Ch. 2

1. Dependence of intrinsic carrier concentration on the temperature:

Let us consider silicon and germanium, both doped with 10^{15} cm^{-3} p-type dopants.

(a) Calculate the temperature at which the intrinsic carrier concentration in silicon is equal to the doping concentration.

(b) Repeat (a) for germanium.

(c) From the above result, explain why silicon is a better material than germanium for high temperature operation.

2. Depletion approximation in a p-n junction:

Why does the depletion approximation work well in a p-n junction? Explain without resorting to a mathematical equation.

3. Analysis of the transition region:

Let us consider the transition region near the edge of depletion region in a p-type semiconductor. In this region, the hole concentration, p, cannot be ignored, and the Poisson equation should be

$$\frac{d^2\psi}{dx^2} = \frac{e}{\varepsilon_s}\left[N_a - p\right]$$

The hole concentration is given as $p = N_a \exp\frac{-e\psi}{k_B T}$.

(a) Write down the Poisson equation by substituting the hole concentration into the Poisson equation.

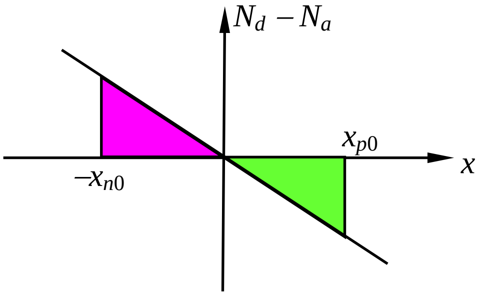
(b) Near the depletion edge, the hole concentration can be comparable to the acceptor concentration. Then, ψ should be sufficiently small ($\psi << k_B T/e$), so that we can approximate $\exp\frac{-e\psi}{k_B T}$ as $\left(1-\frac{e\psi}{k_B T}\right)$. Solve the Poisson equation with this approximation.

Assume the following boundary conditions:

$$\psi(0) = \psi_0,\ \psi(\infty) = 0$$

4. Linearly graded junction:

Let us consider a linearly graded p-n junction shown below. The doping distribution is described by the equation, $N_d - N_a = -ax$, and we assume that the depletion approximation is valid in this case.



(a) For charge neutrality, $x_{p0} = x_{n0} = W_d/2$, where W_d is the total depletion width. Express the built-in potential as a function of the total depletion width.

(b) Calculate the electric field as a function of position, x.

(c) Calculate the potential as a function of position, x. Assume that the potential is zero in the neutral p-region. Then, find the built-in potential as a function of the total depletion width again. This form should be different from the one in (a).

(d) Now, describe how we can find the total depletion width and the built-in potential by combining the results of (a) and (c).

5. Reverse current in a p-n junction:

(a) If we consider the ideal p-n junction current only, what is the main mechanism that generates the reverse current? Explain briefly.

(b) In a real silicon p-n junction diode, the reverse current at room temperature is mainly formed by the generation in the depletion region. In this case, how would the reverse current depend on the reverse bias voltage? Why?

(c) If we measure the reverse current vs. voltage characteristics at temperatures starting from 25^{o}C to 200^{o}C with a 25^{o}C step, what would the curves look like? Sketch them. If the characteristics change as a function of temperature, explain why it is the case.