6

6.1

Assume the JFET shown in Fig. 6-6 is Si and has p^+ regions doped with 10^{18} acceptors/cm^3 and a channel with 10^{16} donors/cm^3. If the channel half-width a is $1\ \mu m$, compare V_P with V_0. What voltage V_{GD} is required to cause pinch-off when V_0 is included? With $V_G = -3V$, at which value of V_D does the current saturate?

✓ Answer

$V_0 = \frac{kT}{q} \ln\left(\frac{N_a N_d}{n_i^2}\right) = 0.0259 \ln\left(\frac{10^{18}10^{16}}{1.5\times10^{20}}\right) = 0.8244\ V$

$a = \sqrt{\frac{2\epsilon(V_P)}{q}\left(\frac{N_a+N_d}{N_a N_d}\right)}$

$\frac{qa^2}{2\epsilon}\left(\frac{N_a N_d}{N_a+N_d}\right) = V_P = \frac{1.6\times10^{-19}(10^{-4})^2}{2(8.85\times10^{-14})(11.8)}\frac{10^{18}10^{16}}{10^{18}+10^{16}} = 7.585\ V$

$V_P \gg V_0$

$V_{GD} = V_P - V_0 = 6.76\ V$

$V_D = V_G + V_{GD} = 3.76\ V$

6.10

Find the maximum depletion width, minimum capacitance C_{min}, and threshold voltage for an ideal MOS capacitor with a $10\ nm$ gate oxide (SiO_2) on p-type Si with $N_a = 10^{16}\ \text{cm}^{-3}$. Next, include the effects of flat band voltage, assuming an n^+ polysilicon gate and fixed oxide charge of $5\times10^{10}\ a(\frac{C}{\text{cm}^2})$.

✓ Answer

$\phi_s = \frac{2kT}{q} \ln\left(\frac{N_a}{n_i}\right) = 2(0.0259) \ln\left(\frac{10^{16}}{1.5\times10^{10}}\right) = 0.6946\ V$

$W_{min} = W\Big|_{V_0 - V = \phi_s} = \sqrt{\frac{2\epsilon\phi_s}{q}\left(\frac{N_a+N_d}{N_a N_d}\right)} = \sqrt{\frac{2(8.85\times10^{-14})(11.8)(0.6946)}{1.6\times10^{-19}(10^{16})}} = 0.301\ \mu m$

$C_i = \frac{\epsilon_i}{d} = \frac{8.85\times10^{-14}(3.9)}{10^{-6}} = 3.315\times10^{-7}\ \frac{F}{cm^{-2}}$

$C_d = \frac{\epsilon_s}{W_{min}} = \frac{8.85\times10^{-14}(11.8)}{3.01\times10^{-5}} = 3.33\times10^{-8}\ \frac{F}{cm^2}$

$C_{min} = \frac{C_i C_d}{C_i + C_d} = 3.028\times10^{-8}\ \frac{F}{cm^2}$

$V_{FB} = \phi_{ms} - \frac{Q_i}{C_i} = -\frac{E_g}{2} + \phi_F - \frac{Q_i}{C_i} = -\frac{1.12}{2} + 0.3473 - \frac{5\times10^{10}\times1.6\times10^{-19}}{3.315\times10^{-7}} = -0.237\ V$

$Q_d = -2(\epsilon_s q N_a \phi_F)^{1/2} = -2((8.85\times10^{-14})(11.8)1.60\times10^{-19}10^{16}0.3473)^{1/2}$

$= -4.818\times10^{-8}$

$$V_T = V_{FB} - \frac{Q_d}{C_i} + \Phi_s = -0.237 - \frac{-4.818\times10^{-8}}{3.315\times10^{-7}} + \Phi_s = 4.548\ V$$