18-08-22

* Conductivity and mobility and its temperature dependent

i) Low temperature the scattering mechanism dominated by doping (impurity atoms or ionised atom present) (0K - 50K)

ii) At high temperature the phonon scattering is dominated.

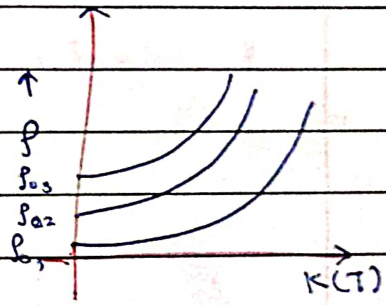
For metals :

conductivity

$\sigma \propto T^{-1}$ $\quad T > \Theta_D$ ← Deby's temperature

$\sigma \propto T^{-5}$ $\quad T < \Theta_D$

$$\rho = \rho_0 + \rho(T)$$



Mobility of a charge carrier is defined as the average drift velocity per unit electric field.

$$\mu = \frac{V}{E} \quad —①$$

$$\mu_e = \frac{V_e}{E}, \quad \mu_h = \frac{V_h}{E}$$

Total ~~mob~~ mobility $\quad \mu_e + \mu_h = \frac{V_e}{E} + \frac{V_h}{E}$

Conductivity (electron) $\sigma_e = \frac{J}{E} = \frac{neV_e}{E} = ne\mu_e \quad —③$

holes $\quad \sigma_h = \frac{nh\,\mu_h}{E} \quad —④$

Total conductivity - $\boxed{\sigma_e + \sigma_h = ne(\mu_e + \mu_h)}$

① The phonon Scattering (high temp.)
② Ionised impurity atoms (low temp.)

At high temp phonon mobility

$$\mu_p \propto T^{-3/2}$$

phonon mobility $\Rightarrow$ $\mu_p = A\,T^{-3/2}$ — ⑥

$$\mu_I \propto T^{3/2}$$

Ionised mobility $\Rightarrow$ $\mu_I = B\,T^{3/2}$ — ⑦

Total resitivity

$$\rho = \rho_p + \rho_I$$

$$\frac{1}{\sigma} = \frac{1}{\sigma_p} + \frac{1}{\sigma_I}$$

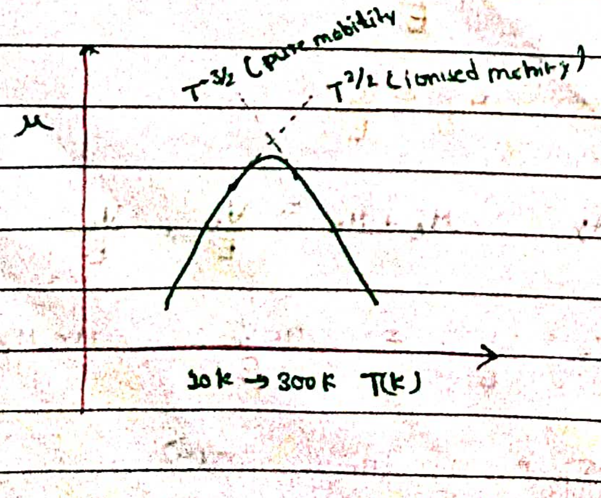
$$\frac{1}{ne\mu} = \frac{1}{ne\mu_p} + \frac{1}{ne\mu_I}$$

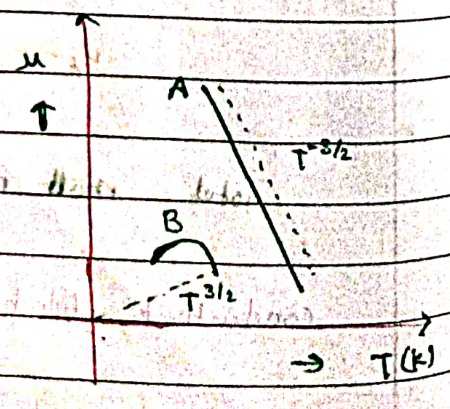
$$\boxed{\frac{1}{\mu} = \frac{1}{\mu_p} + \frac{1}{\mu_I}}$$

$$\frac{1}{\mu} = \frac{T^{3/2}}{A} + \frac{T^{-3/2}}{B}$$

$\mu \propto T^{3/2}$ — (B)

$\mu \propto T^{-3/2}$ — (A)





Compound Semiconductor

Metallic Grade Silicon (MSG) → impure

Electron Grade Silicon (ESG) → pure

→ $A_{III}\ B_{V}$

→ $A_{II}\ B_{VI}$

Binary

III-V: GaAs, GaSb, InAs

II-VI: CdTe, ZnS, ZnTe

Ternary

① $\underbrace{A_x B_{1-x}}_{III} \underset{V}{C}$

$x \rightarrow$ molecular weigh / amounts

$0 \leq x \leq 1$

$Al_x Ga_{1-x} As$

Group 3 — V

② $\underset{III}{A} \underbrace{B_{1-x} C_x}_{V}$

$Ga\ As_{1-x} P_x$

Quarternary

① $\underbrace{A_x B_{1-x}}_{III} \underbrace{C_y D_{1-y}}_{V}$

$In_x Ga_{1-x} As_y P_{1-y}$

② $(\underbrace{A_x B_{1-x}}_{III})_y C_{1-y} \underset{V}{D}$

$(In_x Ga_{1-x})_y Al_{1-y} As$

22-8-22

Thermal conductivity

Heat flow $\rightarrow \vec{j}_q = -K \, \vec{\nabla} T$

$$j_q = \frac{1}{2} n v \left[\mathcal{E}\left[T(x - v\tau)\right] - \mathcal{E}\left[T(x - v\tau)\right] \right]$$

Taylor Expansion :

$$\mathcal{E}[T(x - v\tau)] = \mathcal{E}\left(T(x) \mp v\tau \frac{dT}{dx} + \dots\right)$$

$$\mathcal{E}\left[T(x) \mp v\tau \frac{dT}{dx} + \dots\right] = \mathcal{E}(T(x)) \mp \left(v\tau \frac{dT}{dx}\right) \frac{d\mathcal{E}}{dT} + \dots$$

$$\Rightarrow \quad j_q = -\frac{1}{2} n v \left(2 v \tau \frac{dT}{dx}\right) \frac{d\mathcal{E}}{dT}$$

$$j_q = -n v^2 \tau \frac{dT}{dx} \cdot \frac{d\mathcal{E}}{dT}$$

$$\Rightarrow \quad \vec{j}_q = \underbrace{-\frac{n}{3}\left(v_x^2 + v_y^2 + v_z^2\right) \cdot \tau \frac{d\mathcal{E}}{dT}}_{K} \cdot \vec{\nabla} T$$

$$K = \frac{n}{3} v^2 \tau \frac{d\mathcal{E}}{dT}$$

$$\Rightarrow \quad \frac{n \, d\mathcal{E}}{dT} = \frac{N}{V} \frac{d\mathcal{E}}{dT}$$

$$\frac{1}{V} \frac{d V\mathcal{E}}{dT} = C_v$$

$$\boxed{K = \frac{1}{3} v^2 \tau C_v}$$

$$K = \frac{1}{3} v^2 \tau C_v$$

$$\sigma = \frac{n e^2 \tau}{m}$$

$$\boxed{\frac{K}{\sigma} = \frac{\frac{1}{3} C_v \cdot m v^2}{n e^2}}$$

100 time higher 100 times lower

$$\frac{1}{2}mv^2 = \frac{3}{2}k_BT$$ → Wrong but considered because

$$\Rightarrow \quad E = \frac{3}{2} n k_B T$$

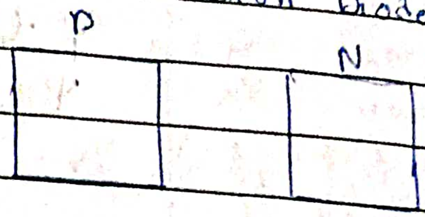
~~and~~ $$C_v = \left.\frac{dE}{dT}\right|_v = \frac{3}{2} n k_B$$

$$\frac{K}{\sigma} = \frac{3}{2}\left(\frac{k_B}{e}\right)^2 T$$

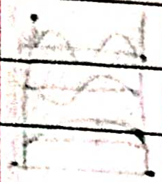
9-09-2029

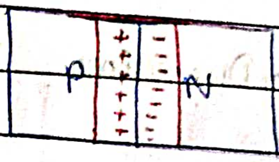
P-N Junctions are made by
1> Diffusion
2> Ion implantation

P-N. Junction Diode

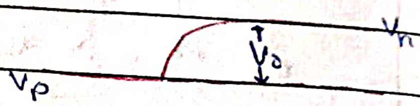


Particle	diffusion	current
$\rightarrow$	Hole	$\rightarrow$
$\leftarrow$	Hole out	$\leftarrow$
$\leftarrow - -$	Electron diffu	$- - \rightarrow$
$- - \rightarrow$	Electron drift	$\leftarrow - -$

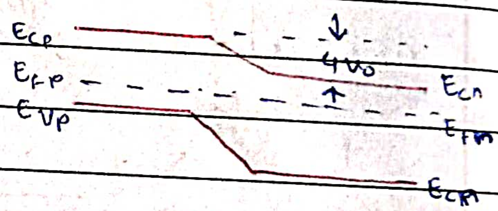




For equili



$$J_p(\text{drift}) + J_p(\text{diff}) = 0$$
$$J_n(\text{drift}) + J_n(\text{diff}) = 0$$



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

$$\boxed{V_0 = V_n - V_p}$$

diff. gradient

$$J_p(x) = q\left[\mu_p\, p(x)\, \mathcal{E}(x) - \underbrace{D_p}_{\text{coeff. of diff}} \frac{dp(x)}{dx}\right] = 0 \quad -(4)$$

$$\frac{\mu_p}{D_p}\mathcal{E}(x) = \frac{1}{p(x)}\frac{dp(x)}{dx} \quad -(5)$$

$$-\frac{q}{KT}\mathcal{E}(x) = \frac{1}{p(x)}\frac{dp(x)}{dx} \quad -(6) \qquad \left[\frac{\mu_p}{D_p} = \frac{KT}{q}\right]$$

$$\frac{-q}{KT}\int_{V_p}^{V_n} dV = \int_{p_p}^{p_n} \frac{1}{p}\,dp$$

V_0 contact potential

$$\frac{-q}{KT}(V_n - V_p) = \ln p_n - \ln p_p$$

$$\frac{-q}{KT} V_0 = \ln \frac{p_n}{p_p}$$

$$V_0 = \frac{KT}{q} \ln \frac{P_p}{P_n}$$

N_a acceptor / cm^3 → p type side

N_d donor / cm^3 → n type side

$$n_i^2 = N_a N_d$$

intrinsic carrier concentration

$$V_0 = \frac{KT}{q} \ln \frac{N_a}{n_i^2} \times N_d$$

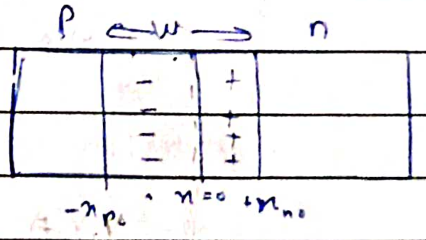
$$\boxed{V_0 = \frac{KT}{q} \ln \frac{N_a N_d}{n_i^2}}$$

→ $$\frac{P_p}{P_n} = e^{\frac{qV_0}{KT}}$$

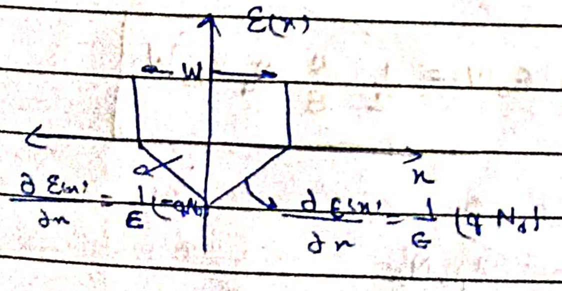
$$\frac{P_p}{P_n} = \frac{n_n}{n_p} = e$$

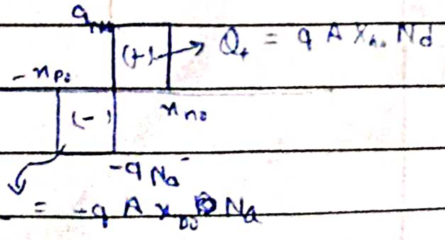
$$Q_+ = q A X_{no} N_d$$

$$Q_- = q A X_{po} N_a$$



$N_a < N_d$





A total uncompensated charge —

$$qA x_{po} N_a = qA x_{no} N_d$$

Poission's equation –

$$\frac{\partial \mathcal{E}(x)}{dx} = \frac{q}{\varepsilon}\left(p - n + N_d^{+} - N_a^{-}\right)$$

$$\frac{dE}{dx} = \frac{q}{\epsilon} N_d \qquad 0 < x < x_{no}$$

$$\frac{dE}{dx} = \frac{-q}{\epsilon} N_a \qquad -x_{po} < x < 0$$

#1

5-09-22

$$\int_{\mathcal{E}_0}^{0} \partial\mathcal{E} = \frac{q}{\epsilon} N_d \int_{0}^{x_{no}} dx \qquad 0 < x < x_{no}$$

$$\int_{0}^{\mathcal{E}_0} \partial\mathcal{E} = \frac{-q}{\epsilon} N_a \int_{-x_{po}}^{0} dx \qquad -x_{po} < x < 0$$

$\Rightarrow$ (1)

$$\mathcal{E}_0 = \frac{-q}{\epsilon} N_d x_{no} = \frac{-q}{\epsilon} N_a x_{po} \quad \text{—} \ (*)$$

$$\mathcal{E}(x) = -\frac{\partial V(x)}{\partial x}$$

$$-V_0 = \int_{-x_{po}}^{x_{no}} \mathcal{E}(x)\, dx$$

$$\boxed{V_0 = -\frac{1}{2}\mathcal{E}_0 W = \frac{1}{2}\frac{q}{\epsilon} N_d x_{no} W}$$

$$x_{no} N_d = x_{po} N_a$$

$$x_{no} = \frac{x_{po} N_a}{N_d}$$

$$W = x_{no} + x_{po}$$

$$x_{no} = \frac{W N_a}{N_a + N_d}$$

$$\boxed{\frac{KT}{q} = 26\ \text{meV}}$$ At room temperature

$$W = \frac{x_{po} N_a}{N_d} + x_{po}$$

$$\boxed{x_{po} = \frac{W N_d}{N_a + N_d}}$$

$$\boxed{V_0 = \frac{1}{2}\frac{q}{\epsilon}\frac{N_a N_d}{N_a + N_d} W^2}$$

$$W = \left[\frac{2\epsilon V_0}{q}\left(\frac{N_a + N_d}{N_a N_d}\right)\right]^{1/2}$$

$$W = \left[\frac{2\epsilon KT}{q^2} \ln \frac{N_a N_d}{n_i^2}\left(\frac{1}{N_a} + \frac{1}{N_d}\right)\right]^{1/2}$$

as, $V_0 = \frac{KT}{q} \ln \frac{N_a N_d}{n_i^2}$

$$x_{po} = \frac{W N_d}{N_a + N_d} = \frac{W}{1 + \frac{N_a}{N_d}}$$

$$x_{po} = \left\{\frac{2\epsilon V_0}{q}\left[\frac{N_d}{N_a(N_a + N_d)}\right]\right\}^{1/2}$$

$$x_{no} = \left\{\frac{2\epsilon V_0}{q}\left[\frac{N_a}{N_d(N_a + N_d)}\right]\right\}^{1/2}$$

Q- ~~Phosphorous~~ ~~Boron~~ is implemented into the n-type side Boron is implemented & into silicon sample forming a junction

$N_d = 10^{16}\ cm^{-3}$ $A = 2\times10^{-3}\ cm^2$, $N_i = 1.5\times10^{10}/cm^2$

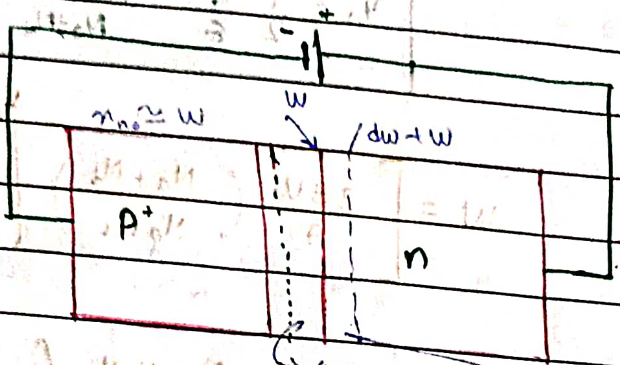
Assume that the acceptor ~~cont~~ concentration in p-typ region is $N_a = 4\times10^{18}\ cm^{-3}$. Calculate the V_0, x_{no}, x_{po}

$\epsilon = 11.8\times10^{-14}$ $V_0 = \frac{KT}{q}\ln\frac{N_a N_d}{n_i^2}$, $W = \sqrt{\frac{2\epsilon V_0}{q}\left(\frac{N_a + N_d}{N_a N_d}\right)}$

$x_{po} = \frac{W N_d}{N_a + N_d}$, $x_{no} = \frac{W N_a}{N_a + N_d}$

Capacitance in p-n junction diode :—

1. The junction capacitance → Reverse biase
2. The charge storage capacitance → Forward biase



$Q = qAN_dW \quad dQ = qAN_d dW$

$$\boxed{C = \frac{dQ}{dV}} \Rightarrow C = \left|\frac{dQ}{dV}\right|$$

$$W = \left(\frac{2\epsilon V_o}{q} \frac{N_a+N_d}{N_aN_d}\right)^{1/2}$$

$$W = \left[\frac{2\epsilon(V_o-V)}{q} \frac{N_a+N_d}{N_aN_d}\right]^{1/2} \rightarrow \text{with bias}$$

$$|Q| = qAx_{no}N_d = qAx_{po}N_a$$

$$x_{no} = \frac{N_aW}{N_a+N_d}, \quad x_{po} = \frac{N_dW}{N_a+N_d}$$

$$|Q| = qA\frac{N_aN_d}{N_a+N_d}W$$

$$= A\left[2q\epsilon(V_o-V)\frac{N_aN_d}{N_a+N_d}\right]^{1/2}$$

$$C = \left|\frac{dQ}{dV}\right|$$

$$C_j = \frac{dQ}{d(V_o-V)}$$

$$C_j = \epsilon^{1/2} A \left[\frac{q}{2(V_0-V)} \frac{N_a N_d}{(N_a+N_d)}\right]^{1/2}$$

$$C_j \propto (V_0 - V)^{-1/2}$$

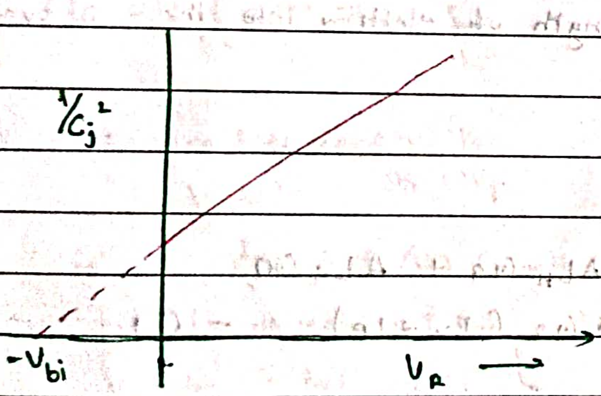
$$C_j = \frac{\epsilon^{1/2} A}{W} \quad \text{[parallel plate capacitor]}$$

p^+-n junction

→ $N_a >> N_d$ $\qquad x_{n0} \cong W$

$$C_j = \frac{A}{2}\left[\frac{2q\epsilon N_d}{V_0-V}\right]^{1/2}$$

$$C_j^2 = \frac{A^2}{4}\left[\frac{2q\epsilon N_d}{V_0-V}\right]$$



slope $= \dfrac{2}{q \epsilon N_d}$

Q— Find out the impurity doping concentration in a p^+-n juction at 300 K. The intrisic $n_i = 1.5 \times 10^{10} /cm^3$

$V_{bi} = 0.855$ V, slope = 1.32×10 F/cm² (volt).

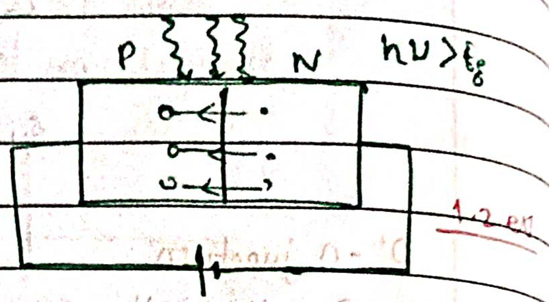
Camlin Page
Date / /

16-09-22

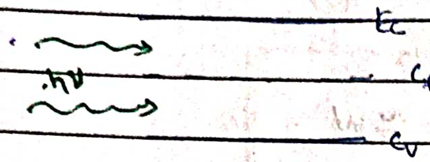
Solar cell

P-N → Junction diode

Photon energy → Electrical power



hν > 1.2 eV



$$h\nu > E_c - E_v = E_g$$

G → rate of generation

L_H → Diffusion length of holes into n-type side

L_e → Diffusion length of electron into the p-type side

→ $A L_H \times G \times q$

→ $A L_e \times G \times q$

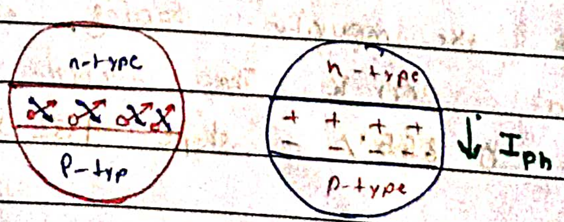
photo current $= A L_H G q + A L_e G q$

$= A G q (L_H + L_e)$ — ①

$$I = I_s \left(e^{\frac{qV}{k_BT}} - 1 \right) \quad — ②$$

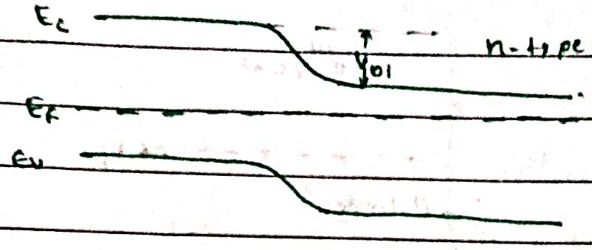
$$I = qA \left[\frac{L_H}{\tau_h} P_{no} + \frac{L_e}{\tau_e} N_{po} \right] \left(e^{\frac{qV}{k_BT}} - 1 \right) \quad — ②$$

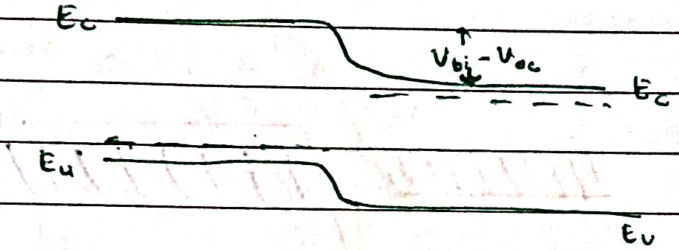
Direction of photocurrent



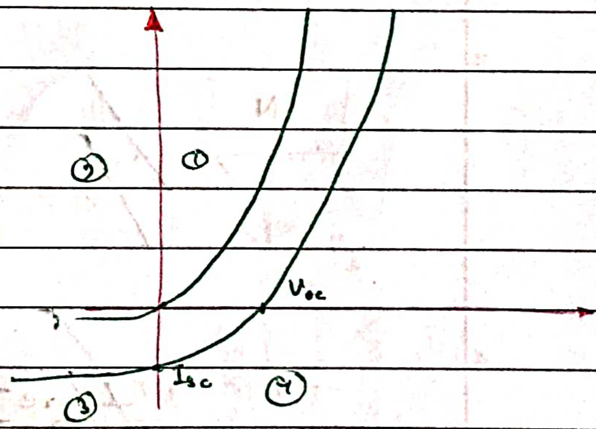
$$I = I_s \left(e^{\frac{qV}{k_BT}} - 1 \right) - I_{ph}$$

Energy band diagram





$$I = I_s\left(e^{\frac{qV}{k_BT}} - 1\right) - I_{ph}$$



The short circuit current

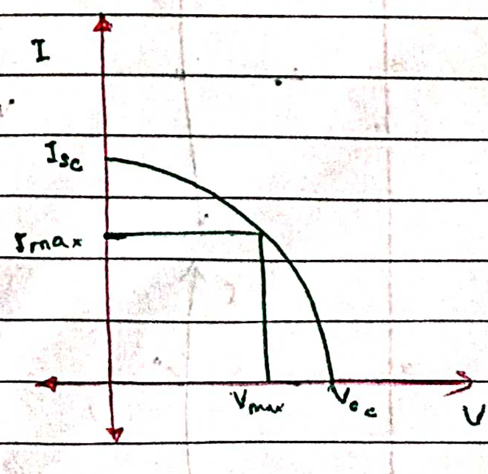
$V = 0$

$$I_{sc} = -I_{ph} = -q A G (L_n + L_p)$$

Open circuit voltage → $I = 0$

$$V = V_{oc} = \frac{k_B T}{q} \ln\left(\frac{I_{ph}}{I_s} + 1\right)$$

$$V_{oc} = \frac{k_B T}{q} \ln\left(\frac{I_{ph}}{I_s}\right)$$



$$P_{out\ max} = V_{max} \times I_{max}$$

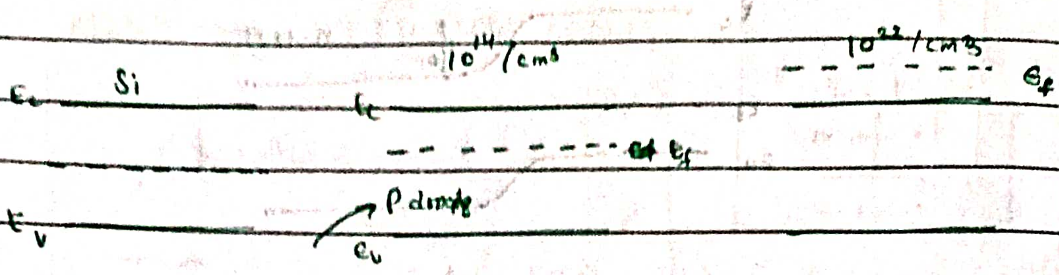
$$F.F = \frac{P_{max}}{J_{sc} \times V_{oc}}$$

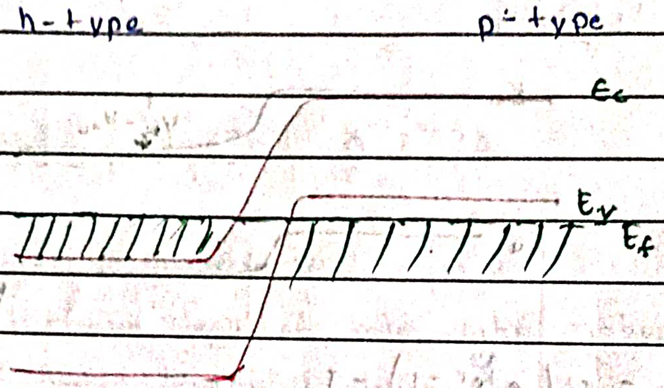
$$= \frac{V_{max} I_{max}}{J_{sc} \times V_{oc}}$$

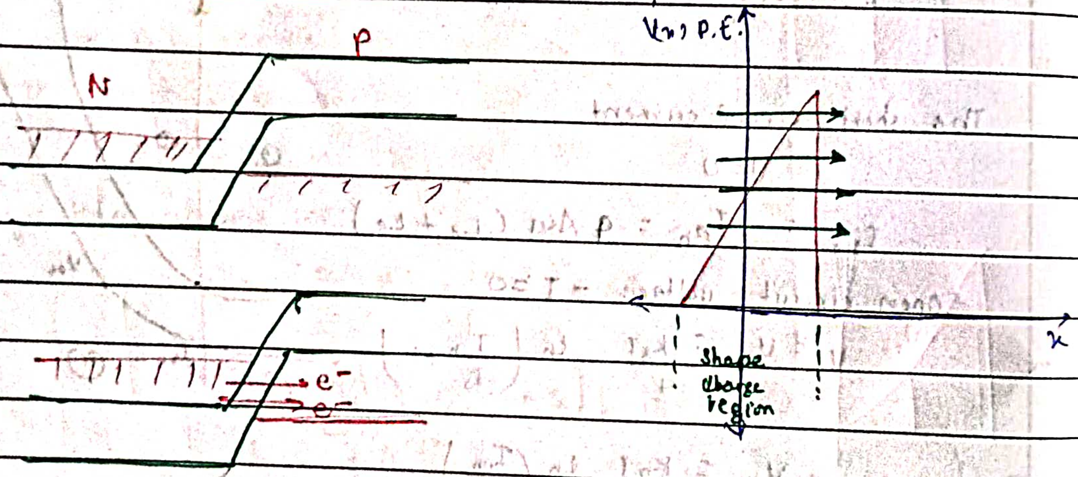
$$PCE = \frac{I_{sc} \times V_{oc} \times F.F}{P_{light}}$$

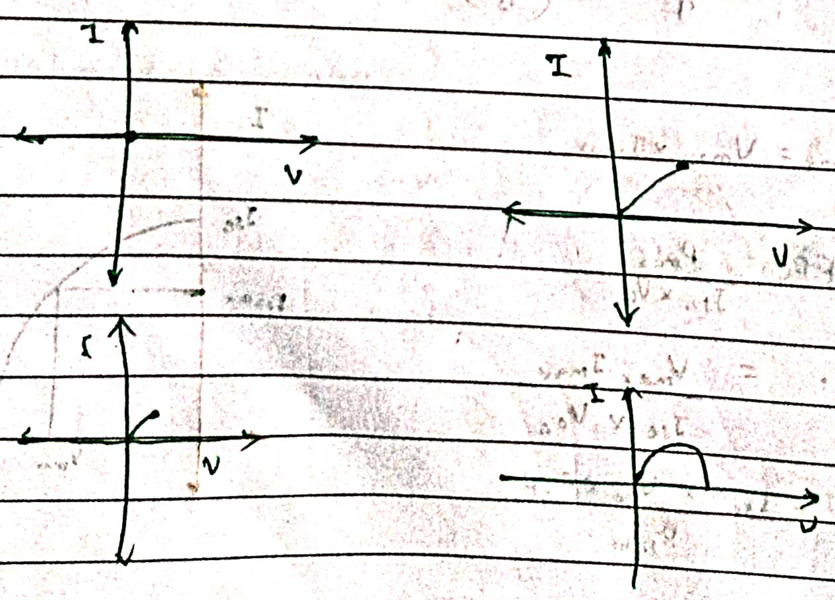
* Tunnel Diode

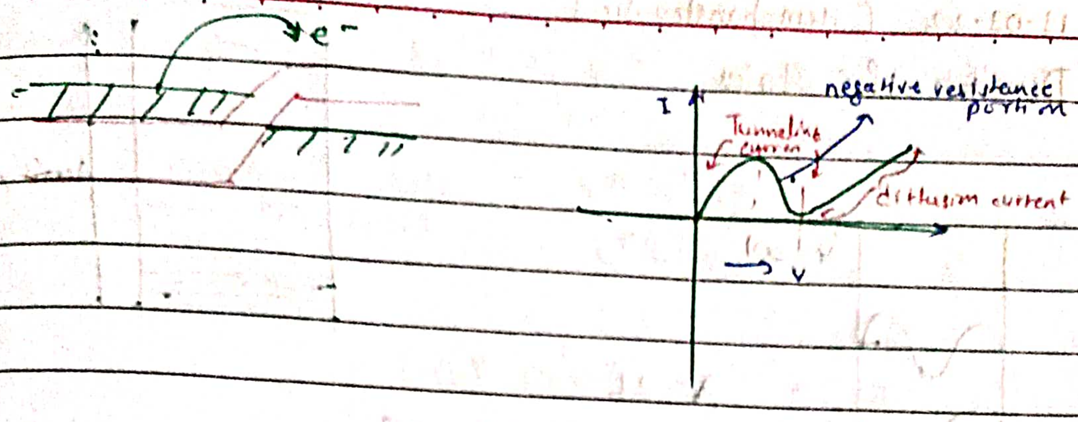
↓ Thickness is so thin, that the electrons can go through it.











- Negative resistance portion → due to increase in voltage, current decreasing
  - This shows diode is oscillating

13/10/22

silicon in form of crystalline

* Semiconductor Device fabrication Crystal growth and wafer preparation

We need 'clean room' / 'clean environment'

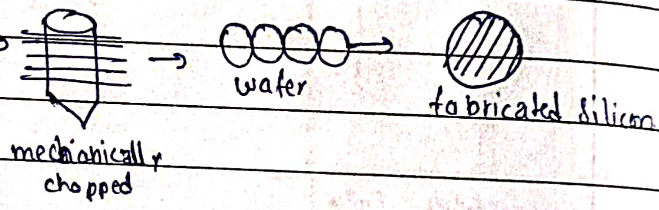
Types of room
- 100000 → order clean room
- 10000 → " " "
- 100 → " " "
- 10 → (Best) " " " — required

Si → Metallurgical grade ~~steel~~ silicon (MGS)

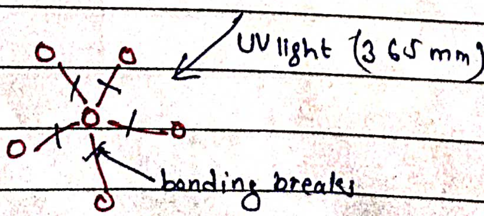
Purification ↓ (bur

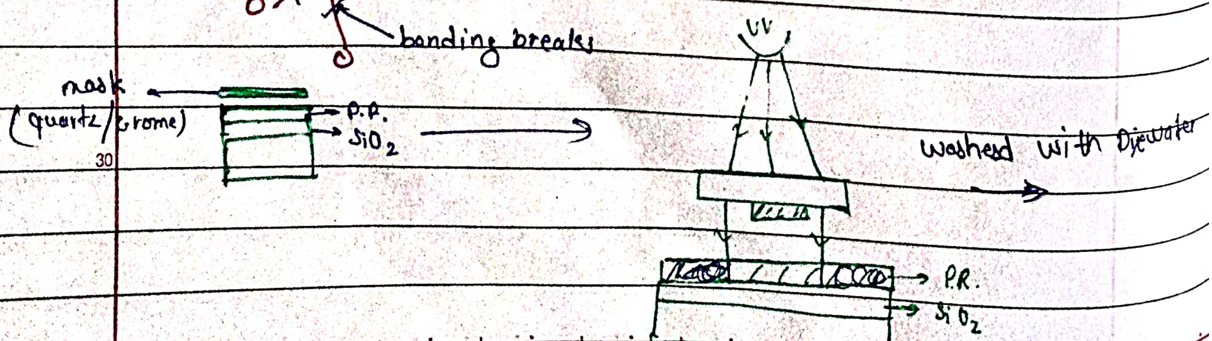
Si → Electronic Grade silicon (EGS)

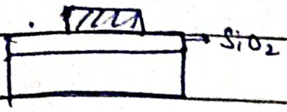
↳ (Si) ingote crystalline



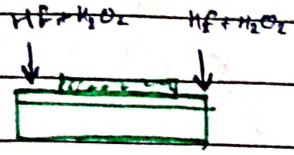
lithography → photosenseive chemical







Etching → Reactive ion Etching
→ chemical ething ($HF + H_2O_2 + H_2O$)



Metalization

Thermal / e-beam evaporation

Process similution

~~P+~~ VLSI Process Integration

Packaging

Yield & Reliability

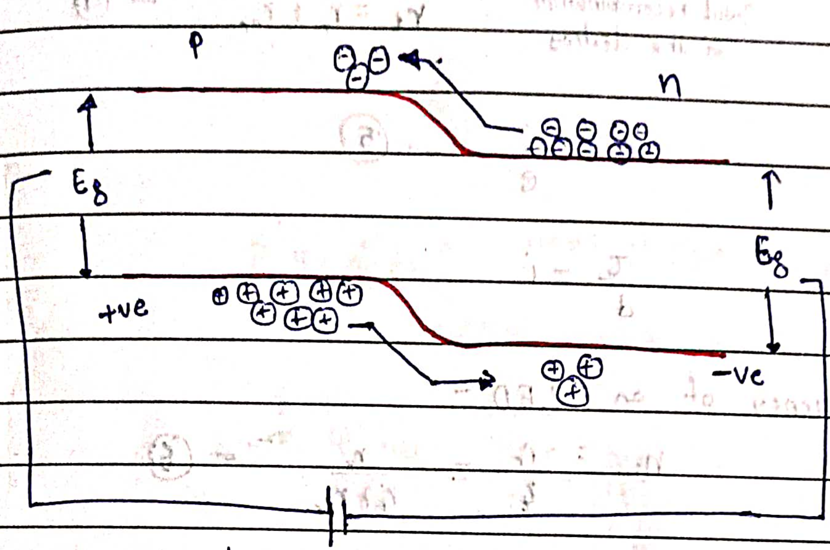
Marketing

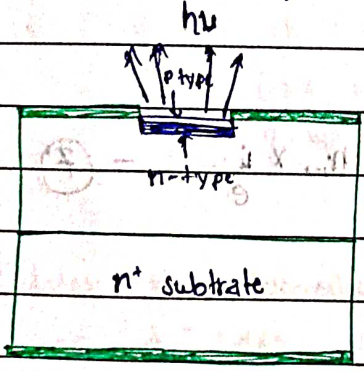
20/10/22

Basic classification

Homojunction | Heterojunction (DH)

Q5 LED → forward bias.





carrier life

$$\Delta n = \Delta n(0) \exp(-t/\tau)$$

no. of minority present in p type side

current at junction density — j A/m²

$\frac{J}{ed}$ → is the electron flow per $m^3 s^{-1}$

$$\frac{d(\Delta n)}{dt} = \frac{J}{ed} - \frac{\Delta n}{\tau} \quad (m^{-3}s^{-1})$$

$$\frac{d(\Delta n)}{dt} = 0$$

Radiative recombination

Non Radiative recombination

$$\Delta n = \frac{I\tau}{ed} \; m^{-3} \quad - (2)$$

$$r_r = \frac{J}{ed} \quad - (3)$$

Total recombination of the electron $\quad r_t = r_r + r_{nr} \quad - (4)$

$$r_t = \frac{i}{e} \quad - (5)$$

$$\frac{I}{d} = i$$

Efficiency of an LED –

$$\eta_{int} = \frac{r_r}{r_t} = \frac{r_r}{r_r + r_{nr}} \quad - (6)$$

$$\eta_{int} = \frac{r_r}{r_t}$$

$$r_r = \eta_{int} \times r_t = \eta_{int} \times \frac{i}{e} \quad - (7)$$

internal power generated

$$P_{int} = \eta_{int} \times \frac{i}{e} \times hf$$

$$P_{int} = \eta_{int} \times \frac{hci}{e\lambda} = W$$

$$\eta_{int} = \frac{1}{1 + \frac{r_{nr}}{r_r}}$$

$$\tau_r = \frac{\Delta n}{r_r}, \quad \tau_{nr} = \frac{\Delta n}{r_{nr}}$$

$$\eta_{int} = \frac{1}{1 + \frac{\tau_r}{\tau_{nr}}}$$

$$\frac{1}{\tau_t} = \frac{1}{\tau_r} + \frac{1}{\tau_{nr}}$$

$$\eta_{int} = \frac{\tau_t}{\tau_r}$$

$$R = \frac{\overset{\text{flux}}{\phi_o}\, \overset{\text{energy of photon}}{h\nu}}{\underset{\text{Total current of the device}}{I}}$$

$$= \frac{\phi_o h\nu}{P_e q} = \eta_o \frac{h\nu}{q}$$

$$R = \frac{1.24}{\lambda(\mu m)} \eta_o \ A/W \qquad P = \eta_o I \times \frac{h\nu}{q}$$

Q Calculate the Responsive net of led given that that $\eta_o = 3\%$ and $\lambda = 1\mu m$

$$R = 1.24 \times 0.03$$

Q- Calculate the output power for an $n^+ - p$ (one side is high doped) of GaAs LED with electron current of 1.0 mA and efficiency $\eta_o = 50\%$.

Ans = 0.7 mW

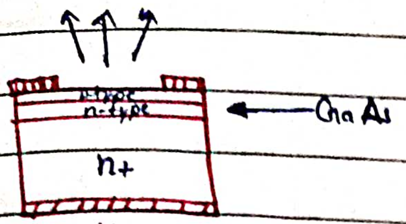
Radiative and non-radiative recombination of an minority carrier in active region of an LED are 60 ns and 100 ns respectively.

i) Determine the total carrier recombination life time.

ii) Power internally generated with in the device when the peak generation emission wavelengh is 0.87 μA. and device current is 40 mA.

Camlin Page
Date / /

31/10/22 [Aniruddha Sir]

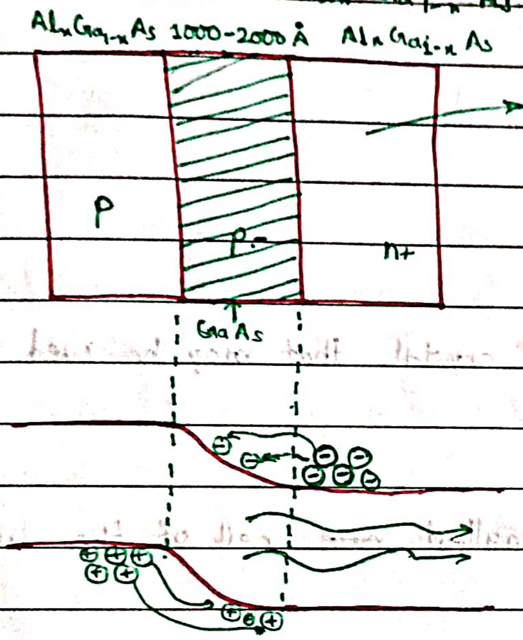


Homo junction LED

① The absorption of photon in the p-type side (low)

②

Heterojunction LED $Al_x Ga_{1-x} As$



Q- Definitions of the radiative and non radiative combinations

Q- The problem find out in homojuction and it's removal with introduction of homogenous led.

Q-

Date / /

Crystal Structure

Amorphous →

Polycrystalline →

Crystalline →

Lattice ← lattice point

↑ arrangement of atoms

Unit cell

A small volume of the crystal that may be used to reproduce the entire crystal.

Primitive cell

The primitive cell is smallest ~~one~~ cell of the unit cell

Basis

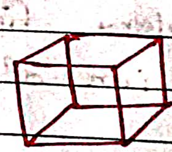
No. of atoms like diatomic (NaCl), triatomic.

Basis + lattice = crystal

Crystal structure

Cubic
1. Simple
2. Body centered cubic (BCC)
3. FCC

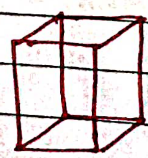
} 3



Nature of unit cell : $a = b = c$, $\alpha = \beta = \gamma = 90^\circ$

Tetragonal
1. Simple
2. Body centered

} 2



$a = b \neq c$

$\alpha = \beta = \gamma = 90^\circ$

Orthorhombic

① Simple
② Body
③ Face
④ Hexagonal

$a \neq b \neq c$
$\alpha = \beta = \gamma = 90^\circ$

Monoclinic

① Simple
② Body

} → ②

$a \neq b \neq c$
$\alpha = \beta = 90^\circ \neq \gamma$

Triclinic

① Simple

$a \neq b \neq c$
$\alpha \neq \beta \neq \gamma \neq 90^\circ$

Trigonal

Simple

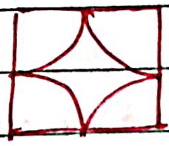
$a = b = c$
$\alpha \neq \beta \neq \gamma \neq 90^\circ$

Hexagonal

simple

$a = b \neq c$
$\alpha = \beta = 90^\circ, \gamma = 120^\circ$

Packing efficiency



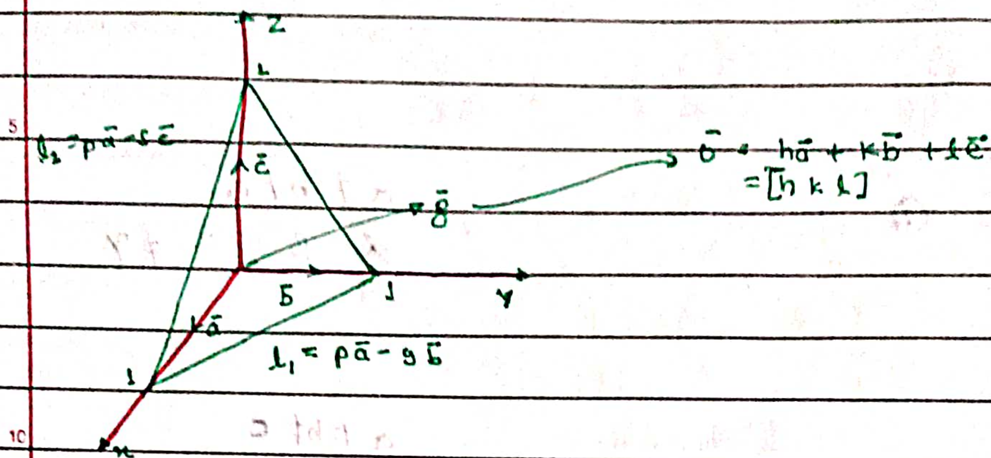
$$P.E. = \frac{\frac{4}{3}\pi r^3}{8 r^3} = \frac{\pi}{6} = \frac{3.14}{6}$$

$$= 0.523$$

$$P.E.\ \% = 52.3\ \%$$

03/11/22 [ANM]

Crystal plane and Miller indices



Imperfection of solids (crystals)

1) Thermal vibrations ⟶ point defects ⟶ schottky defects (anions and cations leave together)
   ⟶ Frankel defects

2) Compositional defects ⟶ ~~Computational defects~~ Substitutional Defects
   ⟶ ~~&~~ Interstitial defects.

3) Line defects · ⟶ Edge dislocation
   ⟶ Screw dislocation

4) Surface defects ⟶ Grain boundaries
   ⟶ Twin boundary
   ⟶ Tilt boundary
   ⟶ Staking fault

Schottky defect — In the case of schottky defect, if an atom displace from ~~the~~ its lattice side to the surface to make the charge neutrality, the opposite side atoms will also move from opposite side from its regular lattice position so the ~~combitric~~ combination of vacancies and imperfections will be created. This kind of defects can be obtained in ionic crystals where ions of both type (cation and anions) migrate to the crystal surface leaving a vacancy on both ionic sides.

and thus maintain charge neutrality of the crystal.

Frenkel defect : If the charge neutrality is maintained by having a positive ion in an interstitial position the pair constitute the frenkel defects, closely related to the interstial.

Schotty defects :

n = no. of vacant side

N = no. of atoms

Probability $P = \left(\frac{N!}{(N-n)!\, n!} \right)^2$

$$S = k_B \log P$$
$$= k_B \log \left[\frac{N!}{(N-n)!\, n!} \right]^2$$

from free energy eq —

$$F = U - TS$$
$$= nE_p - TS$$
$$= nE_p - 2k_B T \log \left[\frac{N!}{(N-n)!\, n!} \right]^2$$

$$= nE_p - 2k_B T \times 2 \left[\log N! - \log (N-n)! - \log n! \right]$$
$$= nE_p - 2k_B T \times 2 \left[N \log N - (N-n) \log (N-n) - n \log n \right]$$

04/11/22 [ANB]

$$F = nE_p - 2K_BT\,[N\log N - (N-n)\log(N-n) - n\log n]$$

$$\left(\frac{dF}{dn}\right)_T = E_p - 2K_BT\log\left(\frac{N-n}{n}\right) = 0$$

$$\frac{E_p}{2K_BT} = \log\left(\frac{N-n}{n}\right)$$

$$\frac{N-n}{n} = \exp\left(\frac{E_p}{2K_BT}\right)$$

$$n = N\exp\left(-\frac{E_p}{2K_BT}\right)$$

$$n << N$$

$$\frac{n}{N} = \exp\left(\frac{-E_p}{2K_BT}\right)$$

$$= \exp\left(\frac{-2.02}{0.025}\right)$$

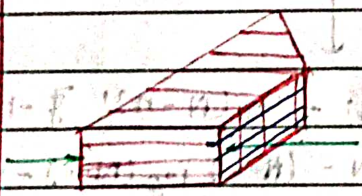
$$= \exp(-40.4)$$

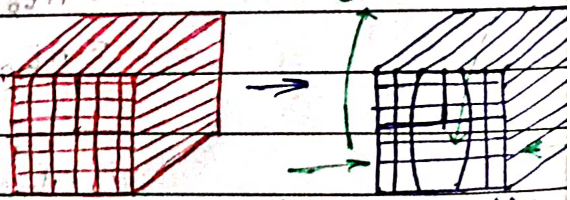
$$\frac{n}{N} = 2.8\times10^{-18}$$

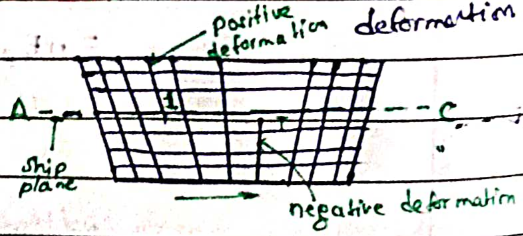
- The magnitude of deformation
- Discretion of the deformation

Edge dislocation

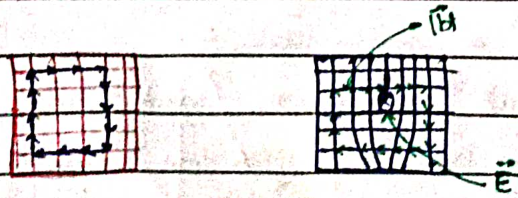
Compositional defects.

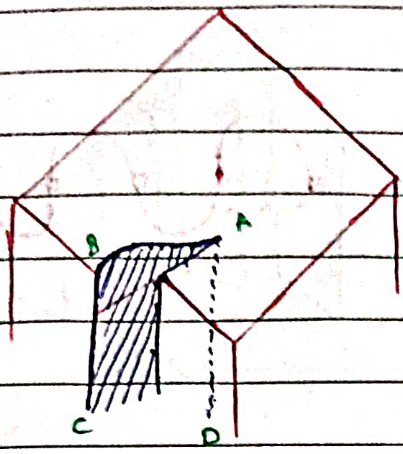


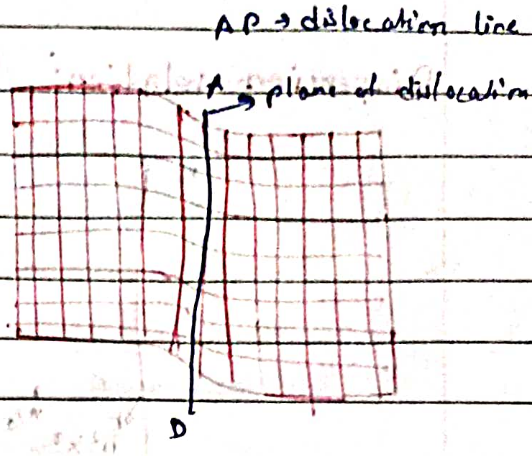


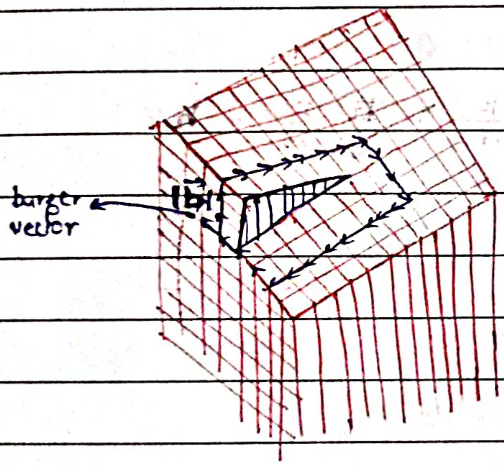


Burger ~~disl~~ dislocation





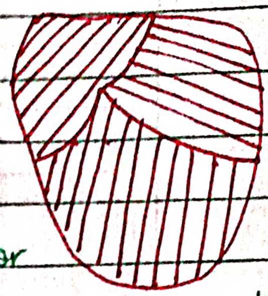




Screw dislocation is parrallel to the direction the burger vector

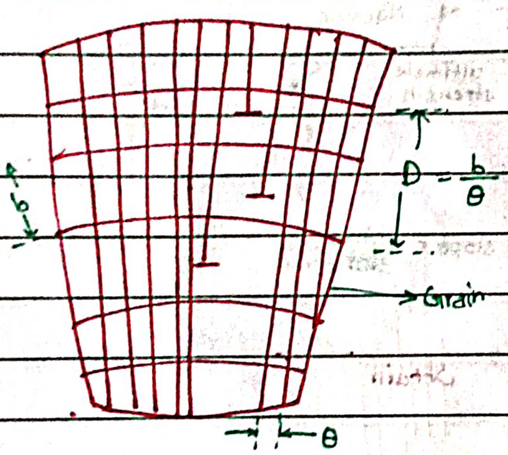
10/11/22

Grain boundaries



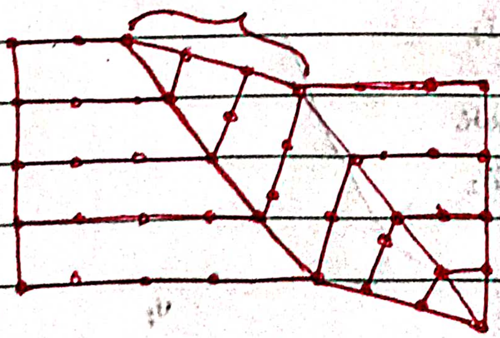
- **Tilt boundaries: ($\theta < 10^\circ$)**

The tilt boundary another surface in perfection which is known as small angle boundary or orientation difference between two neibhouring crystals less than 10°. The low angle boundary can be described by suitable arrays of dislocation.



- **Twin boundaries**

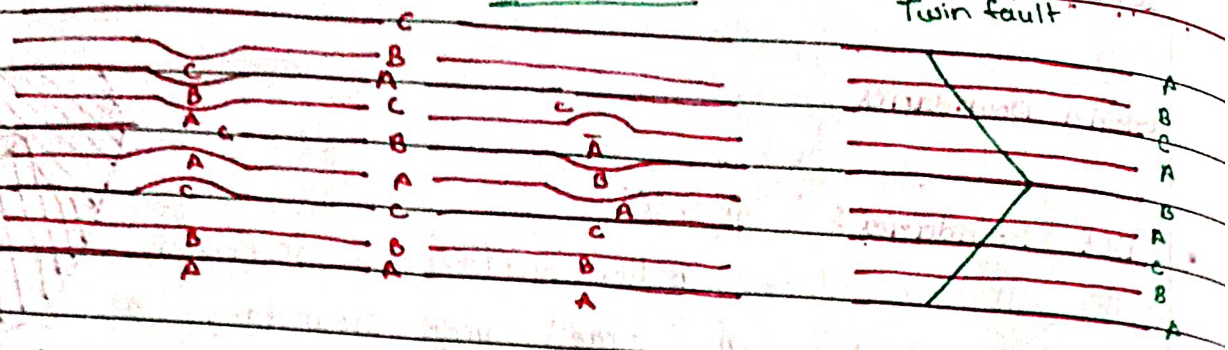
The atomic arrangement on one side of a twin boundaries is a mirror reflection of the arrangement of the other side



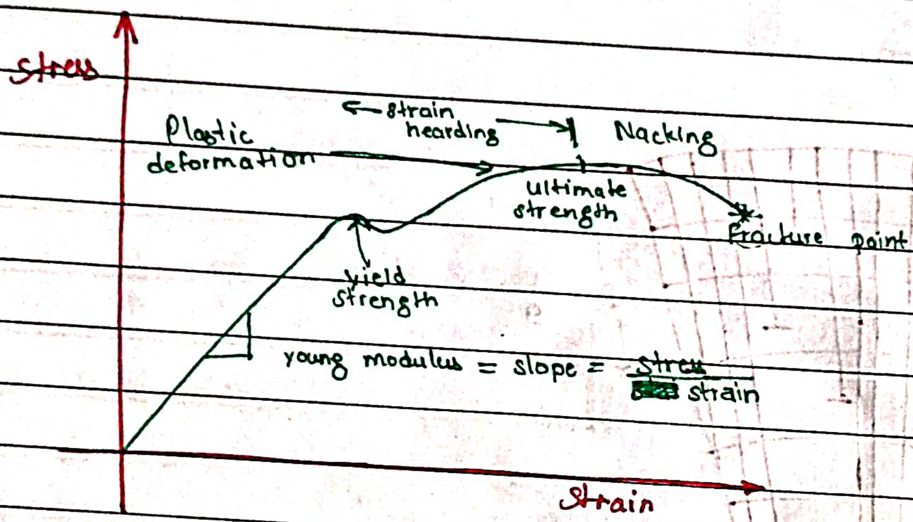
- **Stacking defects**

Staking fault is a fault in surface imperfection that aries from stacking of one atomic plane out of sequence of another while the lattice on either side of the fault is perfect.

Intrinsic fault   Extrinsic fault   Twin fault



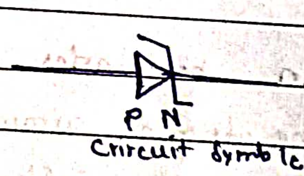
ABC AC ABC

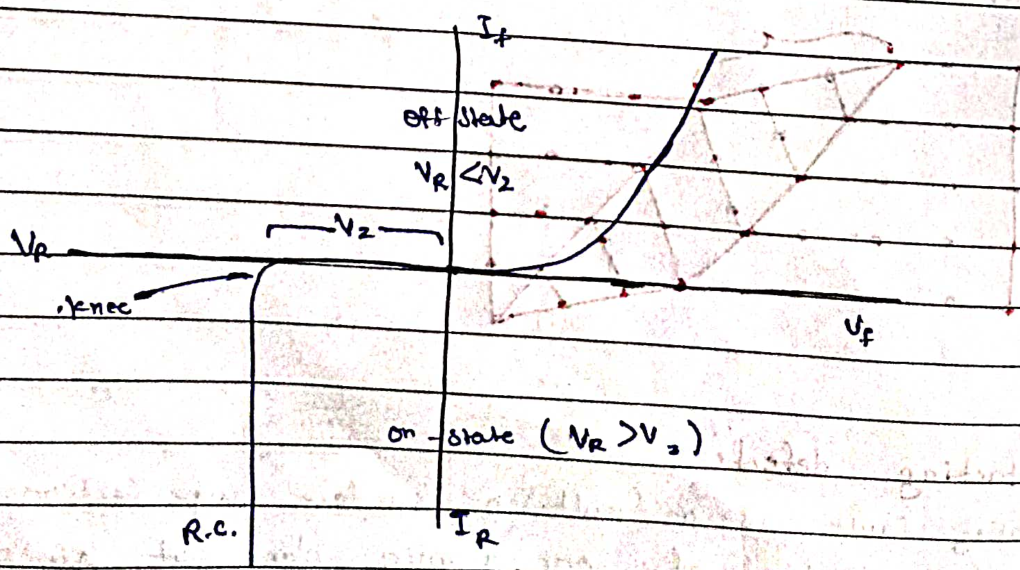


11/11/22

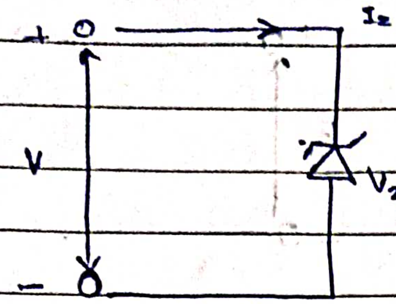
Zener diode

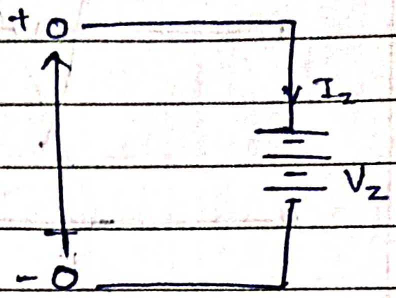
1. Highly doned - P-N Junction
2. The breakdown in zener breakdown





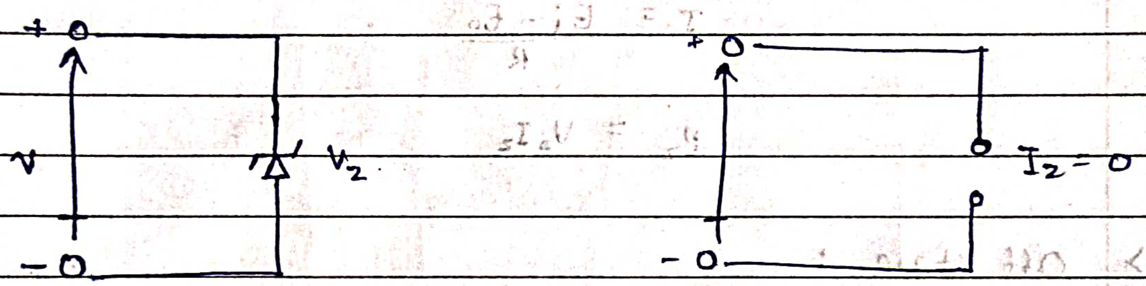
① On state :-





$V \geq V_z$

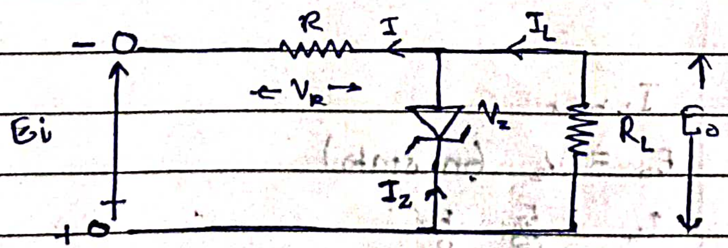
② OFF State :



$V_z > V > 0$

Zener Diode as a voltage stablisation

$I_z + I_L = I$



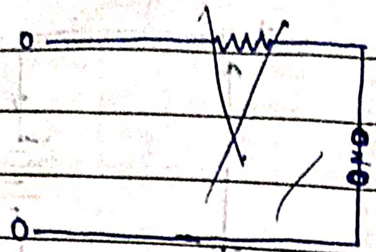
$V_R = E_i - E_o$

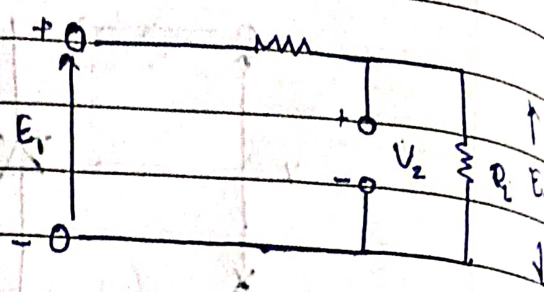
$I = I_z + I_L$

$$R = \frac{E_i - E_o}{I_z + I_L}$$

$$E_o = \frac{R_L E_i}{R + R_L}$$

① E_i and R_L fixed : $V_z = E_o = \dfrac{R_L E_i}{R + R_L}$ ① on state





$$I_z = I - I_L$$

$$I_L = \frac{E_o}{R_L}$$

$$I = \frac{E_i - E_o}{R}$$

$$P_z = V_z I_z$$

ii) Off state :

$\cancel{V_z = E_o}$ = ~~+~~ $\quad I = I_L \quad , \quad I_z = 0$

$V_R = E_i - E_o \quad , \quad V = E_o \quad (V < V_z)$

$P_z = V \times I_z = 0$

② Fixed E_i but variable R_L

① R_L min and I_L max

$E_o = V_z$ (on state)

$I_L = \dfrac{E_o}{R_L}$

$$E_o = V_z = \frac{R_{L\,min} V_i}{R + R_{L\,min}}$$

$$R_{L\,min} = \frac{R V_z}{E_i - V_z} \longrightarrow \text{on state}$$

ii) I_L min and R_L max

$$I_z = I - I_L$$

$$I_{L\,min} = I - I_{zm}$$

$$R_{L\,max} = \frac{E_o}{I_{L\,min}} = \frac{V_z}{I_{L\,min}}$$

③ Fixed R_L but variable E_i:

i> $E_{i\,min}$

$$E_o = V_z$$

$$E_o = V_z = \frac{R_L E_i}{R + R_L}$$

$$E_{i(min)} = \frac{(R+R_L)\,V_z}{R_L}$$

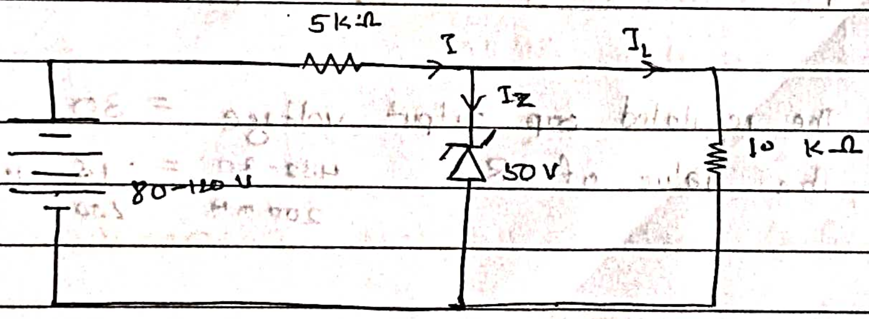
ii> $E_{i\,(max)}$

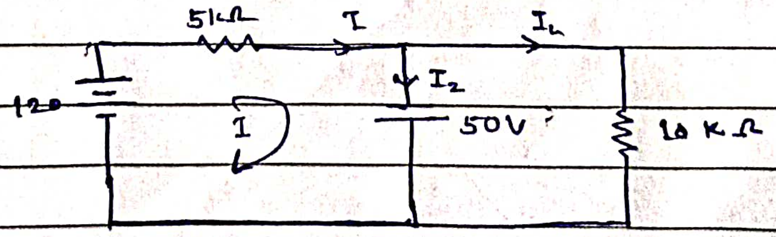
$$I = I_z + I_L$$

$$I_{max} = I_{zm} + I_L$$

$$E_{i\,(max)} = I_{max} R + V_z$$

Q-





$I_L(max) = 9\ mA$

$I_z\ min = 1mA$

$$-5\times10^3\, I + 50 + 120 = 0$$

$$I = \frac{-120}{+5\cancel{0}\times10^3} \Rightarrow I = 34\,mA$$

$$-10 I_L \times 10^3 - 50 = 0$$

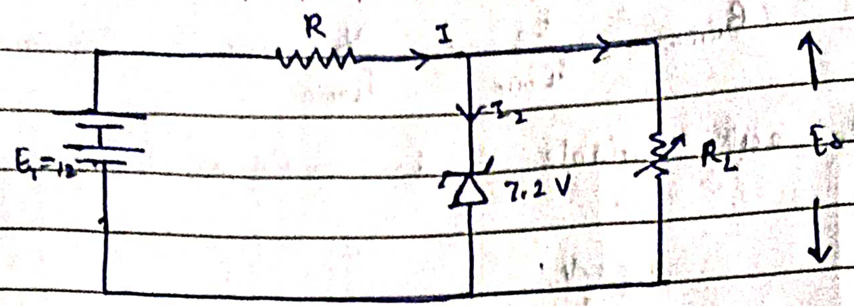
$$I_L = \frac{5\cancel{0}}{1\cancel{0}} \Rightarrow I_L = 5mA$$

$$I_z = I - I_L = 29\ mA$$

$$120 = I \times 5\times10^3 + 50$$

$\frac{7\cancel{0}}{5}$ = 14mA

Q

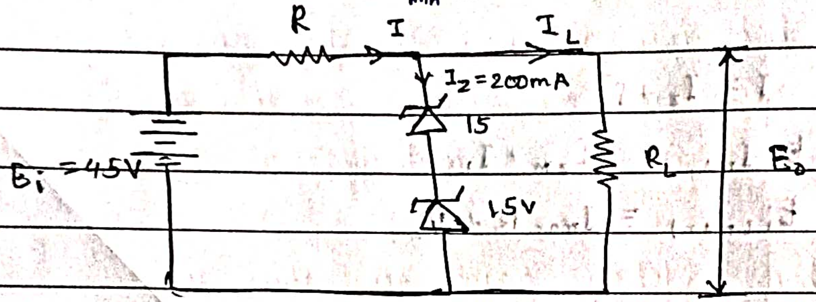


$I_{z\,min} = 10\ mA$

$I_L \neq 12$ to $100\ mA$

$R = \dfrac{E_i - E_o}{(I_z)_{min} + (I_L)_{max}} = 48.5\ \Omega$

Q -



① The regulated ~~exp~~ output voltage = 30

② The value of R $\dfrac{45 - 30}{200\ mA} = \dfrac{15}{200}$ k Ω