EECE 480 FINAL 2009

2 1(a) To combat the effect of decreasing C_{ox} on V_T. i.e., to keep V_T high enough for acceptably low I_{subt}.

2 (b) Halo doping serves to confine the field at the S & D i.e., to prevent DIBL.

2 (c) 50nm FET ∴ need to use LEVEL 49
from (10.48), I_{Dsat} is not directly $\propto$ to μ_{eff}.
This is because the drift velocity is limited to v_{sat},
and not unconstrained to $\mu_{eff} \mathcal{E}_x$.

3 1(d) $S = \dfrac{\partial V_{GS}}{\partial \log_{10} I_D} = 2.303\, m\, V_{th}$ (13.10)

$m = 1 + \dfrac{\gamma}{2\sqrt{2\phi_B + V_{SB}}}$ (10.36)

$\gamma = \dfrac{\sqrt{2q\varepsilon_s N_A}}{C_{ox}}$ following (10.16).

$C_{ox} = \varepsilon_{ox} / t_{ox}$.

$m = 1.18$ CMOS90 $m = 1.23$ CMOS65

$\therefore$ CMOS 90 needs the smaller ΔV_{GS}.

3 1(e) $V_T = V_{fb} + 2\phi_B + \gamma\sqrt{2\phi_B + V_{SB}}$ (10.35).

$V_{fb} = -V_{bi} = \dfrac{\Phi_G - \Phi_S}{q}$ $\therefore V_{fb} \propto \Phi_G$

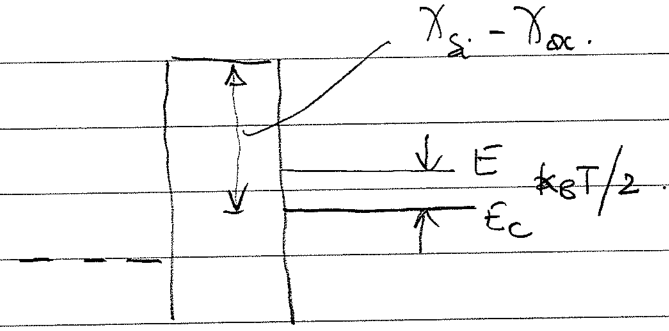
$\therefore V_{fb}(Ni) > V_{fb}(Ti)$ $\therefore V_T(Ni) > V_T(Ti)$

③

4 2(a) Fig. 15.4(d)

4 2(b) Approximate by rectangular barrier,

Fig 15.4c)



$$T \simeq \exp\left[-\frac{2d}{\hbar}\sqrt{2m^*(U_2 - E)}\right]$$

$$\ln T = -\frac{2d}{\hbar}\sqrt{2m^*(U_2 - E)}$$

$$d = -\ln T \cdot \frac{\hbar}{2}\frac{1}{\sqrt{2m^*(U_2 - E)}}$$

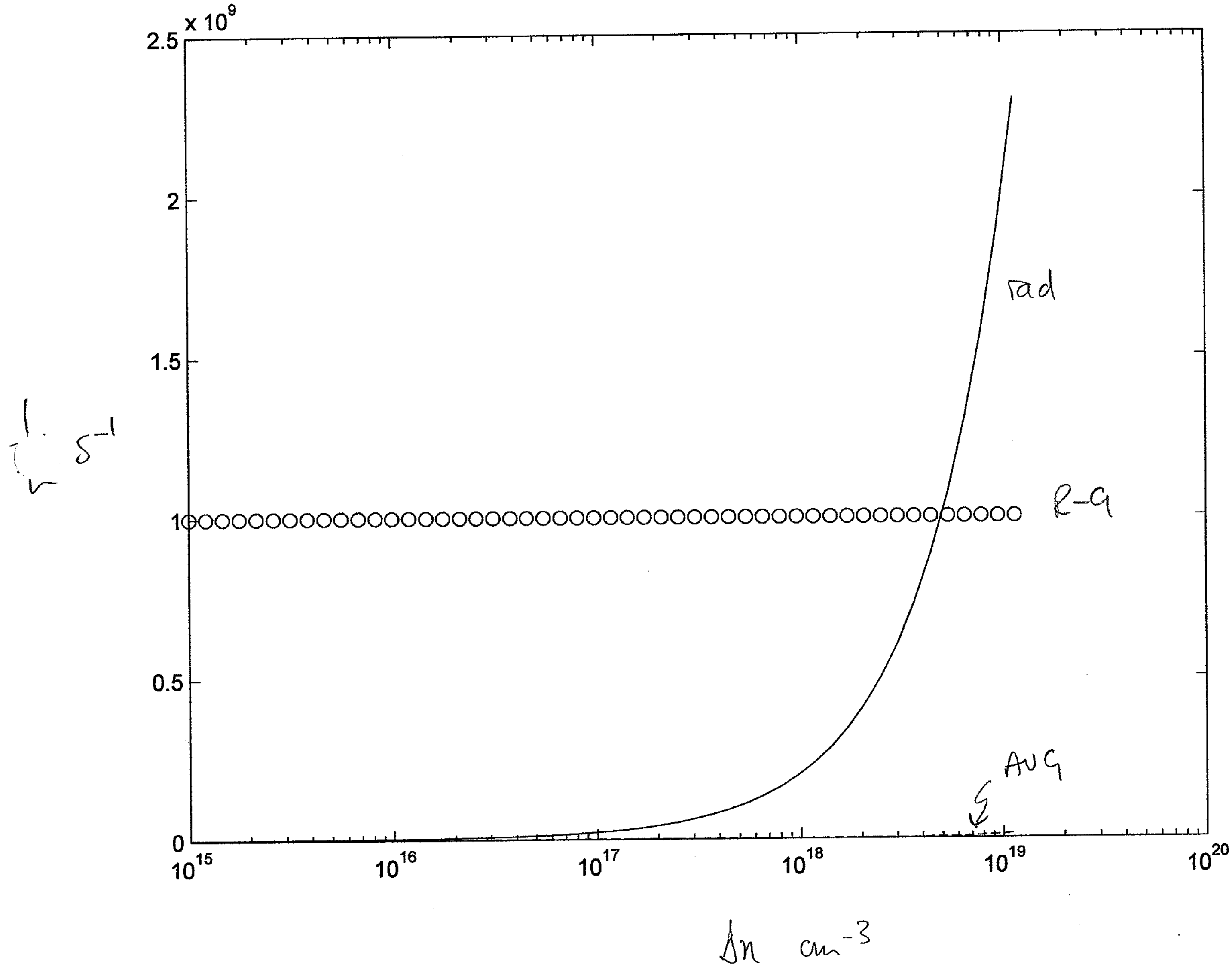
$m^*(SiO_2) = 0.3 \times 9.1 \times 10^{-31}$ kg $\qquad \hbar = 1.05 \times 10^{-34}$ Js

$(U_2 - E) = (\chi_{Si} - \chi_{ox}) - 3k_BT/2 = (4.01 - 0.9) - 3/2 \times 0.0259$ eV
$= 3.071$ eV $\equiv 4.914 \times 10^{-19}$ J.

$d = -\ln T \cdot 1.014 \times 10^{-10} \rightarrow 7$ nm for $T = 1 \times 10^{-30}$.

4 2c) (15.6) $V_B' = \frac{V_{DD}}{2}\left[\frac{C_B - C_{st}}{C_{st} + C_B}\right] \rightarrow \frac{V_{DD}}{2} - \Delta V$

$\frac{C_B - C_{st}}{C_{st} + C_B} = 1 - \frac{2\Delta V}{V_{DD}} = 1 - 0.02 = 0.98 \rightarrow$ $\underline{C_B = 99 \text{ pF}}$



x 10^9
2.5
2
1.5
1
0.5
0
10^15
10^16
10^17
10^18
10^19
10^20
rad
R-G
AUG
1/τ s^-1
Δn cm^-3

1 3 (a) $WPE = \frac{S_{out}}{P_{in}} = \eta_V \cdot \eta_c \cdot \eta_{rad} \cdot \eta_{ext}$

2 $\eta_V = \frac{E_g}{qV_a} = \frac{1.42}{1.25} = 1.14$

2 $\eta_c = \frac{J_{active}}{J_D} = 0.9$

$\eta_{ext} = 0.5$

$\eta_{rad} = \frac{\frac{1}{\tau_{rad}}}{1/\tau_e}$

3 $\tau_{rad} = \frac{1}{B(p_0+\Delta n)}$ $\tau_e = \frac{1}{A}$ $\tau_{Ag} =$

$\eta_{rad} = 0.66$

$\therefore$ $WPE = 1.14 \times 0.9 \times 0.5 \times 0.66 = \underline{33.9\ \%}$

4 (b) Luminous $\eta = \frac{\Phi}{I_D V_D}$ $\Phi = 683\ \gamma\ S_{out}$

≈ 0

3(b) cont. For monochromatic light $\Phi = 683 \, \gamma \, S_{out}$

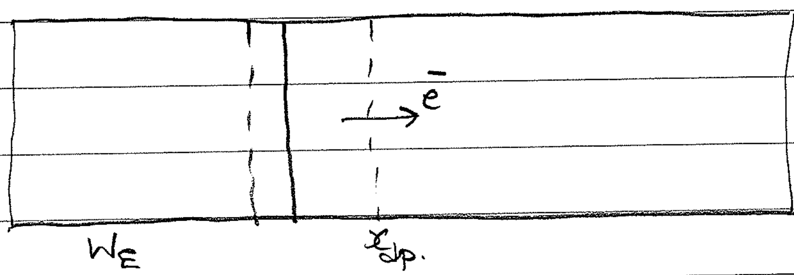
For GaAs, $E_g = 1.42$ eV $= \frac{hc}{\lambda}$

$$\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.42 \times 1.6 \times 10^{-19}} = \frac{1.24 \times 10^{-6}}{1.42} = 875 \text{ nm}$$

From Fig. 8.7, $\gamma \approx 0$

$\therefore$ Luminous $\eta \approx 0$

4 a)



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6

$$I_0 = I_{0h} + I_{0e}$$

$$I_{0e} = -q A n_{op} \frac{D_e}{L_e}$$ Ideal diode (6.37).

$$I_{0h} = -q A p_{on} \frac{D_h}{L_h} \coth \frac{W_E}{L_h}$$ (Assignment 2, Q4)

$$\rightarrow -q A p_{on} \frac{D_h}{L_h} \cdot \frac{L_h}{W_E}$$ $W_E \ll L_e$ (Mid-term)

$$= -q A p_{on} \frac{D_h}{W_E}$$

$$\therefore I_0 = -q A \left[n_{op} \frac{D_e}{L_e} + p_{on} \frac{D_h}{W_E} \right].$$

4b) $N_D = 10^{19}\ cm^{-3}$, $N_A = 10^{16}\ cm^{-3}$

$\mu_h = 65\ cm^2 V^{-1} s^{-1}$ $\quad \tau_h = \dfrac{5 \times 10^{-7}}{1 + 200} = 2.5 \times 10^{-9}\ s.$

$D_h = \dfrac{kT}{q} \mu_h = 1.68\ cm^2 s^{-1}$

$L_h = \sqrt{D_h \tau_h} = 6.48 \times 10^{-5}\ cm = 648\ nm$

$W_E = 100\ nm$

$\mu_e = 1258\ cm^2 V^{-1} s^{-1}$ $\quad D_e = 32.6\ cm^2 s^{-1}$ $\quad \tau_e = \dfrac{5 \times 10^{-7}}{1 + 2 \times 10^{16} \times 10^{-17}}$

$= 4.17 \times 10^{-7}\ s.$

~~4~~ 2

$L_e = 3.69 \times 10^{-3}\ cm.$

$p_{on} = \dfrac{(9.5 \times 10^9)^2}{10^{19}} = 9.025\ cm^{-3}$ $\quad n_{op} = 9.025 \times 10^3$

$$\therefore\ I_o = -q\, 100 \left[\frac{9.025 \times 10^3 \times 32.6}{3.69 \times 10^{-3}} + \frac{9.025 \times 1.68}{100 \times 10^{-7}} \right]$$

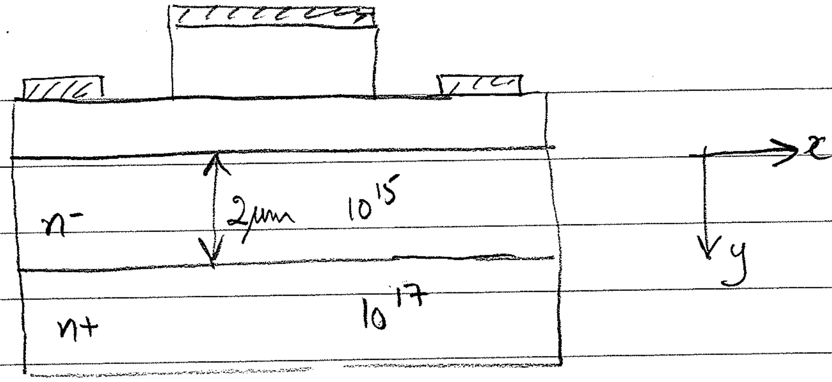
$$= -1.6 \times 10^{-17} \left[7.97 \times 10^7 + 1.516 \times 10^6 \right]$$

$$= \underline{1.3 \times 10^{-9}\ A}$$

2 c) $V_{oc} = V_t \ln \left(\dfrac{I_{ph} + I_o}{I_o} \right) \approx V_t \ln \dfrac{I_{ph}}{I_o} = \underline{0.57\ V}.$

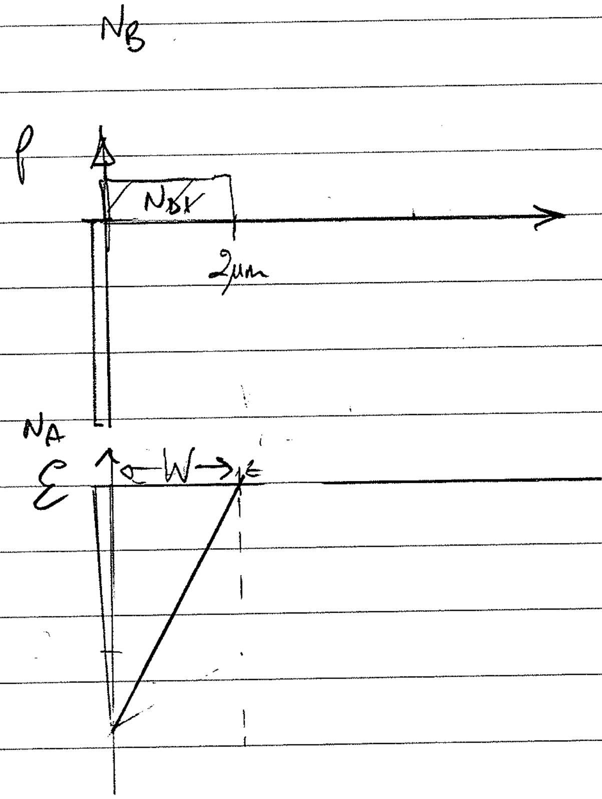
2 d) $\dfrac{I_{ph} V_{oc} FF}{S.A} = \eta$ $\quad FF = \dfrac{100 \times 10^{-3} \times 100 \times 0.2}{4 \times 0.57} = \underline{0.877}$

5(a)



2,2 (i) High BDV, low R_C

(ii)



$$W = \sqrt{\frac{2\varepsilon_s}{q}\left(V_{bi} - V_a\right)\left(\frac{1}{N_B} + \frac{1}{N_C}\right)}.$$

Assume all of W in the collector

Assume $|-V_a| \gg V_{bi}$

$$\therefore \; -V_a = V_{BC} = \frac{W^2 q}{2\varepsilon_s} \frac{1}{1/N_C}$$

b(i) cont

3 $$V_{BC} = \frac{4\times10^{-12} \qquad 10^{22}}{2\times12.9\times8.85\times10^{-12}} \times 1.6\times10^{-19} = 28\,V$$

b(ii) $$\mathcal{E} = -d\psi/dx \quad \rightarrow \quad -d\psi = \int \mathcal{E}\,dx$$

$$28 = \frac{1}{2}\,\mathcal{E}_{max}\cdot W$$

$$\mathcal{E}_{max} = \frac{56}{2\times10^{-6}} = 28\ V/\mu m$$

$$= 28\times10^{-6}\ MV/\mu m$$

1 2 $$= 28\times10^{-6}\times10^{4}\ MV/cm.$$

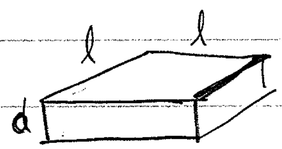
$$= \underline{0.28\ MV/cm}$$

Nearly breaks down!

c) $$f_T = \frac{g_m}{C_\pi + C_\mu\left(1+g_m(R_e+R_c)\right)} \qquad (14.16)$$

$$g_m = \frac{I_e}{V_{th}}, \qquad I_e \propto A$$

$$C_\pi \propto A, \qquad C_\mu \propto A, \qquad R_e \propto \frac{1}{A}$$

4 $$R_c \propto \frac{\rho l}{a}$$ 

$$= \rho\frac{l}{ld}$$ i.e. doesn't scale

$$\therefore \text{New } f_T = \frac{g_m A}{\left[C_\pi A + C_\mu A\left(1+g_m A\left(\frac{R_e}{A}+R_c\right)\right)\right]} = \frac{g_m}{C_\pi + C_\mu\left(1+g_m(R_e+R_c A)\right)}$$

$A = 1/4 \therefore$ new f_T higher.