

Semiconductor: Diffusion current

day06

1. Review

The reading of Razavi section 2.2.1 was assigned and expected to have been completed by the start of this class session. Also §2.2.2, but your reading assignments are intentionally ahead of class time topics.

Tourbook table: Four currents in a semiconductor

Symbol	Name	Units
V		
n		
p		
μ_n		
μ_p		
k_B		
n_i		
N_D		
N_A		
W, h, d		

Charge carriers of interest

- e^-
- h^+

Charges move by

- Electric field $\rightarrow V(\text{olts})_{ab} = - \int_a^b \vec{E} dl$

Motion from high to low regions of concentration

The diagram shows a 3D rectangular block labeled "Semiconductor Material". On the left side, a smaller rectangular block is shown with an arrow pointing into the main block, labeled "Injection of Carriers". Inside the main block, a shaded triangular region at the bottom left represents the initial carrier concentration profile. A series of black dots with arrows pointing to the right are shown above this shaded region, indicating the movement of carriers from the high concentration area towards the right. Below the block, a label "Nonuniform Concentration" has an arrow pointing to the shaded region. Above the block, the text "Motion from high to low regions of concentration" is written.

Semiconductor Material

Injection of Carriers

Nonuniform Concentration

Figure 1. From Razavi Fundamentals of Microelectronics

Figure 2. Electron diffusion current density

Figure 3. Hole diffusion current density

The total **diffusion current density** is then

$$J_{total}(\text{diff}) = J_n + J_p \quad (1)$$

$$= q \left(D_n \frac{\delta n}{\delta x} - D_p \frac{\delta p}{\delta x} \right) \text{ A/cm}^2 \quad (2)$$



Look back at our four currents in a semiconductor and match the terms we've just worked through. **Only** one term has a negative sign, hole diffusion, *be careful* to not make sign errors!

2.1. Einstein relation

Surely there is some relationship between how easily a free charge carrier moves in a semiconductor (**μ , mobility**) and the quickness that a dose of charge disperses within a volume (**$D_{n,p}$, diffusivity**). Why would this make sense? What is happening internally when charges diffuse?

Indeed, this is the *Einstein relation*:

$$\frac{D_n}{\mu_n} = \frac{k_B T}{q} \quad (3)$$

$$\frac{k_B T}{q} = V_T \text{ thermal voltage} \quad (4)$$

$$D_n = \mu_n \frac{k_B T}{q} \quad (5)$$

I like this last presentation of the relationship best for the intuition on how the diffusion constant changes with temperature. Consider a drop of dye in a glass of cold versus hot water—the dye in the hot water will diffuse faster because the thermal motion that creates the movement is greater.