DRAFT

Semiconductor Basic Equations

Lecture 2

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Outline

- Drift Current
- Diffusion Current
- Poisson’s Equation
- Gauss Law
- Fermi Level

Drift Current

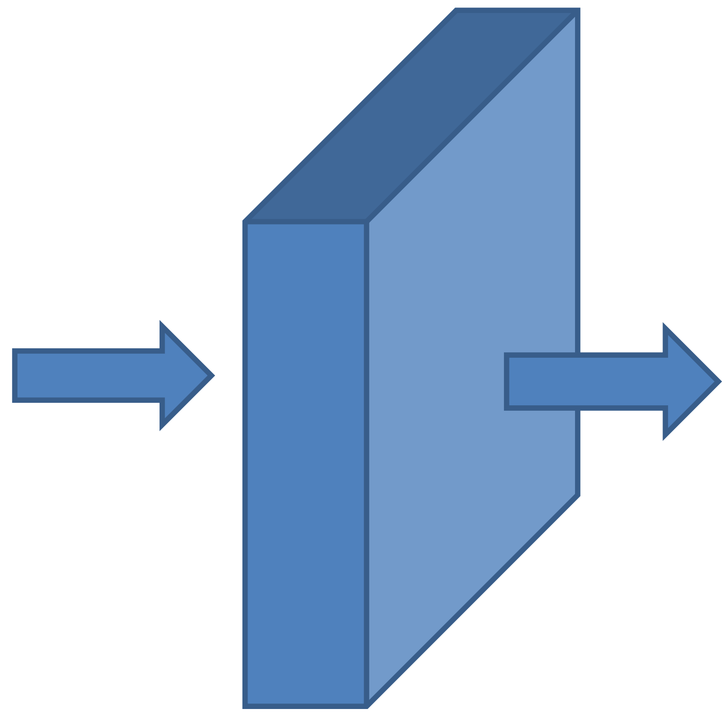
$$J_{drift} = Q\,C\,v_d$$

J = Current Density (A/m²) → J = Current Density (A/m^2)

v_d = *velocity of particles (m/sec)*

C = *number of carriers/unit volume (#/m³)* → ($\#/m^3$)

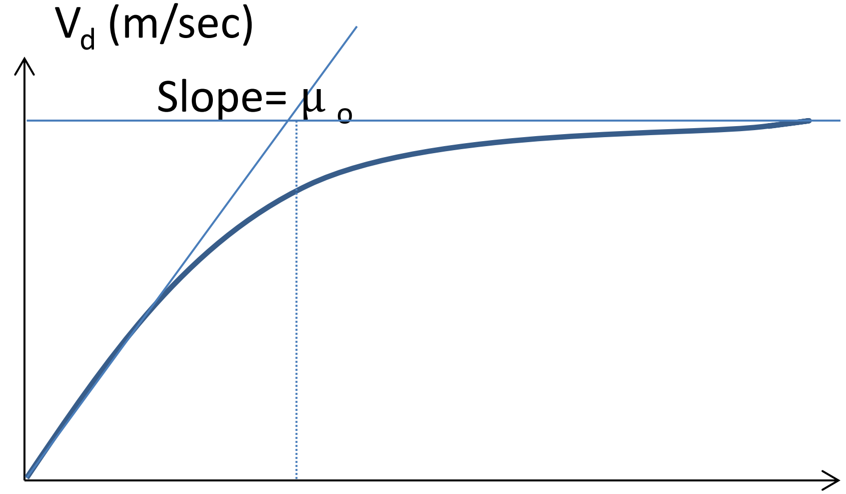
Q = *particle charge (C = Coulomb)*



Drift Velocity

$|v_d| = \mu\,|\mathcal{E}|$

$\rightarrow\ |J_{drift}| = Q\,n\,\mu\,|\mathcal{E}|$



For Electrons :

$$v_{d\,n} = -\mu_n\,\mathcal{E}$$

$$J_{n\ drift} = -q\,n(-\mu_n\,\mathcal{E})$$
$$= q\,n\mu_n\,\mathcal{E}$$

For Holes:

$$v_{d\,p} = +\mu_p\,\mathcal{E}$$

$$J_{n\ drift} = q\,p\,\mu_n\,\mathcal{E}$$

Particle Diffusion Under Concentration Gradient

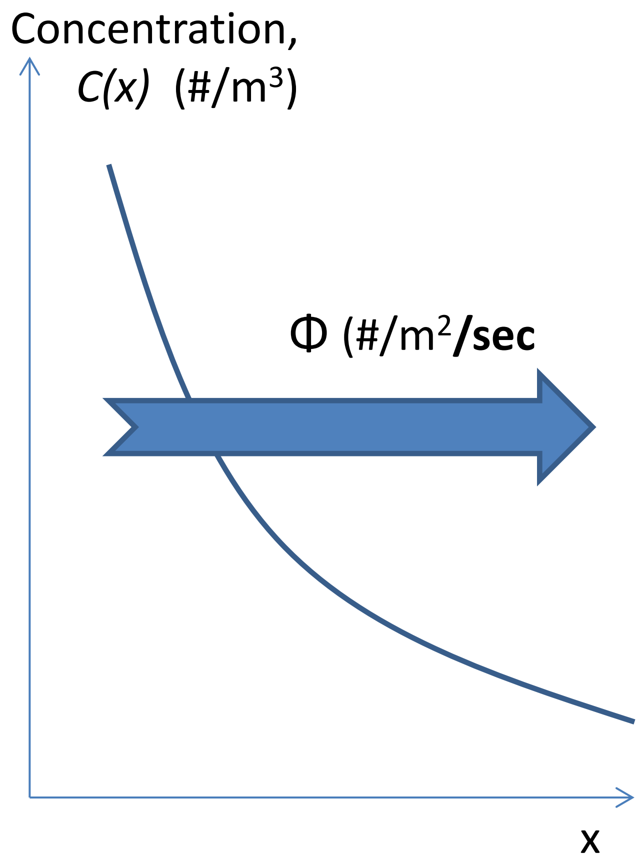
For any particle under

Number of particles/unit area/unit time:

Flux = $\phi = -D \frac{dC(x)}{dx}$

D=Diffusion Coefficient (cm^2/sec)

Energy is obtained from temperature



Diffusion Current Density

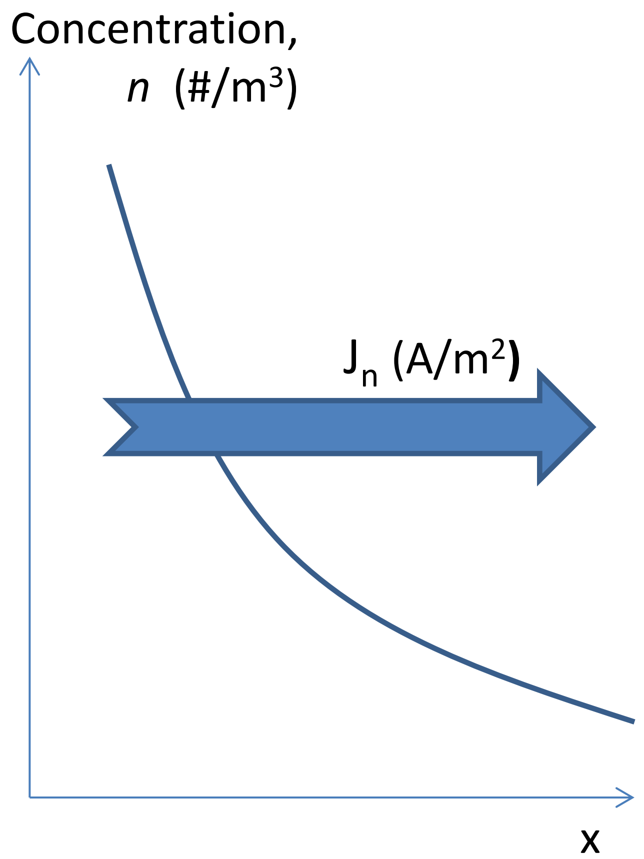
Diffusion Current Density:

J = Charge x Particle Flux = $Q\ \Phi$

$$J_{n,\ Diffusion} = -(-q)D_n \frac{dn(x)}{dx}$$

$$J_{p,\ Diffusion} = -qDp \frac{dn(x)}{dx}$$

$$D = \mu k_B T/q$$



Drift-Diffusion Equation

$$J_{total} = Jn + Jp$$

For Electrons: $J_n = q\, n(x)\mu_n \mathcal{E} + qD_n \frac{dn(x)}{dx}$

$$= -q\, n(x)\mu_n \frac{dV_i(x)}{dx} + \mu_n K_B T \frac{dn(x)}{dx}$$

$$= -q\, n(x)\mu_n \left[\frac{dV_i(x)}{dx} - \frac{K_B T}{q} \frac{1}{n(x)} \frac{dn(x)}{dx}\right]$$

$$= -q\, n(x)\mu_n \left[\frac{dV_i(x)}{dx} - \frac{K_B T}{q} \frac{d\, ln(n(x))}{dx}\right]$$

$$= -q\, n(x)\mu_n \frac{d}{dx}\left[Vi(x) - \frac{K_B T}{q} ln(\, n(x)\,)\right]$$

Setting Quasi-Fermi Potential $V_{QF}(x)$=V(x):

$$J_n = -q\, n(x)\, \mu_n \frac{d}{dx}[V_{QF}(x)]$$

Drift-Diffusion Equation

For Holes:

$$J_p = q\,p(x)\mu_p\boldsymbol{\mathcal{E}} - qD_p\frac{dp(x)}{dx}$$

$$= -q\,p(x)\mu_p\frac{dV_i(x)}{dx} + \mu_p K_B T\frac{dp(x)}{dx}$$

$$J_p = -q\,p(x)\mu_p\left[\frac{dV_i(x)}{dx} + \frac{K_B T}{qp(x)}\frac{dp(x)}{dx}\right]$$

$$= -q\,p(x)\mu_p\left[\frac{dV_i(x)}{dx} + \frac{K_B T}{q}\frac{d\,ln(p(x))}{dx}\right]$$

$$= -q\,p(x)\mu_p\frac{d}{dx}\left[V_i(x) + \frac{K_B T}{q}ln(\,p(x)\,)\right]$$

Setting Quasi-Fermi Potential $V_{QF}(x)=V(x)$:

$$J_p = -q\,p(x)\,\mu_p\frac{d}{dx}[V_{QF}(x)]$$

Poisson's Equation

$$\nabla^2 V(x) = -\frac{\rho(x)}{\varepsilon}$$

$$\mathcal{E}(x) = -\frac{dV(x)}{dx} = \int \frac{\rho(x)}{\varepsilon}\ dx$$

$$V(x) = \int \mathcal{E}(x)\, dx$$

Gauss's Law

Fermi-Dirac Distribution

Energy Bands