Chapter-14
Semi-Conductor Devices

Intrinsic Semi-Conductor :-

The pure semi-conductors (impurity less than 1 part in 10^{10}) are called intrinsic semiconductors. The presence of the mobile charge carriers (electrons and holes) in an intrinsic property of the material & these charge are obtain as a result of thermal excitation. In an intrinsic semiconductor, the no. density of electrons (n_e) is equal to no. density of holes (n_h).

$$\underset{\substack{\downarrow \\ \text{Free electron} \\ \text{density}}}{n_e} = \underset{\substack{\downarrow \\ \text{hole density} \\ \text{in valence} \\ \text{band}}}{n_h} = n_i \rightarrow \substack{\text{intrinsic} \\ \text{carrier} \\ \text{concentration}}$$

Extrinsic Semi-Conductor :

The semiconductors obtained by adding or doping the pure semiconductor with small amounts of certain specify impurity atoms having valency difference from that of the host atoms are called entrinsic semiconductor.

Doping :

Limitations :

1. Intrinsic semiconductors have low intrinsic charge carrier concentration & hence have low electrical conductivity
2. As intrinsic charge carriers are always thermally generated, so flexibility is not available to control their numbers.

Def^n: The process of deliberate addition of a desirable impurity to a pure semi-conductor so as to increase

it's conductivity is called doping.
The impurity atoms added are called dopants.

Dopants are of two types:

1. **Pentavalent dopants** such as As, Sb and P. These are also called **donors**.

2. Trivalent dopands such as In, B & Al. These are also called acceptors.

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Valence bond model of Extrinsic Semi-Conductor:

A semi-conductor doped with some suitable impurity atom so as to increase it's no. of charge carriers is called an extrinsic semi-conductor.

Extrinsic conductor's are of two types:

1. **n-type semiconductor:** The prevalent impurity atoms are called donors because they donate electrons to the host crystal and the semi-conductor doped with donors is called n-type semi-conductor.
In n-type semi-conductors electrons are the majority charge carriers and holes are the minority charge carriers.

$$\boxed{n_e \approx N_D > n_h}$$

2. **p-type semiconductor:** The invalent impurity atoms are called acceptors because they create holes which can accept electrons from the nearby bonds. A semi-conductor doped with acceptor typ

Note:- The vacancy or absence of electron in the bond of a co-valently bonded crystal is called a hole.

impurities is called a p-type semi-conductor. In this holes are the majority carriers & electrons are the minority charge carriers.

$$n_h \approx N_A > n_e$$

Electrical Conductivity of a semi-conductor:-

$$E = \frac{V}{l} \quad \rightarrow ①$$

$$\underset{\substack{\swarrow \\ \text{Total Current}}}{I} = \underset{\substack{\downarrow \\ \text{Electron} \\ \text{Current}}}{I_e} + \underset{\substack{\searrow \\ \text{Hole} \\ \text{Current}}}{I_h} \quad \rightarrow ②$$

$$I_e = e n_e A v_e$$

$$I_h = e n_h A v_h$$

$$I = e n_e A v_e + e n_h A v_h$$

$$= eA(n_e v_e + n_h v_h) \quad \rightarrow ③$$

$$R = \rho \frac{l}{A} \quad \rightarrow ④$$

From ① & ④

$$I = \frac{V}{R} \Rightarrow I = \frac{E\cancel{l}}{\rho \cancel{l}/A} \rightarrow ⑤ \quad \Rightarrow I = \frac{EA}{\rho}$$

From ③ & ⑤

$$I = \frac{EA}{\rho} = eA(n_e v_e + n_h v_h)$$

$$\frac{E}{\rho} = e(n_e v_e + n_h v_h) \rightarrow ⑥$$

$$\mu_e = \frac{v_e}{E} \quad \text{or} \quad \underset{\substack{\downarrow \\ \text{drift velocity}}}{v_e} = \overset{\substack{\text{mobility of electron} \\ \nearrow}}{\mu_e} E$$

Hole mobility

$\mu_h = \frac{v_h}{E}$ or $E\mu_h = v_h$

Substituting the values of μ_e & μ_e in eq. ⑥

$$\frac{E}{\rho} = e(n_e\mu_e E + n_h\mu_h E)$$

~~$\sigma = \frac{1}{\rho} = eE$~~

$$\frac{\cancel{E}}{\rho} = e\cancel{E}(n_e\mu_e + n_h\mu_h)$$

$$\boxed{\sigma = \frac{1}{\rho} = e(n_e\mu_e + n_h\mu_h)}$$

Resistivity of the semiconductor

$$\boxed{\rho = \frac{1}{e(n_e\mu_e + n_h\mu_h)}}$$

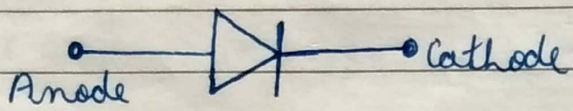
Photoconductivity :-

The increase in the conductivity of a semi-conductor as a result of incident photons of suitable energy is called photoconductivity.

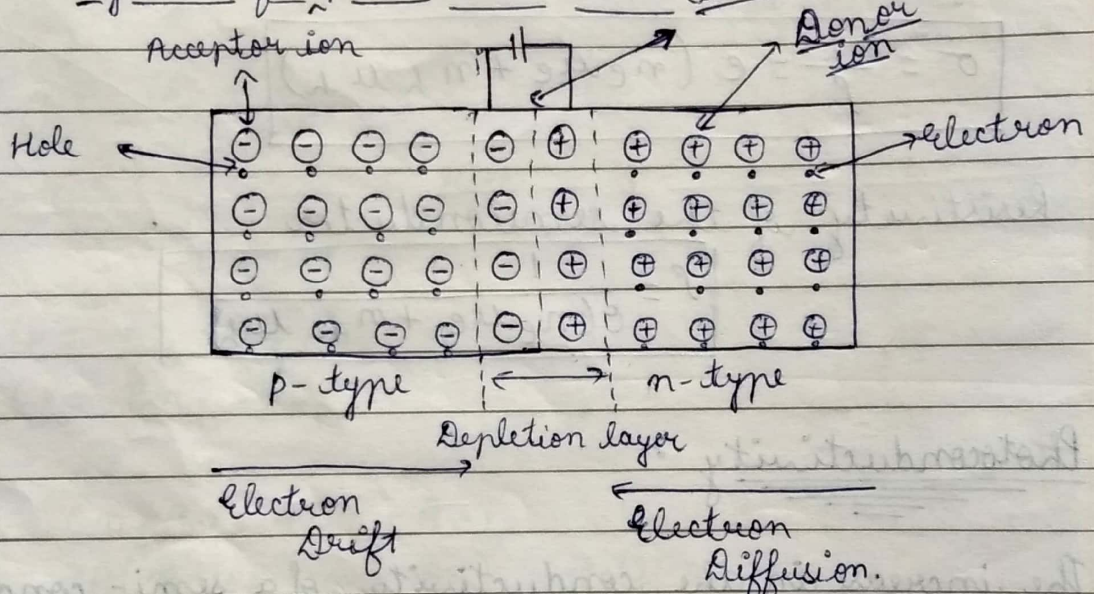
p-n junction :-

It is a single crystal of Ge or Si doped in such a manner that one half portion of it acts as p-type semi-conductor and the other half as n-type semi-conductor.

As soon as p-n junction is formed, the holes from the p-region diffuse into the n-region and electrons from n-region diffuse into p-region. This results in the development of potential barrier V_B across the junction which opposes the further diffusion of electrons and holes through the junction. The small region in the vicinity of the junction which is depleted of free charge carriers and has only immobile ions is called depletion region.



Symbol for a p-n Junction Diode Junction



Working of p-n Junction:-

Forward Biasing:- If the (+)ve terminal of a battery is connected to the p side and (-)ve terminal to the n-side then the p-n junction is said to be forward biased.

(i) Electrons ~~m~~ & holes move towards the junction

(ii) p-n junctions offers low resistance during forward biasing.

Parallel Plate Capacitor :

$$E=\frac{V}{d}$$

$$\frac{\sigma}{\epsilon_0}=\frac{V}{d}$$

~~$d=\frac{V\epsilon_0}{\sigma}$~~

$$\frac{q/A}{\epsilon_0}=\frac{V}{d}$$

$$\frac{q}{A}=\frac{V\epsilon_0}{d}$$

$$\boxed{C=\frac{\epsilon_0 A}{d}} \because \boxed{\frac{q}{V}=\frac{\epsilon_0 A}{d}}$$

Energy stored in a capacitor :

$$dW=V\,dq$$

$$W=\int_0^q \frac{q}{C}\,dq=\frac{q^2}{2C}$$

$$\boxed{U=\frac{1}{2}\frac{q^2}{C}} \rightarrow ①$$

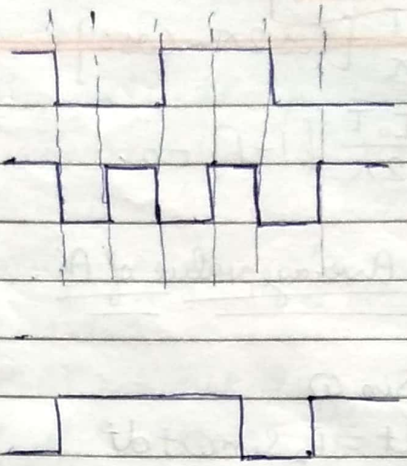
$$=\frac{1}{2}\frac{C^{\cancel{2}}V^2}{\cancel{C}} \because [q=CV]$$

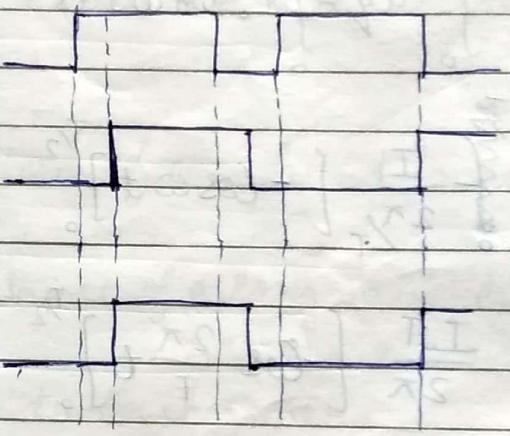
$$\boxed{=\frac{1}{2}CV^2} \rightarrow ②$$

From ①

$$U=\frac{1}{2}\frac{q^2}{q/V}$$

$$\frac{q^{\cancel{2}}}{1}\times\frac{V}{\cancel{q}} \quad \boxed{U=\frac{1}{2}qV}$$





Alternating Current

Average value of a.c.

$$I=I_0 \sin\omega t$$

$$dq=I\,dt \Rightarrow dq=I_0\sin\omega t\,dt$$

$$q=\int dq$$

$$q=\int_0^T I_0\sin\omega t\,dt$$

$$q=I_0\left[\frac{-\cos\omega t}{\omega}\right]_0^T$$

$$q=-\frac{I_0}{2\pi/3}\left[\cos\frac{2\pi}{T}t\right]_0^T$$

$$= -\frac{I_0 T}{2\pi}\left[\cos 2\pi - \cos 0\right]$$

$$= -\frac{I_0 T}{2\pi}\left[1-1\right] = 0.$$

Mean or Average value of AC.

$$I = I_0 \sin \omega$$

$$dq = I\,dt = I_0 \sin\omega t\,dt$$

$$q = \int_0^{T/2} dq = \int_0^{T/2} I_0 \sin\omega t\,dt$$

$$= \frac{I_0}{2\pi/T}\left[-\cos\omega t\right]_0^{T/2}$$

$$= \frac{I_0 T}{2\pi}\left[-\cos \frac{2\pi}{T} t\right]_0^{T/2}$$

$$= -\frac{I_0 T}{2\pi}\left[\cos\pi - \cos 0\right]$$

$$= -\frac{I_0 T}{2\pi}(-1-1)$$

$$= \frac{I_0 T}{\pi}$$

$$I_{av} = \frac{\text{Charge}}{\text{Time}} = \frac{q}{T/2} = \frac{2q}{T}$$

$$= \frac{2}{T} \cdot \frac{I_0 T}{\pi}$$

$$I_{av} = \frac{2}{\pi} I_0 = 0.637 I_0$$

Root Mean sq. (RMS) or effective or Virtual Value of AC

$$dH = I^2 R\,dt$$

$$H = \int_0^T I^2 R\,dt.$$

~~$H_{eff} \int_0^T I^2 dt$~~

$$H_{eff} = I_{eff}^2 RT$$

$$I_{eff}^2 R = \int_0^T I^2 R\,dt$$

$$I_{eff}^2 = \frac{1}{T}\int_0^T I^2 ~~R~~ dt$$

$$I_{eff} = I_{rms} = \int_0^T I_0^2 \sin^2\omega t\,dt$$

$$=$$

Expression for Internal Resistance.
Internal resistance of cell vary with temp.
Density of matter in nuclei independent of mass no. A.
Potentiometer.
Rate of change of charge during charging of a parallel plate capacitor.
Expression for max K.E of e^- emmited from a metal surface
Expression for the slope of of Einstein photoelectric eq^n.
Derive an expression for torque acting on it.
Expression for energy stored in a $\parallel^{el}$ plate capacitor.
Bright & dark fringes.
Expression for magnification of compound microscope.
Cyclotron..
Expression for self inductance of a long air-cored solenoid.
~~Ste~~ Expression for Step up transformer.
Expression of an impedance of an ac. circuit.
Derive lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}. = \frac{1}{u} + \frac{1}{v} = \frac{1}{f}$