UNIVERSITY OF CALIFORNIA, SANTA BARBARA

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ECE 137A WINTER 2009 Instructor: Luke Theogarajan

HOMEWORK ASSIGNMENT #1 SOLUTION

3.1

$$\phi_j = V_T \ln\frac{N_A N_D}{n_i^2} = (0.025V)\ln\frac{(10^{19}\cdot cm^{-3})(10^{18}\cdot cm^{-3})}{10^{20}\cdot cm^{-6}} = 0.979V$$

$$w_{do} = \sqrt{\frac{2\varepsilon_s}{q}\left(\frac{1}{N_A}+\frac{1}{N_D}\right)\phi_j} = \sqrt{\frac{2(11.7\cdot 8.854x10^{-14}F\cdot cm^{-1})}{1.602x10^{-19}C}\left(\frac{1}{10^{19}cm^{-3}}+\frac{1}{10^{18}cm^{-3}}\right)(0.979\text{V})}$$

$$\text{w}_{\text{do}} = 3.73\ x\ 10^{-6}cm = 0.0373\mu m$$

$$x_n = \frac{w_{do}}{1+\frac{N_D}{N_A}} = \frac{0.0373\mu m}{1+\frac{10^{18}cm^{-3}}{10^{19}cm^{-3}}} = 0.0339\ \mu\text{m} \ \ | \ \ x_p = \frac{w_{do}}{1+\frac{N_A}{N_D}} = \frac{0.0373\mu m}{1+\frac{10^{19}cm^{-3}}{10^{18}cm^{-3}}} = 3.39\ \text{x}\ 10^{-3}\ \mu\text{m}$$

$$\text{E}_{\text{MAX}} = \frac{qN_A x_p}{\varepsilon_s} = \frac{(1.60x10^{-19}C)(10^{19}cm^{-3})(3.39x10^{-7}cm)}{11.7\cdot 8.854x10^{-14}F/cm} = 5.24\ \text{x}\ 10^5\frac{V}{cm}$$

3.6

$$w_d = w_{do}\sqrt{1+\frac{V_R}{\phi_j}}\ \ |\ \ \text{(a)}\ w_d = 2w_{do}\ \text{requires}\ \text{V}_\text{R} = 3\phi_j = 2.55\ V\ \ |\ \ w_d = 0.4\mu m\sqrt{1+\frac{5}{0.85}} = 1.05\ \mu\text{m}$$

3.12

$$j_p = q\mu_p pE - qD_p\frac{dp}{dx} = 0 \rightarrow E = -\left(\frac{D_p}{\mu_p}\right)\frac{1}{p}\frac{dp}{dx} = -\left(\frac{kT}{q}\right)\frac{1}{p}\frac{dp}{dx}$$

$$p(x) = N_o\exp\left(-\frac{x}{L}\right)\ \ |\ \ \frac{1}{p}\frac{dp}{dx} = \frac{1}{L}\ \ |\ \ \text{E} = -\frac{V_T}{L} = -\frac{0.025V}{10^{-4}cm} = -250\frac{V}{cm}$$

The exponential doping results in a constant electric field.

3.13

$$j_p = qD_n \frac{dn}{dx} = q\mu_n V_T \frac{dn}{dx} \quad | \quad \frac{dn}{dx} = \frac{2000 A/cm^2}{\left(1.60x10^{-19} C\right)\left(500 cm^2/V-s\right)\left(0.025V\right)} = \frac{1.00\ x\ 10^{21}}{cm^4}$$

3.34

$$\frac{dv_D}{dT} = \frac{v_D - V_G - 3V_T}{T} = \frac{0.7 - 1.21 - 3(0.0259)}{300} = -1.96 \frac{mV}{K}$$

3.37

$$\phi_j = V_T \ln \frac{N_A N_D}{n_i^2} = (0.025V) \ln \frac{\left(10^{16} cm^{-3}\right)\left(10^{15} cm^{-3}\right)}{10^{20} cm^{-6}} = 0.633\ V$$

$$w_{do} = \sqrt{\frac{2\varepsilon_s}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)\phi_j} = \sqrt{\frac{2\left(11.7 \cdot 8.854x10^{-14} F \cdot cm^{-1}\right)}{1.602x10^{-19} C}\left(\frac{1}{10^{16} cm^{-3}} + \frac{1}{10^{15} cm^{-3}}\right)(0.633\text{V})}$$

$$w_{do} = 0.949\ \mu m \quad | \quad w_d = w_{do}\sqrt{1 + \frac{V_R}{\phi_j}}$$

$$w_d = 0.949 \mu m \sqrt{1 + \frac{10V}{0.633V}} = 3.89\ \mu\text{m} \quad | \quad w_d = 0.949 \mu m \sqrt{1 + \frac{100V}{0.633V}} = 12.0\ \mu\text{m}$$

3.39

$$E_{\max} = \frac{2\left(\phi_j + V_R\right)}{w_d} = \frac{2\left(\phi_j + V_R\right)}{w_{do}\sqrt{1 + \frac{V_R}{\phi_j}}} = \frac{2\phi_j}{w_{do}}\sqrt{1 + \frac{V_R}{\phi_j}}$$

$$3x10^5 \frac{V}{cm} = \frac{2(0.6V)}{10^{-4} cm}\sqrt{1 + \frac{V_R}{0.6}} \rightarrow V_R = 374\ V$$