Problem 1 (28%)

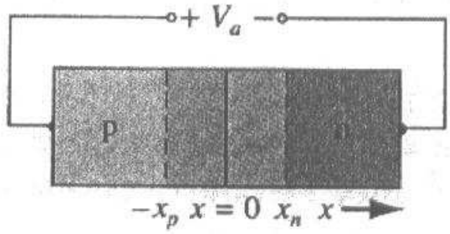
A silicon step junction has uniform impurity doping concentrations of $N_a = 5\times10^{15}$ cm^{-3} and $N_d = 1\times10^{15}$ cm^{-3}, and a cross-sectional area of $A = 1\times10^{-4}$ cm^2. Let $\tau_{n0} = 4\times10^{-7}$ s and $\tau_{p0} = 1\times10^{-7}$ s. Consider the geometry shown below and answer the following questions.

(a) Calculate the ideal reverse saturation current due to holes. (7%)

(b) Calculate the ideal reverse saturation current due to electrons. (7%)

(c) Calculate the hole concentration at x_n if $V_a = \frac{1}{2}V_{bi}$, where V_{bi} is the built-in potential barrier. (7%)

(d) Calculate the electron current at $x = x_n + \frac{1}{2}L_p$ for $V_a = \frac{1}{2}V_{bi}$, where L_p is the hole diffusion length. (7%)



Problem 2 (22%)

A constant electric field, $E = 12$ V/cm, exists in the $+x$ direction of an n-type gallium arsenide semiconductor for $0 \le x \le 50\,\mu$m. The total current density is a constant and is $J = 100$ V/cm^2. At $x = 0$, the drift and diffusion currents are equal. Let $T = 300^\circ$ K and $\mu_n = 8000$ cm^2/V-sec.

(a) Determine the expression for the electron concentration *n(x)*. (10%)

(b) Calculate the electron concentration at $x = 0$ and at $x = 50\mu m$. (6%)

(c) Calculate the drift and diffusion current densities at $x = 50\mu m$. (6%)

Problem 3 (30%)

Consider a pn junction LED, and the bandgap energy is 2.7 eV. Answer the questions below:

(a) Calculate the emission wavelength of this LED. (3 %)

(b) Show the processing flowchart for the fabrication of this LED in detail. (including materials, and facilities,…etc.). (10 %)

(c) The internal quantum efficiency (η_i) of LED is $\eta_i = \gamma\eta$, where γ is the injection efficiency and η is the radiative efficiency. Derive the equations of γ and η. (10 %)

(d) Discuss what kind of the photon loss mechanisms can influence the external quantum efficiency (η_{ext}), and derive the expression of the external quantum efficiency (assuming that photons are emitted uniformly in all directions, and neglecting photons absorption). (7 %)

Problem 4 (20%)

Consider a pn junction solar cell.

(a) Plot the I-V curve of the solar cell, and indicate and explain the I_{SC} (short-circuit current), V_{OC} (open-circuit voltage), and maximum power rectangle. (10 %)

(b) Derive the equations of the relationship between fill factor (FF) and power conversion efficiency (η) of a solar cell. (10 %)