EI-27003: Electronics Devices and Circuits
Lecture - 5

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LECTURE - 5

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Relation Between Mobility and Diffusivity

- Let us consider three definitions:

Thermal velocity(v_{th}), collision time(t), mean free path(l).

- Thermal velocity(v_{th}): It is average velocity of carriers going in positive or negative direction.
- Collision time(t): It is time during which carriers will move with same velocity before a collision occurs with an atom or with another carrier.
- Mean free path(l): It is average length a carrier will travel between collision

Derivation …..continue

- These three averages are related by:

$$V_{th} = \frac{l}{t} \quad \text{----(1)}$$

- In previous class we have seen equation for drift velocity:

$$v_d = \frac{qt}{m}E$$

But we know: $V_d = \mu E$ Hence : $t = \frac{\mu m}{q}$ ------(2)

We also know that the diffusion constant: $D_n = V_{th}.l$ ----(3)

- The diffusion current in n-type semiconductor is:

$$J_n = qD_n\frac{dn}{dx} \quad \text{-----(4)}$$

Put eq.(3) in eq.(4)

$$J_n = qV_{th}.l\,\frac{dn}{dx} \quad \text{-----(5)}$$

But from eq.(1) $l = V_{th}.t$ ----(6)

Derivation .....continue

- Put eq.(6) in eq.(5):

$$J_n = qV_{th}V_{th}t\,\frac{dn}{dx} \quad \text{------(7)}$$

- Theorem of equipartitation of energy states that the molecules in thermal equilibrium have same average energy associated with each independent degree of freedom of their motion and that the energy is:

$$\frac{1}{2}\,m.V^2_{th} = \frac{1}{2}KT \quad \text{-----(8)}$$

$$\text{Hence: } V^2_{th} = \frac{KT}{m} \quad \text{-----(9)}$$

Put eq.(9) in eq.(7)

$$J_n = q\,\frac{KT}{m}\,t\,\frac{dn}{dx} = qD_n\frac{dn}{dx} \quad \text{------(10)}$$

$$\text{But from eq.(2) } t = \frac{\mu m}{q}$$

Derivation …..continue

- Hence eq.(10) becomes:

$$J_n = q \frac{KT}{m} \frac{\mu m}{q} \frac{dn}{dx} = qD_n \frac{dn}{dx}$$

Now simplify:

$$KT\mu_n = qD_n$$

OR

$$\frac{KT}{q} = \frac{D_n}{\mu_n}$$

This is called as Einstein's equation.

Derivation .....continue

- Here $\frac{KT}{q}$ is called as Volt equivalent of temperature:V_T

K=Boltzman's constant=

q=charge of electron=

T= temp in kelvin= 273 + ^{0}C

$\frac{KT}{q} = V_T =$ 26mV at room temp=27^{o}c

Numerical: The hole density in an n-type silicon wafer ($N_d=10^{17}cm^{-3}$) decreases linearly to $10^{13}cm^{-3}$ between x=0 to x=1um. Calculate the hole diffusion current. Given: mobility of hole $\mu_p=317cm^2/v\text{-}s$. Assume room temperature.

$J_p= qD_p\frac{dp}{dx} = 1.6x10^{-19}x8.2x\frac{9X1013}{10^{-4}}$ $=1.18A/cm^2$

Its Quiz Time

https://forms.gle/M21pKoB2mgU36r4o6