

- 10.2 (a) Calculate the maximum space charge width x_{dT} and the maximum space charge density $|Q'_{SD}(\max)|$ in a MOS capacitor with a p-type silicon substrate at $T = 300$ K for doping concentrations of (i) $N_a = 7 \times 10^{15} \text{ cm}^{-3}$ and (ii) $N_a = 3 \times 10^{16} \text{ cm}^{-3}$.

➤ Also, find ϕ_{fp} .

$$V_t = \frac{k_B T}{e} = \frac{8.617333 \times 10^{-5} \text{ eV/K} (300 \text{ K})}{e} = 0.025852 \text{ V}$$

From Table B.4, $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$ for Si @ 300 K
 $\epsilon_s = 11.7 \epsilon_0$

a) (i) $N_a = 7 \times 10^{15} \text{ cm}^{-3} = 7 \times 10^{21} \text{ m}^{-3}$

Per (10.4), $\phi_{sp} = V_t \ln\left(\frac{N_a}{n_i}\right) = 0.025852 \ln\left(\frac{7 \times 10^{15}}{1.5 \times 10^{10}}\right)$

$$\phi_{sp} = 0.337456 \text{ V}$$

Per (10.6), $x_{dT} = \left(\frac{4 \epsilon_s \phi_{sp}}{e N_a}\right)^{1/2}$

$$= \left(\frac{4(11.7) 8.8541878 \times 10^{-12} (0.337456)}{1.6021766 \times 10^{-19} (7 \times 10^{21})}\right)^{1/2}$$

$$x_{dT} = 3.53103 \times 10^{-7} \text{ m} = 0.353 \text{ } \mu\text{m}$$

Per (10.27), $|Q'_{SD}(\max)| = e N_a x_{dT} = 1.6022 \times 10^{-19} (7 \times 10^{21})$

$$= 1.6022 \times 10^{-19} (7 \times 10^{21}) 3.531 \times 10^{-6}$$

$$|Q'_{SD}(\max)| = 3.9601 \times 10^{-4} \text{ C/m}^2 = 3.96 \times 10^{-8} \text{ C/cm}^2$$

$$(ii) N_a = 3 \times 10^{16} \text{ cm}^{-3} = 3 \times 10^{22} \text{ m}^{-3}$$

$$\phi_{fp} = 0.025852 \ln \left(\frac{3 \times 10^{16}}{1.5 \times 10^{10}} \right)$$

$$\underline{\underline{\phi_{fp} = 0.375078 \text{ V}}}$$

$$X_{dT} = \left\{ \frac{4(11.7)8.8541878 \times 10^{-12} (0.375078)}{1.6021766 \times 10^{-19} (3 \times 10^{22})} \right\}^{1/2}$$

$$\underline{\underline{X_{dT} = 1.79822 \times 10^{-7} \text{ m} = 0.1798 \mu\text{m}}}$$

$$|Q_{SD}'(\text{max})| = 1.6021766 \times 10^{-19} (3 \times 10^{22}) 1.79822 \times 10^{-7}$$

$$\underline{\underline{|Q_{SD}'(\text{max})| = 8.6432 \times 10^{-4} \text{ C/m}^2 = 8.6432 \times 10^{-8} \text{ C/cm}^2}}$$