau_n = \frac{dI}{dV_a}\cdot\tau_n = \frac{I}{V_{th}}\cdot\tau_n$

$$= \frac{W_B^2}{D_n}\cdot\frac{1}{V_{th}}\ (W_B = 1.6\times10^{-3}\ cm) = \frac{1.7\times7.3\times10^{-8}}{0.026} = 4.8\times10^{-6}\ F/cm^2 = 48\ fF/\mu m^2$$

(a) n type substrate.

(b) $\frac{\varepsilon_{ox}}{T_{ox}} \cdot A = 50pF = 5.0 \times 10^{-12}\,F = C_{max} = C_{ox}$

$\frac{3.9 \times 8.85 \times 10^{-14}}{T_{ox}} \cdot 10^{4} \times 10^{-8}\,cm^{2} = 5 \times 10^{-11}$, $T_{ox} = \frac{34.5 \times 10^{-18}}{5 \times 10^{-11}} = 6.9 \times 10^{-7}\,cm$

$= \underline{6.9\,nm}$

$\boxed{T_{ox} = 6.9\,nm}$

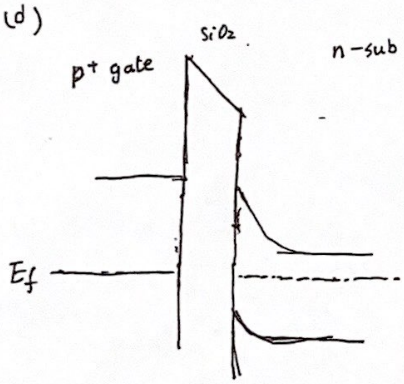
(c) $C_{min} = \frac{C_{dep}\,C_{ox}}{C_{ox} + C_{dep}}$, $\frac{C_{max}}{C_{min}} = \frac{50}{10} = \frac{C_{ox}}{\frac{C_{dep}\,C_{ox}}{C_{ox}+C_{dep}}} = \frac{C_{ox}+C_{dep}}{C_{dep}}$

$\Rightarrow \frac{C_{ox}}{C_{dep}} + 1 = 5$, $C_{ox} = 4\,C_{dep}$.

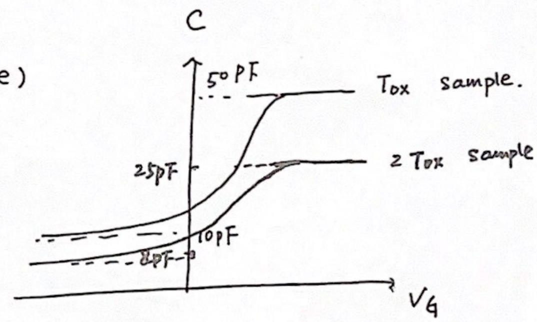
$C_{dep} = \frac{\varepsilon_{si}}{W_{dep}}$, $C_{ox} = \frac{\varepsilon_{ox}}{T_{ox}}$

$\frac{C_{ox}}{C_{dep}} = 4 = \frac{\varepsilon_{ox}}{\varepsilon_{si}} \frac{W_{dep}}{T_{ox}} = \frac{1}{3} \frac{W_{dep}}{T_{ox}}$ $W_{dep} = 12 \cdot T_{ox} = 83\,nm = 0.08\,\mu m$.

(d)



(e)



(e)

$C_{ox} = 25\,pF$ (∵ tox 變 2倍)

$C_{dep} = 13\,pF$

$C_{min} = \frac{25 \times 13}{25 + 13} = 8.55\,pF$ ※

(a) $\psi_s = 2\phi_p = 2 V_{th} \ln \frac{N_{sub}}{n_i} = 2 \cdot 0.026 \ln \frac{10^{17}}{10^{10}} = 0.84V.$ $\boxed{\psi_s = 0.84V}$

(b) $V_T = V_{FB} + 2\phi_p + V_{ox} = 0.6V$

$V_{ox} = 0.6 + 1 - 0.84 = 0.76\ V.$ $\boxed{\mathcal{E}_{ox} = 1.5\ MV/cm}$

$\mathcal{E}_{ox} = \frac{V_{ox}}{T_{ox}} = \frac{0.76V}{5\times10^{-7}} = 0.152\times10^{7}\ V/cm = 1.5\times10^{6}\ V/cm = 1.5\ MV/cm$

(c) $V_{GS} = -1V = V_{FB}.\ \mathcal{E}_{ox} = 0. \Rightarrow \mathcal{E}_{\perp} = 0.$ $\boxed{\mathcal{E}_{\perp} = 0}$

(d) $\mathcal{E}_{//} = \frac{V_{DS}}{L_g} = \frac{0.1V}{0.5\mu m} = 0.2\ V/\mu m = 0.2\times10^{4}\ V/cm = 2\times10^{3}\ V/cm$

$\boxed{\mathcal{E}_{//} = 2\times10^{3}\ V/cm}$

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4. (a) $V_{SG} = 0.8V,\ V_{SD} = 0.2V \Rightarrow$ linear region., $\theta = 0.3$

$I_D = \frac{\mu_p C_{ox} \frac{W}{L}}{1+\theta(V_{SG}-|V_T|)} \left(V_{SG} - |V_T| - \frac{V_{SD}}{2} \right) V_{SD}$

$= \frac{50 \cdot 10}{1+\theta(0.8-0.5)} (0.8 - 0.5 - 0.1)\ 0.2$

$= \frac{500}{1+0.3\cdot0.3} (0.2)(0.2) = \frac{20}{1+0.09} = 18\ \mu A.$ $\boxed{I_D = 18\mu A}$

(b) $V_{SG} = 2.5 = V_{SD} \Rightarrow$ device in sat.

$I_D = \frac{1}{2} \frac{\mu_p C_{ox} \frac{W}{L}}{1+\theta(V_{SG}-|V_T|)} (V_{SG} - |V_T|)^2$

$= \frac{1}{2} \frac{50 \cdot 10}{1+0.3(2.5-0.5)} (2.5-0.5)^2 = \frac{500}{2} \frac{4}{1+0.3\cdot2} = \frac{1000}{1.6} = 625\mu$

$\boxed{I_D = 625\mu A}$

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5. (a) $S = \frac{0.6V - 0.42V}{\log_{10} \frac{10nA}{100pA}} = \frac{180mV}{2} = 90\ mV/dec.$ $\boxed{S = 90mV/dec}$

(b) $\frac{S_1}{S_2} = \frac{\frac{kT_1}{q}}{\frac{kT_2}{q}} = \frac{T_1}{T_2}$

$\frac{90mV}{60mV} = \frac{300°K}{T_2}$

$T_2 = \frac{300}{1.5} = 200°K.$

$\boxed{T_2 = 200°K}$

$$f_T \approx \frac{g_m}{C_g} \approx \frac{\mu V_{sat} \cdot C_{ox}}{W L_g C_{ox}}$$

$$f_T \propto \frac{V_{sat}}{L_g}$$

(a) $f_T \propto \frac{1}{L_g} \rightarrow f_T(45nm) = 2 \cdot 100GHz$

$= 200GHz$

(b) $f_T = 200 \times 1.3 = 260GHz.$

7.

$L_{nB} = 1\mu m$

(a) $\beta = \frac{10^{-2}}{10^{-4}} = 100$

(b) $\alpha_T = 1 - \frac{W_B^2}{2 D_{nB} \tau_{nB}} = 1 - \frac{1}{2}\left(\frac{0.1}{L_{nB}}\right)^2 = 1 - \frac{1}{2}\left(\frac{0.1}{1\mu m}\right)^2 =$

$= 1 - \frac{1}{2} \times \left(\frac{1}{10}\right)^2$

$= 1 - \frac{1}{200} = \frac{199}{200}$

$= 0.995$ #

(c) $\alpha = \frac{\beta}{1+\beta} = \gamma \cdot \alpha_T \cdot M = \gamma \cdot \quad = \frac{100}{101}$

$$\gamma = \frac{100}{101} \times \frac{200}{199} = 0.99507 = \frac{1}{1 + \frac{P_E(0^-)}{n_B(0^+)} \frac{D_{PE}}{D_{nB}} \frac{W_B}{W_E}} = \frac{1}{1 + \frac{P_E(0^-)}{n_B(0^+)} \frac{1}{3}}$$

$\frac{D_{PE}}{D_{nB}} = \frac{450}{1350}$

$$\gamma = \frac{1}{1 + \frac{N_B}{N_E}\frac{1}{3}} \qquad 1 + \frac{N_B}{3N_E} = \frac{1}{0.99507} = 1.00495$$

$$\frac{N_B}{3N_E} = 0.00495$$

$N_B = 0.00495 \times 3 \times 10^{19}$

$= 1.485 \times 10^{17}\ cm^{-3}$ #