Assignment 5: *pn* junctions

1. A Si pn junction of 1 cm^2 area consists of a n region with 10^{17} $donors\ cm^{-3}$ and a p region with 2×10^{17} $acceptors\ cm^{-3}$. Calculate the

   (a) Built-in potential

   (b) Total depletion width

   (c) Depletion widths on the p and n sides.

   The junction is in equilibrium.

2. A pn junction diode has a concentration of 10^{16} $acceptor\ atoms\ cm^{-3}$ on the p-side and 10^{17} $donor\ atoms\ cm^{-3}$ on the n side. What will be the built-in potential for the semiconducting materials Ge, Si, and GaAs?

Semiconductor	E_g (eV)	n_i (cm^{-3})
Ge	0.7	2.40×10^{13}
Si	1.1	1.0×10^{10}
GaAs	1.4	2.10×10^{6}

3. A Si abrupt junction in equilibrium at $T = 300\ K$ is doped such that $E_c E_F = 0.21\ eV$ in the n region and $E_F E_v = 0.18\ eV$ in the p region. Take $n_i = 10^{10}\ cm^{-3}$, $E_g = 1.10\ eV$, and $E_{Fi} = 0.55\ eV$.

   (a) Draw the energy band diagram of the junction.

   (b) Determine the impurity doping concentrations in each region.

   (c) Determine the built-in potential.

4. An abrupt np^+ junction diode has a cross sectional area of 1 mm^2, an acceptor concentration of 5×10^{18} boron $atoms\ cm^{-3}$ on the p-side and a donor concentration of 10^{16} arsenic $atoms\ cm^{-3}$ on the n-side. The lifetime of holes in the n-region is 417 ns, whereas that of electrons in

the p-region is only 5 ns. Mean thermal generation lifetime is 1 μs. $\mu_e = 120\ cm^2V^{-1}s^{-1}$, $\mu_h = 44\ cm^2V^{-1}s^{-1}$, $E_g = 1.1\ eV$. The length of the p and n regions are 5 and 100 μm respectively.

(a) Calculate the minority diffusion lengths and determine what type of diode this is.

(b) What is the built-in potential across the junction?

(c) What is the current when there is a forward bias of 0.6 V across the diode? Take $T = 300\ K$.

(d) Estimate the forward current at 373 K when the voltage across the diode remains at 0.6 V. Assume temperature dependence of n_i dominates D,L, and μ.

(e) What is the reverse current when the diode is reverse biased by a voltage $V_r = 5\ V$?

5. A Ge p^+n diode at $T = 300\ K$ has the following parameters: $N_A = 10^{18}\ cm^{-3}$, $N_D = 10^{16}\ cm^{-3}$, $D_h = 49\ cm^2s^{-1}$, $D_e = 100\ cm^2s^{-1}$, $\tau_h = \tau_e = 5\mu s$, and $A = 10^{-4}\ cm^2$. Determine the diode current for a forward bias voltage of 0.2 V. Take $n_i = 2.4 \times 10^{13}\ cm^{-3}$.