Ve320 Introduction of Semiconductor Device

Homework 2

Due Date: June. 22

6.6 Consider a one-dimensional hole flux as shown in Figure 6.4. If the generation rate of holes in this differential volume is $g_p = 10^{20}$ cm^{-3}-s^{-1} and the recombination rate is 2×10^{19} cm^{-3}-s^{-1}, what must be the gradient in the particle current density to maintain a steady-state hole concentration?

Repeat Problem 6.6 if the generation rate becomes zero.

6.9 A silicon sample at $T = 300$ K has a uniform acceptor concentration of 7×10^{15} cm^{-3}. The excess carrier lifetime is $\tau_{n0} = 10^{-7}$ s. (*a*) Determine the ambipolar mobility. (*b*) Find the ambipolar diffusion coefficient. (*c*) What are the electron and hole lifetimes?

6.12 Consider a silicon sample at $T = 300$ K that is uniformly doped with acceptor impurity atoms at a concentration of $N_a = 10^{16}$ cm^{-3}. At $t = 0$, a light source is turned on generating excess carriers uniformly throughout the sample at a rate of $g' = 8 \times 10^{20}$ cm^{-3} s^{-1}. Assume the minority carrier lifetime is $\tau_{n0} = 5 \times 10^{-7}$ s, and assume mobility values of $\mu_n = 900$ cm^2 /V-s and $\mu_p = 380$ cm^2 /V-s. (*a*) Determine the conductivity of the silicon as a function of time for $t \geq 0$. (*b*) What is the value of conductivity at (*i*) $t = 0$ and (*ii*) $t = \infty$?

6.14 A bar of silicon at $T = 300$ K has a length of $L = 0.05$ cm and a cross-sectional area of $A = 10^{-5}$ cm^2. The semiconductor is uniformly doped with $N_d = 8 \times 10^{15}$ cm^{-3} and $N_a = 2 \times 10^{15}$ cm^{-3}. A voltage of 10 V is applied across the length of the material. For $t < 0$, the semiconductor has been uniformly illuminated with light, producing an excess carrier generation rate of $g' = 8 \times 10^{20}$ cm^{-3} s^{-1}. The minority carrier lifetime is $\tau_{p0} = 5 \times 10^{-7}$ s. At $t = 0$, the light source is turned off. Determine the current in the semiconductor as a function of time for $t \geq 0$.

6.15 Silicon at $T = 300$ K is uniformly doped with impurity atoms at concentrations of $N_a = 2 \times 10^{16}$ cm^{-3} and $N_d = 6 \times 10^{15}$ cm^{-3} and is in thermal equilibrium for $t < 0$. A light source turns on at $t = 0$ producing excess carriers with a uniform generation rate of $g' = 2 \times 10^{21}$ cm^{-3} s^{-1}. The electric field is zero. (*a*) If the maximum, steady-state excess carrier concentrations are $\delta n = \delta p = 5 \times 10^{14}$ cm^{-3}, determine the excess minority carrier lifetime. (*b*) Derive the expressions for the excess carrier concentration and excess carrier recombination rate as a function of time. (*c*) Determine the times at which the excess carrier concentration is equal to (*i*) one-fourth, (*ii*) one-half, (*iii*) three-fourths, and (*iv*) 95% of the steady-state value.

6.18 A semiconductor is uniformly doped with 10^{17} cm^{-3} acceptor atoms and has the following properties: $D_n = 27$ cm^2/s, $D_p = 12$ cm^2/s, $\tau_{n0} = 5 \times 10^{-7}$ s, and $\tau_{p0} = 10^{-7}$ s. An external source has been turned on for $t < 0$ producing a uniform concentration of excess carriers at a generation rate of $g' = 10^{21}$ cm^{-3} s^{-1}. The source turns off at time $t = 0$ and back on at time $t = 2 \times 10^{-6}$ s. (*a*) Derive the expressions for the excess carrier concentration as a function of time for $0 \le t \le \infty$. (*b*) Determine the value of excess carrier concentration at (*i*) $t = 0$, (*ii*) $t = 2 \times 10^{-6}$ s, and (*iii*) $t = \infty$. (*c*) Plot the excess carrier concentration as a function of time.

6.20 The $x = 0$ end of an $N_a = 1 \times 10^{14}$ cm^{-3} doped semi-infinite ($x \ge 0$) bar of silicon maintained at $T = 300$ K is attached to a "minority carrier digester" which makes $n_p = 0$ at $x = 0$ (n_p is the minority carrier electron concentration in a p-type semiconductor). The electric field is zero. (*a*) Determine the thermal-equilibrium values of n_{p0} and p_{p0}. (*b*) What is the excess minority carrier concentration at $x = 0$? (*c*) Derive the expression for the steady-state excess minority carrier concentration as a function of x.

6.25 Assume that a p-type semiconductor is in thermal equilibrium for $t < 0$ and has an infinite minority carrier lifetime. Also assume that the semiconductor is uniformly illuminated, resulting in a uniform generation rate, $g'(t)$, which is given by

$$g'(t) = G_0' \qquad \text{for } 0 < t < T$$
$$g'(t) = 0 \qquad \text{for } t < 0 \text{ and } t > T$$

where G_0' is a constant. Find the excess minority carrier concentration as a function of time.

***6.41** Consider an n-type semiconductor as shown in Figure P6.41, doped at $N_d = 10^{16}$ cm^{-3} and with a uniform excess carrier generation rate equal to $g' = 10^{21}$ cm^{-3}-s^{-1}. Assume that $D_p = 10$ cm ^{2}/s and $\tau_{p0} = 10^{-7}$ s. The electric field is zero. (*a*) Determine the steady-state excess minority carrier concentration versus x if the surface recombination velocity at $x = 0$ is (*i*) $s = 0$, (*ii*) $s = 2000$ cm/s, and (*iii*) $s = \infty$. (*b*) Calculate the excess minority carrier concentration at $x = 0$ for (*i*) $s = 0$, (*ii*) $s = 2000$ cm/s, and (*iii*) $s = \infty$.

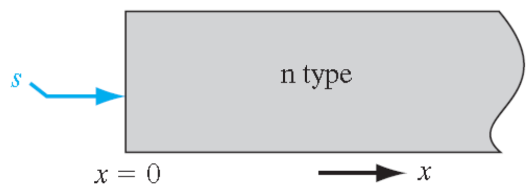

Figure P6.41 | Figure for Problem 6.41.

***6.42** (*a*) Consider the p-type semiconductor shown in Figure P6.42 with the following parameters: $N_a = 5 \times 10^{16}$ cm^{-3}, $D_n = 25$ cm^2/s, and $\tau_{n0} = 5 \times 10^{-7}$ s. The surface recombination velocities at the two surfaces are shown. The electric field is zero. The semiconductor is illuminated at $x = 0$ with an excess carrier generation rate equal to $g' = 2 \times 10^{21}$ cm^{-3}-s $^{-1}$. Determine the excess minority carrier electron concentration versus x in steady state. (*b*) Repeat part (*a*) for $\tau_{n0} = \infty$.

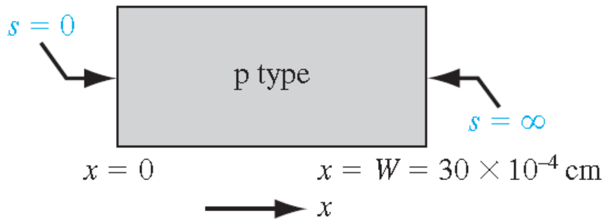

Figure P6.42 | Figure for Problem 6.42.