EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 7 (Spring 2025)

Name Key A

Instructions: Open book/notes. Place answers in indicated spaces and **show all** work for credit. Carry *at least* **6** significant figures on constants/parameters in calculations. Give answers with **4-5** significant figures.

A wafer of gallium arsenide (GaAs) has an intrinsic carrier concentration of 1.93×10^8 #/cm^3 and bandgap of 1.4 eV at **350 K**. A pn junction is created on the wafer with uniform doping concentrations of 5×10^{16} cm^{-3} acceptor atoms on p side and 8×10^{16} #/cm^3 donor atoms on n side. Find the thermal voltage and built-in potential. Next, determine the depletion layer width W (m), maximum electric field magnitude $|E_{max}|$ (V/m), and junction capacitance C (F) ($\varepsilon_s = 13\varepsilon_0$, pn junction has a cross-sectional area of 0.1 mm × 40 μm).

Per (7.10), $V_{bi} = \frac{kT}{e}\ln\left(\frac{N_a N_d}{n_i^2}\right) = V_t \ln\left(\frac{N_a N_d}{n_i^2}\right)$

$V_t = \frac{8.617333\times10^{-5}\ \frac{eV}{K}\,(350K)}{e} = 0.0301607\ V$

$V_{bi} = 0.0301607 \ln\left(\frac{5\times10^{16}(8\times10^{16})}{(1.93\times10^8)^2}\right) = 1.18275655\ V$

(7.31) $W = \left\{\frac{2\varepsilon_s V_{bi}}{e}\left(\frac{N_a + N_d}{N_a N_d}\right)\right\}^{1/2}$ ← use MKS!

$W = \left\{\frac{2(13)8.8541878\times10^{-12}(1.18275655)}{1.602176634\times10^{-19}}\left(\frac{5\times10^{22}+8\times10^{22}}{5\times10^{22}(8\times10^{22})}\right)\right\}^{1/2}$

$W = 2.350148\times10^{-7}\ m = 235.015\ nm$

(7.37) $E_{max} = \frac{-2V_{bi}}{W} \Rightarrow |E_{max}| = \frac{2(1.18276)}{2.35\times10^{-7}} = 1.006538\times10^7\ \frac{V}{m}$

(7.43) $C' = \varepsilon_s/W = \frac{13(8.8542\times10^{-12})}{2.35015\times10^{-7}} = 4.89775\times10^{-4}\ F/m^2$

$C = C'A = 4.89775\times10^{-4}(0.1\times10^{-3})(40\times10^{-6})$

$C = 1.9591\times10^{-12}\ F$

thermal voltage = 0.030161 V built-in potential = 1.18276 V

W = 235.015 nm $|E_{max}|$ = 10.0654 MV/m C = 1.9591 pF

EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 7 (Spring 2025)

Name Key B

Instructions: Open book/notes. Place answers in indicated spaces and **show all** work for credit. Carry *at least* **6** significant figures on constants/parameters in calculations. Give answers with **4-5** significant figures.

A wafer of gallium arsenide (GaAs) has an intrinsic carrier concentration of 8.51×10^8 #/cm^3 and bandgap of 1.4 eV at **370 K**. A pn junction is created on the wafer with uniform doping concentrations of 9×10^{16} #/cm^3 acceptor atoms on p side and 6×10^{16} #/cm^3 donor atoms on n side. Find the thermal voltage and built-in potential. Next, determine the depletion layer width W (m), maximum electric field magnitude $|E_{max}|$ (V/m), and junction capacitance C (F) ($\varepsilon_s = 12.9\varepsilon_0$, pn junction has a cross-sectional area of 0.8 mm × 60 μm).

(7.10) $V_{bi} = \frac{k_B T}{e} \ln\left(\frac{N_a N_d}{n_i^2}\right) = V_t \ln\left(\frac{N_a N_d}{n_i^2}\right)$

$V_t = \frac{8.617333\times10^{-5}\ \frac{eV}{K}\,(370K)}{e} = 0.0318841\ V$

$V_{bi} = 0.031884 \ln\left(\frac{9\times10^{16}(6\times10^{16})}{(8.51\times10^8)^2}\right) = 1.165297\ V$

(7.31) $W = \left\{\frac{2\varepsilon_s V_{bi}}{e}\left(\frac{N_a+N_d}{N_a N_d}\right)\right\}^{1/2}$ ← use MKS!

$W = \left\{\frac{2(12.9)8.8541878\times10^{-12}(1.1653)}{1.602176634\times10^{-19}}\left(\frac{9\times10^{22}+6\times10^{22}}{9\times10^{22}(6\times10^{22})}\right)\right\}^{1/2}$

$W = 2.148306\times10^{-7}\ m = 214.831\ nm$

(7.37) $E_{max} = \frac{-2V_{bi}}{W} \Rightarrow |E_{max}| = \frac{2(1.1653)}{214.831\times10^{-9}} = 1.08485\times10^7\ \frac{V}{m}$

(7.43) $C' = \frac{\varepsilon_s}{W} = \frac{12.9(8.8542\times10^{-12})}{2.148306\times10^{-7}} = 5.3167\times10^{-4}\ F/m^2$

$C = C'A = 5.3167\times10^{-4}(0.8\times10^{-3})(60\times10^{-6})$

$C = 2.55202\times10^{-11}\ F = 25.5202\ pF$

thermal voltage = 0.031884 V built-in potential = 1.1653 V

W = 214.831 nm $|E_{max}|$ = 10.8485 MV/m C = 25.5202 pF