4

4.23

A recently discovered semiconductor has $N_c = 10^{19}\ cm^{-3}$, $N_v = 5 \times 10^{18}\ cm^{-3}$, and $E_g = 2\ eV$. If it is doped with 10^{17} donors (fully ionized), calculate the electron, hole, and intrinsic carrier concentrations at $627^{\circ}C$. Sketch the simplified If band diagram, and specify the value of E_F and E_i with respect to the band edges. If we apply $5\ V$ across a piece of this semiconductor $8\ \mu m$ long, what is the current? The piece is $2\ \mu m$ wide and $1.5\ \mu m$ thick. The diffusion coefficient of holes and electrons is $25\ cm^2/s$ and $75\ cm^2/s$, respectively.

Answer

$n_i = \sqrt{N_c N_v} e^{-E_g/2kT}$
$n_i = 1.784 \times 10^{13}\ cm^{-3}$

$n_0 \approx 10^{17}$
$n_0 p_0 = n_i^2$
$p = \frac{n_i^2}{n}$
$p = 3.18 \times 10^9$

$n_0 = n_i e^{(E_F - E_i)/kT}$
$E_F - E_i = 0.6696\ eV$
Where E_i is the center of the edges of the band

$J = q(p\mu_p + n\mu_n)\varepsilon$
$J = \frac{q}{kT}(pD_p + nD_n)\frac{E}{L}$
$J = 96674\ \frac{A}{cm^2}$
$I = JA = 2.9\ mA$

5.9

An abrupt Si junction (area = $0.0001\ cm^2$) has the following parameters:

n-side: $N_d = 5 \times 10^{17}\ cm^{-3}$
p-side: $N_a = 10^{17}\ cm^{-3}$

Draw and label the band diagram, and calculate the difference between the Fermi level and the intrinsic Fermi level on both sides. Calculate the built-in potential at the junction in equilibrium and the depletion width. What is the total number of exposed acceptors in the depletion region?

✓ **Answer**

$n_i = 1.5 \times 10^{10}\ cm^{-3}$

On the n-side

$n_0 = n_i e^{(E_F - E_i)/kT}$

$E_F - E_i = 0.4486\ eV$

On the p-side

$p_0 = n_i e^{(E_i - E_F)/kT}$

$E_i - E_F = 0.4070\ eV$

$V_0 = \frac{kT}{q} \ln\left(\frac{N_a N_d}{n_i^2}\right)$

$V_0 = 0.8556\ V$

$W = \sqrt{\frac{2\epsilon V_0}{q}\left(\frac{N_a + N_d}{N_a N_d}\right)}$

$W = 1.1577 \times 10^{-5}\ cm$

$x_{p0} = W \frac{N_d}{N_a + N_d}$

$x_{p0} = 9.65 \times 10^{-6}$

5.15

Boron is implanted into an n-type Si sample ($N_d = 10^{16}\ cm^{-3}$), forming an abrupt junction of square cross section with area $= 2 \times 10^{-3}\ cm^2$. Assume that the acceptor concentration in the p-type region is $N_a = 4 \times 10^{18}\ cm^{-3}$. Calculate V_0, x_{n0}, x_{p0}, Q_+, and E_0 for this junction at equilibrium (300 K). Sketch ε and the charge density to scale, as in Fig. 5–12.

✓ **Answer**

$A = 2 \times 10^{-3}\ cm^2$

$N_d = 10^{16}\ cm^{-3}$

$N_a = 4 \times 10^{18}\ cm^{-3}$

$V_0 = \frac{kT}{q} \ln\left(\frac{N_a N_d}{n_i^2}\right)$
$V_0 = 0.8498\ V$

$W = \sqrt{\frac{2\epsilon V_0}{q}\left(\frac{N_a + N_d}{N_a N_d}\right)}$
$W = 3.335 \times 10^{-5}\ cm$

$x_{n0} = W \frac{N_a}{N_a + N_d}$
$x_{n0} = 3.327 \times 10^{-5}$

$x_{p0} = W \frac{N_d}{N_a + N_d}$
$x_{p0} = 8.316 \times 10^{-8}$

$Q_+ = qAx_{n0}N_d = qAx_{p0}N_a$
$Q_+ = 1.06 \times 10^{-10}$

$\varepsilon_0 = -\frac{q}{\varepsilon} x_{n0} N_d$
$\varepsilon_0 = -50966\ \frac{V}{cm}$