Solutions

HW #10

ECE - 606, Fall 2012

Q1

$$W = \sqrt{\frac{2\varepsilon_s \phi_s}{q N_A}}$$

Substituting known values

$$\phi_s = \frac{q N_A W^2}{2\varepsilon_s} = \underline{0.1914\ V}$$

6/2

16.12

(a) $\boxed{\text{Curves } a \text{ and } b}$ are standard low- and high-frequency C–V curves that result when the semiconductor component of the MOS-C is in equilibrium under d.c. biasing conditions. Curve c is a nonequilibrium deep-depletion characteristic.

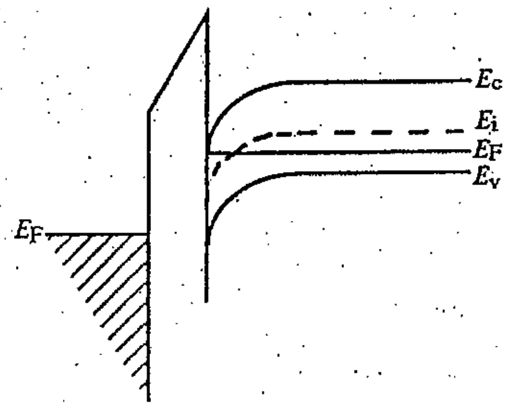
(b) In accumulation $C \rightarrow C_O = K_O \varepsilon_0 A_G / x_o$. Since both devices exhibit the same capacitance in accumulation, the two devices have the same oxide thickness. With x_o being the same, the lower capacitance of device b in inversion indicates this device has a lower doping. (W_T increases with decreasing doping, thereby giving rise to a smaller capacitance; also see Fig. 16.14b.)

6b

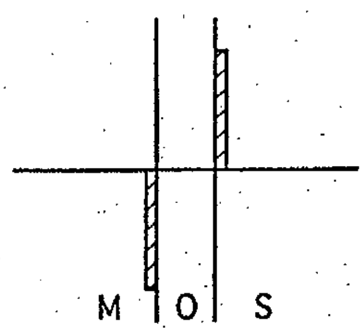
16.13

(a) $\boxed{p\text{-type}}$ ...For p-type devices accumulation (C_{max}) occurs for negative V_G and inversion (C_{min}) occurs at positive V_G. The exact opposite is true for n-type devices.

(b) At point (2) the p-type MOS-C is far into inversion. Thus



(c) At point (1) the MOS-C is clearly deep into accumulation.



(d) From Fig. P16.13, $C_{max} = 100$pF. However,

$$C_{max} = C_O = \frac{K_O\varepsilon_0 A_G}{x_o}$$

$$x_o = \frac{K_O\varepsilon_0 A_G}{C_{max}} = \frac{(3.9)(8.85\times10^{-14})(3\times10^{-3})}{(10^{-10})} = \mathbf{0.104\mu m}$$

(e) In the delta-depletion formulation

$$C = \frac{C_O}{1+\dfrac{K_O W_T}{K_S x_o}} \quad \text{inv } (\omega\to\infty) \qquad (16.34d)$$

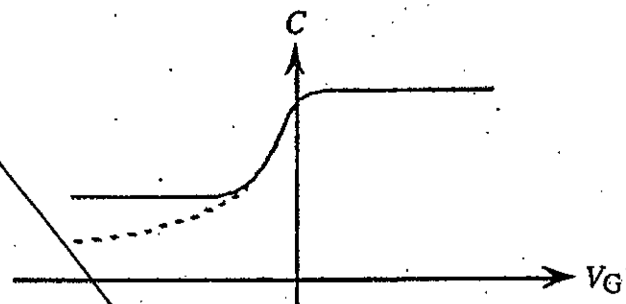
Thus

$$W_T = \frac{K_S x_o}{K_O}\left(\frac{C_O}{C}-1\right) = \frac{(11.8)(0.104)}{(3.9)}\left(\frac{100}{20}-1\right) = \mathbf{1.26\mu m}$$

Employing Fig. 16.9, we conclude $N_A \cong 5\times10^{14}/\text{cm}^3$.

16.14

(a)



(b) $C_{MAX} = C_O = \frac{K_O\varepsilon_0 A_G}{x_o} = \frac{(3.9)(8.85\times10^{-14})(10^{-3})}{10^{-5}} = \mathbf{34.5\ pF}$

(c) $\phi_F = -(kT/q)\ln(N_D/n_i) = -0.0259\ln(2\times10^{15}/10^{10}) = -0.316$

$$W_T = \left[\frac{2K_S\varepsilon_0}{qN_D}(-2\phi_F)\right]^{1/2} = \left[\frac{(2)(11.8)(8.85\times10^{-14})(2)(0.316)}{(1.6\times10^{-19})(2\times10^{15})}\right]^{1/2} = 6.42\times10^{-5}\text{ cm}$$

Q4 Short channel MOSFET.

1) V_{th} reduction, the gate no longer controls the total gate depletion.

2) Mobility reduction

3) High electric fields imply
   a) Carrier velocity saturation
   b) Gate oxide charging
   c) Impact ionization near the drain.

4) Punch through

5) Channel length modulation.

Q5 $\phi_B = V_T \ln(N_A/n_i) = 0.35\ V$

$\phi_s = \chi_s + \frac{E_g}{2q} + \phi_B = 4.95V$

Q6 Hole concentration: $p = p_0 \exp(-\psi_s/V_T) = 2.1 \times 10^{14}\ cm^{-3}$

Electron " $= \frac{n_i^2}{p_0} \exp(\psi_s/V_T) = \cancel{1.6 \times 10^6}\ 10^6\ cm^{-3}$

Q7 Max depletion: $W_{max} = \sqrt{\frac{2\varepsilon_s (2\phi_B)}{q N_A}} = 0.304\ \mu m$

(We have used $\phi_B = 0.35V$ from Q5)

To compute V_{th}

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = 3.45 \times 10^{-8}\ F/cm^2$$

$$\psi_{ox} = \frac{q N_A W_{max}}{C_{ox}} = 1.41V$$

$$V_{th} = \psi_{ox} + \psi_s = 1.41 + 0.7 = 2.11V$$

(Also $\psi_s = 2\phi_B$)

$\therefore \psi_s = 0.7$

— X —