Lec 02: Electronic Devices 13/7/2015

* Properties of Semiconductors

a) Polarity of charge carriers.
b) Concentration of charge carriers.
c) Transport of charge carriers.
d) Interaction of SC with E-m field.

→ Current flow is due to flow of charges!

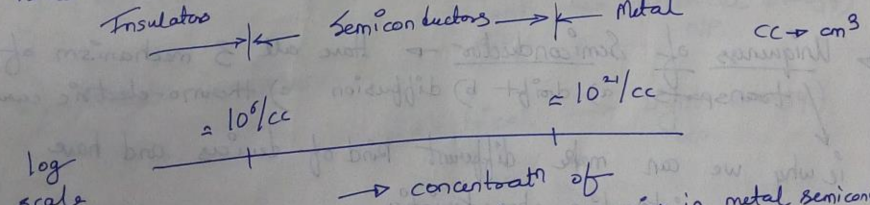
a) Polarity of charge carriers:-

. In semiconductor, we have both +vely charged (holes) and -ve charged (e^-s) carriers.

. In metals, we have only -vely charge carrier (e^-s).

b) Concentration of charge carriers:-

Interesting property of semiconductor is that → It's concentration can be varied over several order's of magnitude.



→ concentratn of charge carrier in metal, semiconductor & insulator.

Q. How do u achieve variation in conc^n.?

Ans: 1) By introducing impurities in semi-conductor (doping)

2) Changing the temperature

3) By Illumination (shining light)

c) <u>Transport of charge carriers</u>: due to →

a) Drift mechanism

b) Diffusion mechanism

c) Thermo-electric current.

· In metals and semiconductor's current flows whenever Electric-field is applied. This kind of transport is called "<u>Drift</u>".

In drift mechanism, transport of charge carriers is becoz of <u>potential gradient</u>. (ie high & low potential at different points of semiconductor)

· In semiconductor, current flows also becoz of "diffusion". ie (current becoz of <u>concentratn gradient</u>) (ie from high to low & low to high conc^n).

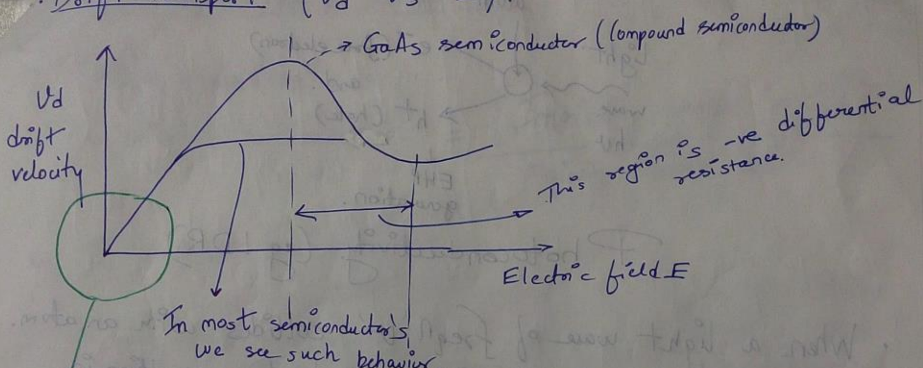
Note: Possibility of "Diffusion" is v.v strong in semiconductor's. (since conc^n of carriers in semi-cond^c can be varied in wide range).

· Thermo-electric current is becoz of temperature gradient.

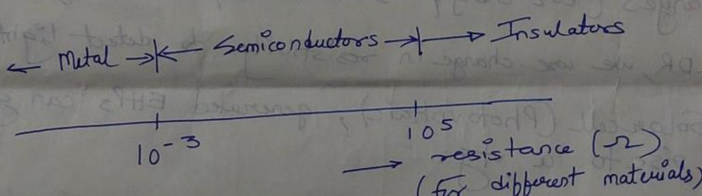
→ <u>Uniqueness</u> of <u>Semiconductor</u> → Have all 3 mechanism of transports a) drift b) diffusion c) thermo-electric current.

ie why we can make different kind of devices and have very interesting characteristics.

Drift transport (V_d Vs E):



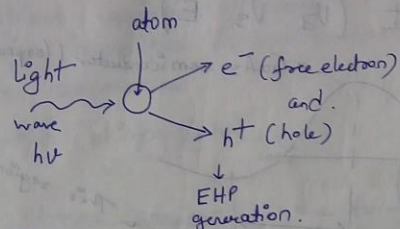
For small E-field, we have $\boxed{\frac{V_d}{E} = \mu}$ → Mobility.



* Interaction of semiconductor with Electromagnetic field:-
or other forms of energy

1) Photoconductivity (Photovoltaic)
(light → electrical energy)
I/P → O/P

2) Electro-luminesence
(electrical → light energy)
I/P → O/P

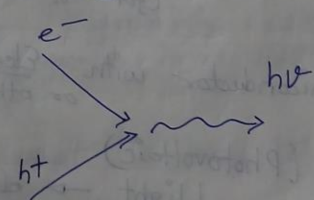


Photoconductivity. (eg LDR)

- When a light wave of freq^n 'ν' collides with an atom of semiconductor material, it breaks bonds, resulting in electron-hole pair generation, due to this conductivity changes (coz energy is absorbed) — of semiconductor.

eg: In LDR, we use change in resistivity to detect light.

In Solar cell (Photovoltaic), generated EHPs can give rise to a vtg.



Electro-luminesence (eg LED, Laser diode).

- A free e⁻ & hole in semiconductor when they recombine, energy given away as light.

Equilibrium Carrier concentration:

→ Minority carrier concⁿ in extrinsic semiconductor = $\frac{[\text{Intrinsic Carrier Conc}^n]^2}{\text{Majority carrier conc}^n}$

eg In N-type semiconductor

$$P_{n_0} = \frac{n_i^2}{n_{p_0}}$$

(P → hole concⁿ; n_0 → equilibrium, in n type)

P_{n_0} → equilibrium concⁿ of holes in ntype semiconductor.

In general, $p_0 n_0 = n_i^2$; n_i – intrinsic carrier concentratⁿ

↳ Law of mass Action

• Classification of Semiconductor:-

- Pure (No impurities or defects) (regular crystalline structure)
- Intrinsic (concⁿ of e^- & h^+ same) as in Pure semicond
- Extrinsic (defects and impurities present) → (concⁿ of e^- & h^+ not same under equilibrium condⁿ)

Classification of Semiconductor:
- Simple (Elemental) eg Si, Ge
- Compound eg GaAs, InP, GaInAs
  - InP → Indium phosphite

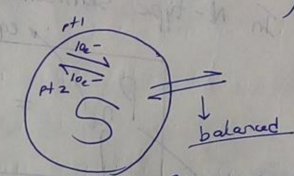
No impurity means : no atoms other than Si is present in Si

* Concept of thermal equilibrium:-

(Deal a complex real life situation) $\approx$ with a { small deviation (disturbance) from idealized conditions, eg Quasi-equilibrium }

- For every process, that is going on, there is a inverse process going on at same rate.

ie



(Semiconductor in equilibrium with its environment)

- Semiconductor is in thermal equilibrium

$\Rightarrow$ IF $\longrightarrow$ There is

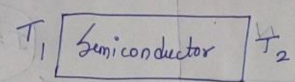
1. No external excitation other than temperature. (voltage or Electric field)

2. No NET motion of charge or energy

$\hookrightarrow$ (it does not mean there is no motion)

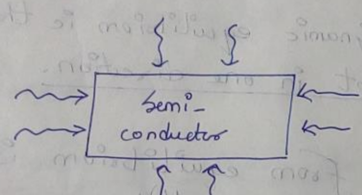
$\rightarrow$ To understand this ideal, lets us see what is meant by Non-equilibrium, with it's inference, we understand equilibrium:

Example: (Non - Equilibrium conditions)

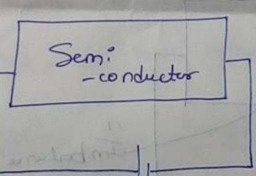
1) 

, 1^{st} $cond^n$ is satisfied

Not under equilibrium, since ($T_2 < T_1$), then there is flow of energy (heat) from one end to another.

2) 

Not under equilibrium becoz, Light shining on semiconductor.
ie (photon's are being absorbed & that energy is converted into another form of energy)

3) 

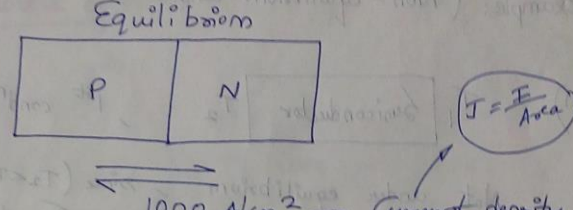
1^{st} $cond^n$ is not satisfied since external excitat^n is applied (ie vtg)

Note:- Semiconductor devices are only useful in non-equilibrium conditions.

→ Many practical situation for semiconductor devices can be treated as " Quasi - equilibrium situation"

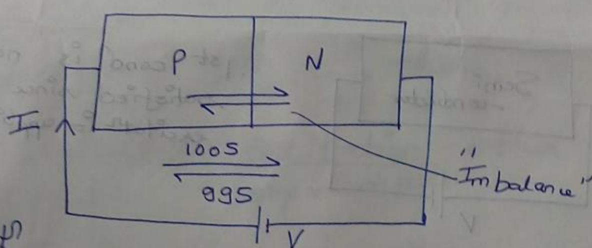
Let us understand why ?

eg PN Junction



Thermal equilibrium ⇒ is a dynamic equilibrium ie there is intense activity, but not in one direction.

· Practical condⁿ (deviation from equilibrium is V.V small):



On applicatⁿ of voltage, Practical current $I = 10\ A/cm^2$

→ Quasi - Equilibrium

means → (small deviation from)