Solutions | HW #2

#1 given: $V_T = 0.5V$

when $V_{SB} = 0V \rightarrow N_A = 2e^{17}\ cm^{-3}$

$C_{ox} = 3.5\ fF/um^2$

Eq needed

① $V_{TO} = \phi_{ms} + 2\phi_F + \frac{\sqrt{2qN_A\varepsilon_{Si}|2\phi_F|}}{C_{ox}} - \frac{Q_{ox}}{C_{ox}}$

② $\phi_F = \frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right)$ ③ $C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$

④ $V_T = V_{TO} + \gamma\left(\sqrt{|2\phi_F - V_{BS}|} - \sqrt{|2\phi_F|}\right)$

⑤ $\gamma = \frac{\sqrt{2qN_A\varepsilon_{Si}}}{C_{ox}}$

(a) This is determined by the body effect in MOSFET, where bulk is at a different potential than the source. For NMOS (this case $V_{SB} > 0$).

This equation is given by ④

$$\boxed{V_T = V_{TO} + \gamma\left(\sqrt{|2\phi_F - V_{BS}|} - \sqrt{|2\phi_F|}\right)}$$

(b) $V_T = 1V$ (desired) @ $V_S = 0V$

Using eq in part (a) we calc for V_{BS}.

First calc for V_{TO}, ϕ_F and other variables

$V_{TO} = 0.5V$, given

$$\gamma = \frac{\sqrt{2q N_A \varepsilon_{Si}}}{C_{ox}} = 0.736$$

$q = 1.6 \times 10^{-19}$ C

$N_A = 2 \times 10^{17}$

$\varepsilon_{Si} = 11.7 \times 8.85 \times 10^{-14}$ F/cm

$C_{ox} = 3.5 \times 10^{-7}$ F/cm^2

$$2\phi_F = 2\left[\frac{kT}{q} \ln\left(\frac{N_A}{n_i}\right)\right] = 2\left[0.0259 \ln\left(\frac{2\times10^{17}}{10^{10}}\right)\right]$$

$n_{i_{Si}} = 10^{10}$ @ 300K

$2\phi_F = 0.870$

$\Rightarrow$ Sub into eq (4)

$$|V| = 0.5 + 0.736\left(\sqrt{|0.870 - V_{BS}|} - \sqrt{|0.870|}\right)$$

$V_{BS} = -1.73$ or ~~3.47V~~

$$V_X = V_B = -1.73V$$

(c)

$$V_T = \frac{Q}{C_{ox}} - V_{TO} \Rightarrow 0.5V = \frac{Q'}{C_{ox}}$$

$Q' = 0.5 \times 3.5\,f$ F/um^2 $= 1.75\,V_f$ F/um^2

$$Q' = qN_A \Rightarrow N_A = Q'/q = \frac{1.75\,V_f \text{ F/um}^2}{1.6 \times 10^{-19}}$$

$$\boxed{N_{A\ \text{acceptor}} = 1.09 \times 10^{+12}\ \text{cm}^{-3}}$$