

ECSE-2210 Microelectronics Technology
Class Activity 10 – Solution

1. The equation below is called minority carrier diffusion equation for electrons.

$$\frac{\partial \Delta n_P}{\partial t} = D_N \frac{\partial^2 \Delta n_P}{\partial x^2} - \frac{\Delta n_P}{\tau_n} + G_L$$

- (a) Why is it called a *diffusion equation*?

The \mathcal{E} -field is assumed to be zero, and hence the drift current is zero. Only the diffusion current is involved.

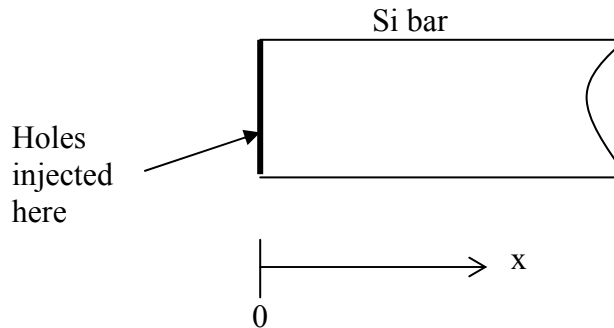
- (b) Why is it referred to as a *minority carrier equation*?

The equation is valid for minority carriers. No change in majority carrier concentrations is taken into consideration.

- (c) The equation is valid only under low-level injection conditions. Why?

The recombination part ($\Delta n/\tau$) was derived assuming low level conditions.

2. Consider an n-type Si bar doped with N_D donors and with a cross sectional area A of 1 cm^2 as shown below. Let us assume that holes are injected from the left by some means such that the excess minority carrier concentration maintained at $x = 0$ is Δp_{no} with $\Delta p_{no} \ll N_D$. There is no other generation of carriers taking place inside the bar. Assume that the hole lifetime is τ_p and the hole diffusion length is L_p .



- a. Write down the general form of the minority carrier diffusion equation. Make appropriate simplifications to get the simplified differential equation that should be solved to get the carrier profile inside the bar under steady state conditions.

$$\frac{\partial \Delta p_n}{\partial t} = D_p \frac{\partial^2 \Delta p_n}{\partial x^2} - \frac{\Delta p_n}{\tau_p} + G_L$$

Under Steady State conditions $\frac{\partial \Delta p_n}{\partial t} = 0$

Also $G_L = 0$ as there is no light shining on the sample

So, the above equation can be written as

$$D_p \frac{\partial^2 \Delta p_n}{\partial x^2} - \frac{\Delta p_n}{\tau_p} = 0 \quad \text{for } x > 0$$

- b. Write down the general form of the solution to the above equation and the appropriate boundary conditions.

$$\Delta p_n(x) = A e^{-x/L_p} + B e^{x/L_p}$$

Subject to the boundary conditions

$$\Delta p_{n \rightarrow 0} = \Delta p_{n0}$$

$$\Delta p_{n \rightarrow \infty} = 0$$

- c. Establish the expression for the minority carrier profile inside the bar.

$$\Delta p_n(x) = \Delta p_{n0} \exp\left(-\frac{x}{L_p}\right) \quad \text{where} \quad L_p = \sqrt{D_p \tau_p}$$

- d. Integrate the equation in (c) to get the total number of minority carriers stored inside the bar. Hence, find the total amount of stored charge inside the bar.

The integration from zero to infinity gives: $\Delta p_{n0} L_p$

Hence total number of stored charge is: $q \Delta p_{n0} L_p$

- e. Differentiate the equation in (c) to get the hole diffusion current at $x = 0$. [Hint: See the equation (3.68)].

Differentiating the equation and setting $x = 0$, you get $d(\Delta p_n)/dx = -\Delta p_{n0}/L_p$

Hence, hole diffusion current is: $+q D_p \Delta p_{n0}/L_p$

- f. Note that the total amount of steady state stored charge divided by the lifetimes gives the diffusion current at $x = 0$. Can you give an explanation to this?

Total charge divided by lifetime is: $q \Delta p_{n0} L_p / \tau_p$

Since the total charge dies down on average every τ_p seconds, the current should be supplying this amount of charge to maintain the steady state value.