PSC Assignment 6

Q1 Consider the following parameters in a silicon pn junction:

$$N_a = N_d = 10^{16}\ \text{cm}^{-3} \qquad n_i = 1.5 \times 10^{10}\ \text{cm}^{-3}$$
$$D_n = 25\ \text{cm}^2/\text{s} \qquad \tau_{p0} = \tau_{n0} = 5 \times 10^{-7}\ \text{s}$$
$$D_p = 10\ \text{cm}^2/\text{s} \qquad \epsilon_r = 11.7$$

(a) Determine the ideal reverse-saturation current density J_s at $T = 300$ K.

(b) Design the diode such that electron and hole current densities $J_n = 20$ A /cm^2 and $J_p = 5$ A /cm^2 at $Va = 0.65$ V.

Ans (a) $J_s = 4.16 \times 10^{-11}$ A/cm^2

(b) $N_a = 1.0 \times 10^{15}$ /cm^3, Nd = 2.5×10^{15} /cm^3

Q2 Consider a silicon pn junction initially biased at 0.60 V at $T = 300$ K. Assume the temperature increases to $T = 310$ K. Calculate the change in the forward-bias voltage required to maintain a constant current through the junction.

Ans V = 0.583V

Q3 A silicon pn junction at $T = 300$ K has the following parameters: $N_a = 5 \times 10^{16}\ \text{cm}^{-3}$, $N_d = 1 \times 10^{16}\ \text{cm}^{-3}$, $D_n = 25\ \text{cm}^2/\text{s}$, $D_p = 10\ \text{cm}^2/\text{s}$, $\tau_{n0} = 5 \times 10^{-7}$ s, and $\tau_{p0} = 1 \times 10^{-7}$ s. The cross-sectional area is $A = 10^{-3}\ \text{cm}^2$ and the forward-bias voltage is $V_a = 0.625$ V. Calculate the (*a*) minority electron diffusion current at the space charge edge, (*b*) minority hole diffusion current at the space charge edge, and (*c*) total current in the pn junction diode.

Ans (a) 0.154 mA (b) 1.09 mA (c) 1.24 mA

Q4 Consider an ideal silicon pn junction diode. (*a*) What must be the ratio of N_d/N_a so that 90 percent of the current in the depletion region is due to the flow of electrons? (*b*) Repeat part (*a*) if 80 percent of the current in the depletion region is due to the flow of holes.

Ans (a) Nd/Na = 12.7 (b) Na/Nd = 2.8

Q5 A silicon pn junction with a cross-sectional area of $10^{-4}\ \text{cm}^2$ has the following properties at $T = 300$ K:

n region	p region
$N_d = 10^{17}\ \text{cm}^{-3}$	$N_a = 5 \times 10^{15}\ \text{cm}^{-3}$
$\tau_{p0} = 10^{-7}$ s	$\tau_{n0} = 10^{-6}$ s
$\mu_n = 850\ \text{cm}^2/\text{V-s}$	$\mu_n = 1250\ \text{cm}^2/\text{V-s}$
$\mu_p = 320\ \text{cm}^2/\text{V-s}$	$\mu_p = 420\ \text{cm}^2/\text{V-s}$

(*a*) Sketch the thermal equilibrium energy-band diagram of the pn junction, including the values of the Fermi level with respect to the intrinsic level on each side of the junction. (*b*) Calculate the reverse-saturation current I_s and determine the forward-bias current I at a forward-bias voltage of 0.5 V. (*c*) Determine the ratio of hole current to total current at the space charge edge x_n.

Ans (a) Is = 4.4×10^{-15} A , 1×10^{-6} A, (c) 0.074