SketchBook

Brush Properties

Felt Tip Pen

Marker

Basic | Advanced

Size 3.2

Flow 60%

Wetness 100%

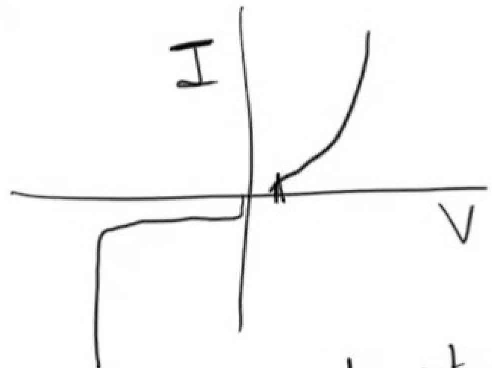
Layer Editor

Normal

Background

(16)

VI characteristics Equation of Diode



V I characteristic

I_o = reverse satn current.

$$\boxed{I = I_o\left(e^{V/\eta V_T} - 1\right)}$$

where Shockley eqn

I = current

V = applied voltage (+ve for FB & −ve for RB)

η = constant = 1 for Ge
= 2 for Si

V_T = volt ~~of e~~ equivalent of temp
= $T/11600$ where T is temp in °K

At Room temp $V_T = 26$ mV.

ENG 13:40

18

$$I = I_0\left(e^{V/2V_T} - 1\right)$$

~~Si~~ Ge Diode

RT

$V = 0.5\,V$ in FB & $-0.5\,V$ in RB

$I_0 = 10\,nA$

FB

$$I = 10\times10^{-9}\left(e^{\frac{0.5}{1\times26\times10^{-3}}} - 1\right) = \cancel{2.248\,mA}$$

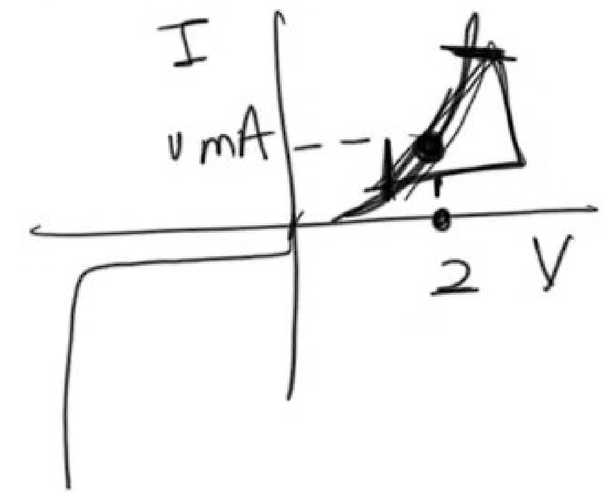
RB

$$I = 10\times10^{-9}\left(e^{\frac{-0.5}{1\times26\times10^{-3}}} - 1\right) = -10\,nA$$

(9)

Dynamic resistance of diode

$$\boxed{R = V/I}$$



$V = 2V \quad I = 1mA$

$$\boxed{R = \frac{V}{I}} = \frac{2}{1mA} = 2k\Omega$$

→ static resistance. (DC value)

Dynamic resistance
$$\boxed{r = \frac{\Delta V}{\Delta I} = \frac{V_2 - V_1}{I_2 - I_1}}$$ → AC values

19

Dynamic resistance expression

$$r = \frac{dV}{dI}$$

$$I = I_o\left(e^{V/\eta V_T} - 1\right) \longrightarrow (1)$$

differentiate I with respect to V

$$\frac{dI}{dV} = \frac{I_o e^{V/\eta V_T}}{\eta V_T} \checkmark$$

$$\Longrightarrow \boxed{r = \frac{dV}{dI} = \frac{\eta V_T}{I_o e^{V/\eta V_T}}}$$

$$\boxed{r = \frac{dV}{dI} = \frac{\eta V_T}{I + I_o}}$$

20

$$I = I_o\left(e^{V/\eta V_T} - 1\right)$$

$$I = I_o e^{V/\eta V_T} - I_o$$

$$\boxed{I + I_o = I_o e^{V/\eta V_T}}$$

$$r = \frac{\eta V_T}{I_o e^{V/\eta V_T}} \Rightarrow$$ dynamic resistance in terms of applied voltage V

$$r = \frac{\eta V_T}{I + I_o} \Rightarrow$$ dynamic resistance in terms of current through diode

21 — Numerical

For a Ge Diode, reverse saturation current is $2\mu A$, what will be the forward & reverse dynamic resistance at an applied voltage of $0.26V$ at RT

Given

$I_0 = 2\mu A$

$V_T = 26\,mV$

$\eta = 1$

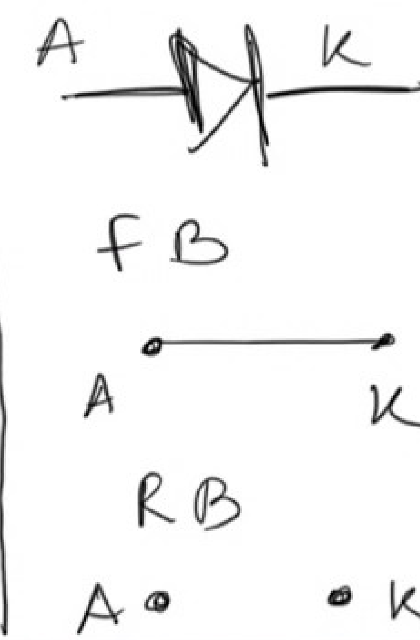
$$r = \frac{\eta V_T}{I_0 e^{V/\eta V_T}}$$

$\boxed{FB} \Rightarrow V = 0.26\,V$

$$\boxed{r_f = 0.59\,\Omega}$$

$\boxed{RB} \Rightarrow V = -0.26\,V$

$$\boxed{r_r = 286\,M\Omega}$$



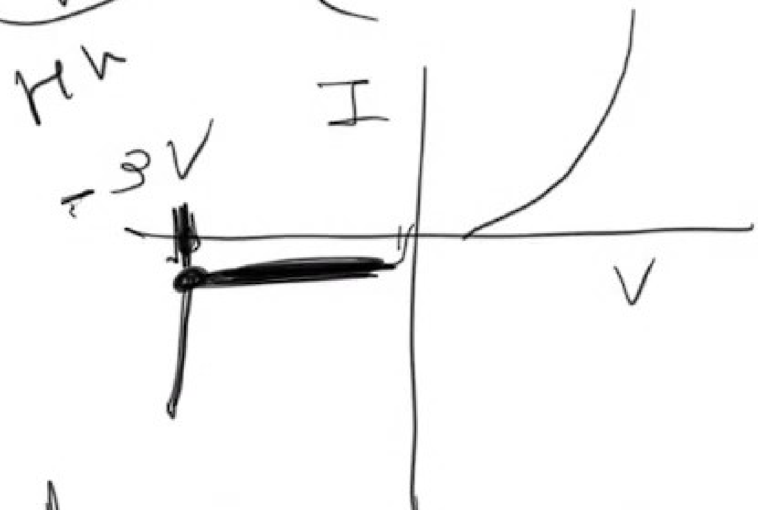
(22)

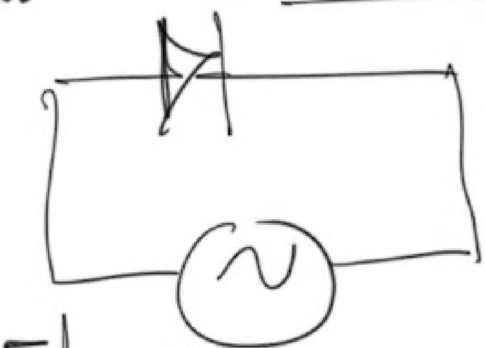
Peak Inverse voltage Rating of Diode

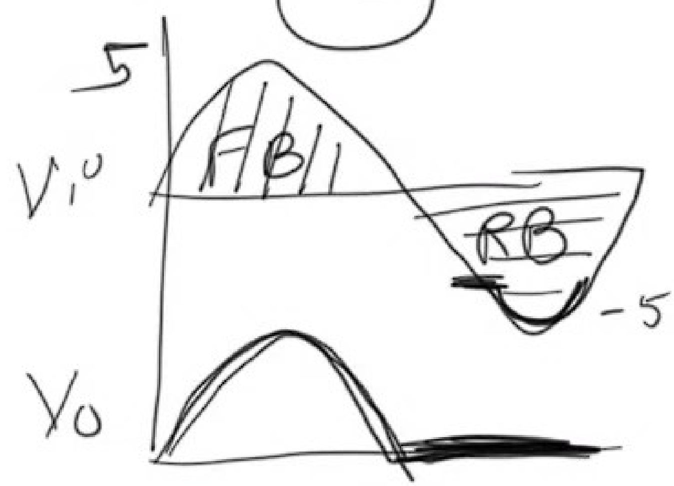
(PIV rating)

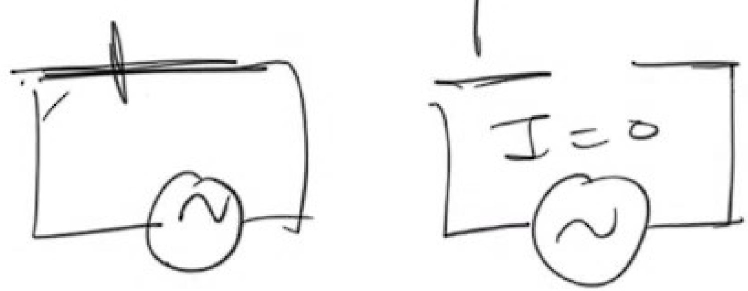
Define

Rectifire

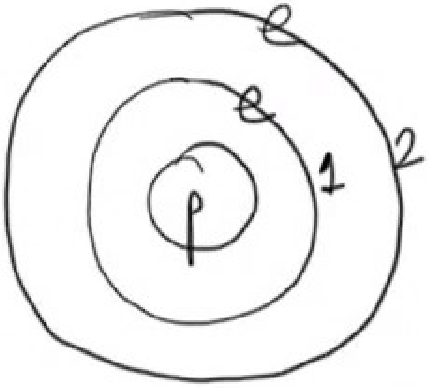








Atom



energy level of $el^{e}s$

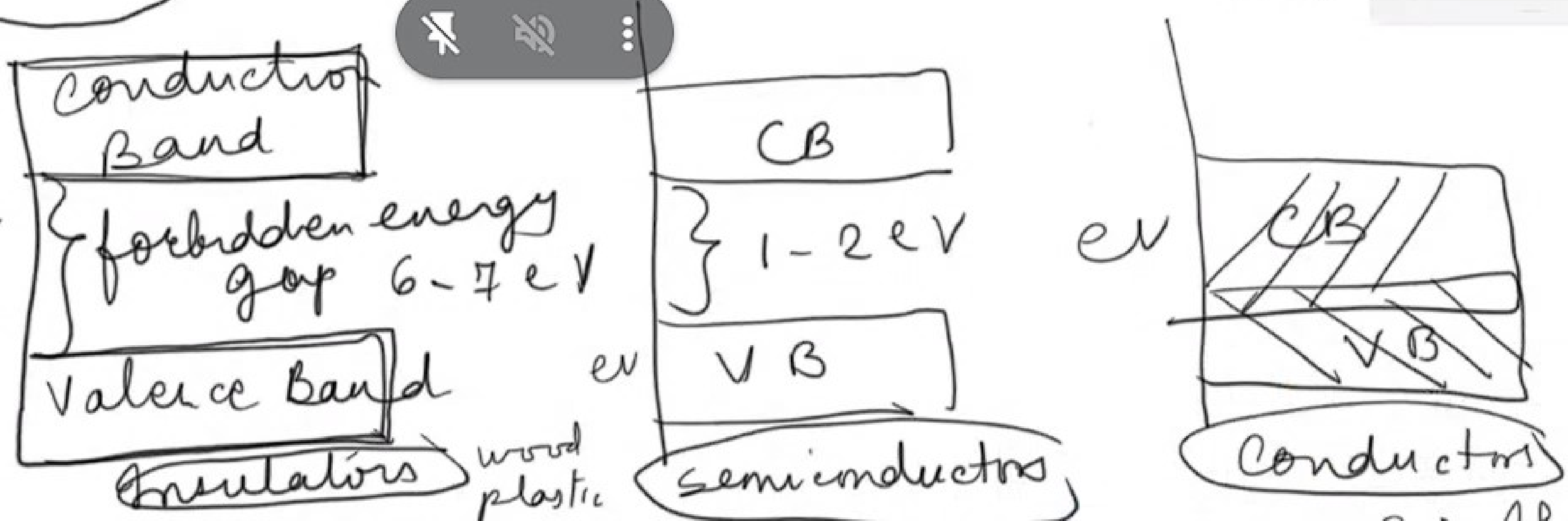
inner band → valence band

energy level ↑

Classification based on energy band dia

Energy level

eV



Energy band diagram

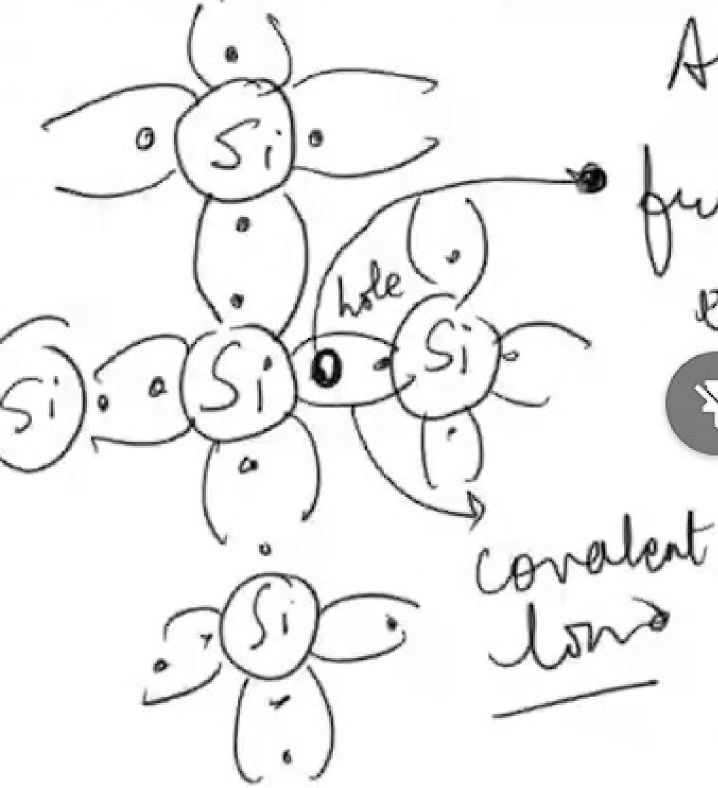
Si, Ge

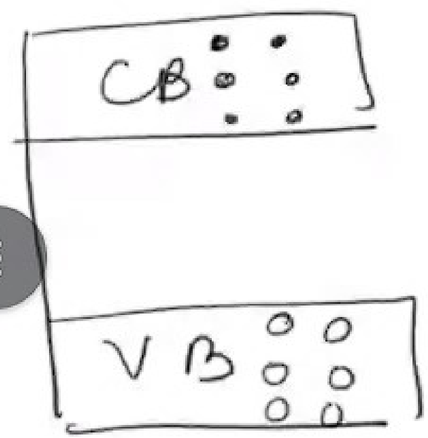
Si; Al, Cu

Intrinsic Semiconductor (Pure)

Si & Ge → Tetravalent

At 0° Kelvin $(-273°C)$





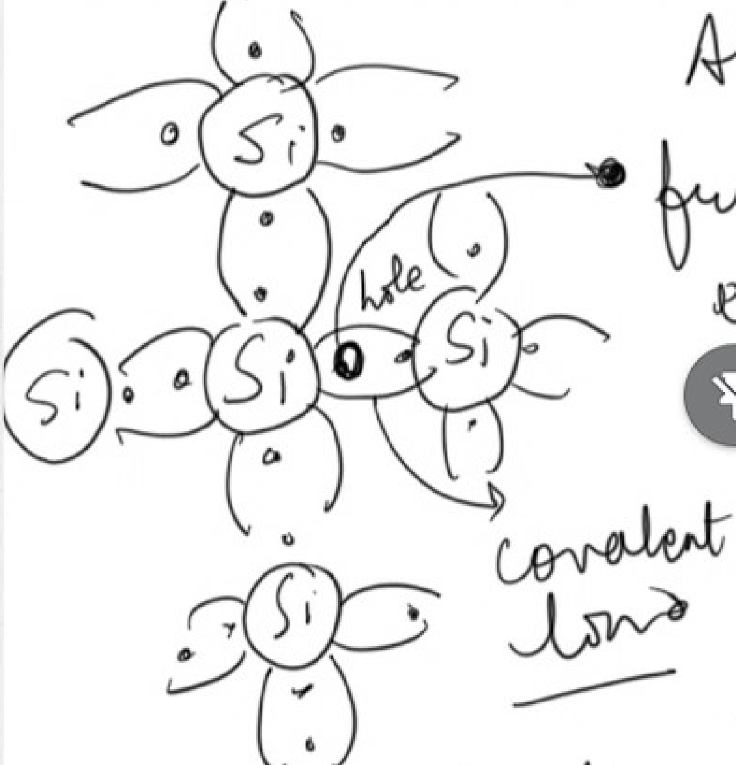
1) no of holes = no of el's
2) formation of hole el pair → increase in temp.
3) $n = p = n_i$ → intrinsic carrier concentration

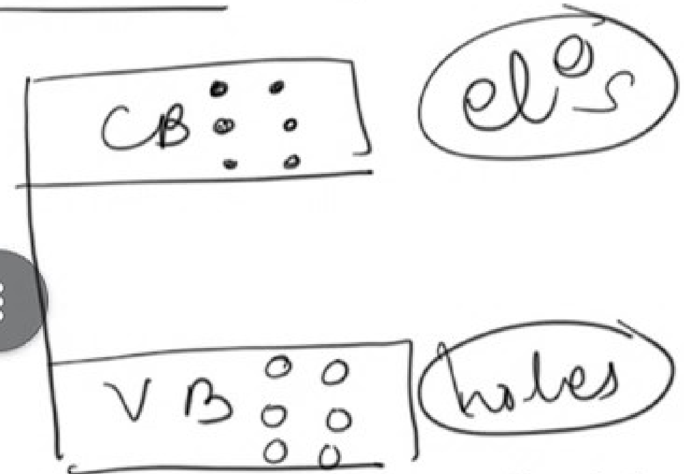
$/cm^3$ $/cm^3$

(2) Intrinsic semiconductor (Pure)

Si & Ge → Tetravalent

At 0° Kelvin ($-273°C$)





1) no of holes = no of el$^{\ominus}$s
2) formation of hole el$^{\ominus}$ pair → increase in temp.
3) $n = p = n_i$ → intrinsic carrier concentration

$/cm^3$ $/cm^3$

n_i = constant at a given temp

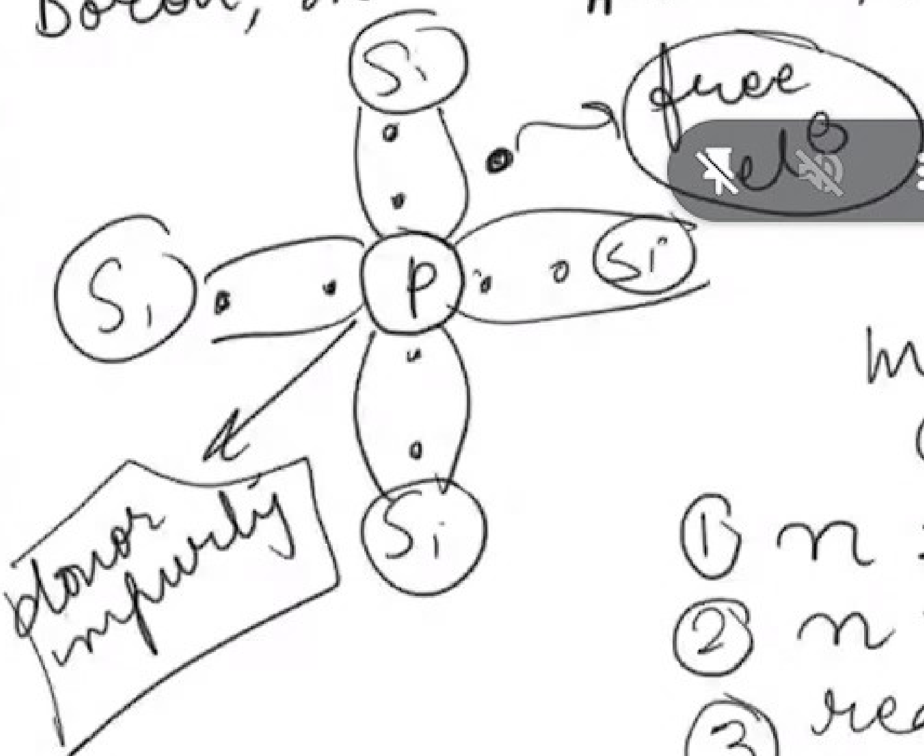
As temp ↑ n_i ↑

③

Extrinsic Semiconductor (Impurity addition)

Impurities

- Trivalent: Boron, In
- Pentavalent: Arsenic, Phosphorus



$\boxed{n >>> p}$

N Type semicond.

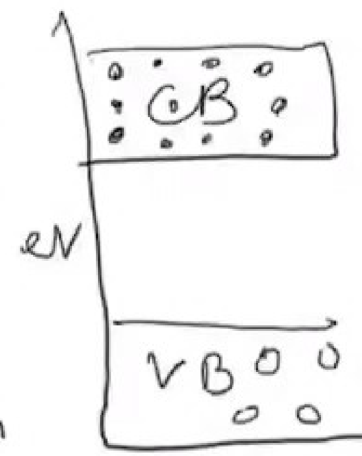
majority carriers

minority carrier

① $n = N_D$ → conc of donor impurity

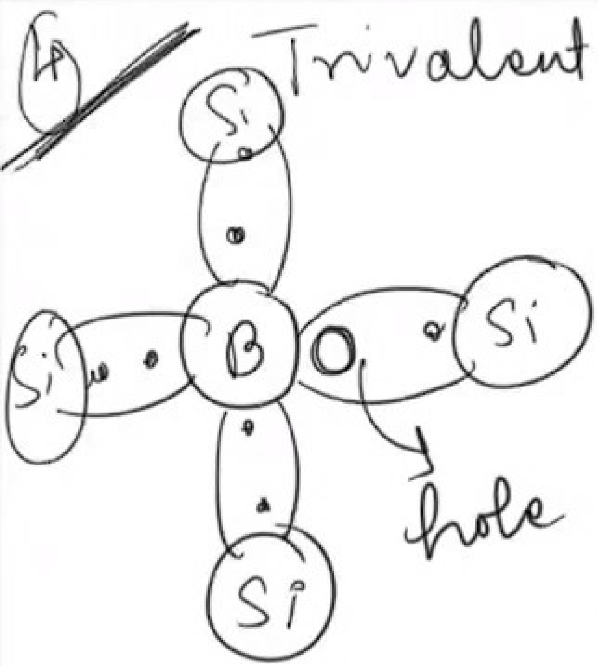
② $n >> p$

③ reason of majority carrier ⟶ Impurity



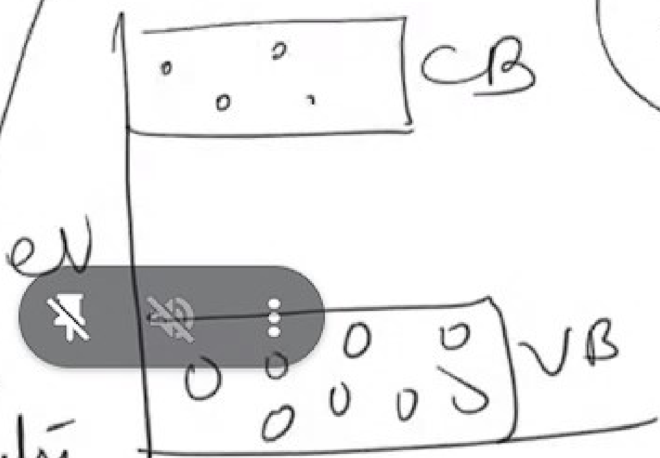
N Type

(4) Trivalent impurity



$p >> n$ → P Type semiconductor

minority carrier



majority carrier

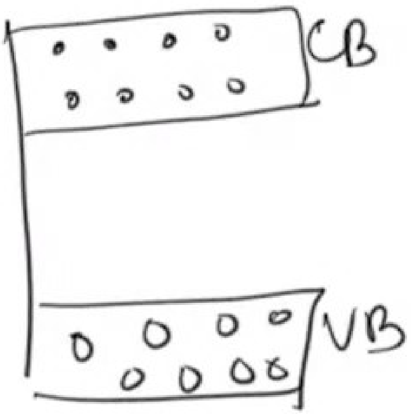
① $p = N_A$ conc of acceptor impurity

② $p >> n$ → p type semiconductor

③ Reason of majority carrier is doping

Extrinsic

Intrinsic

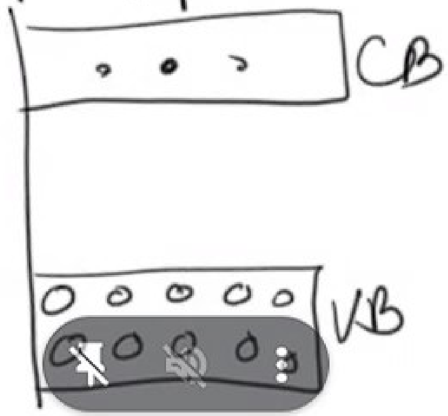


$n = p = n_i$

mass action law

$np = n_i^2$

p Type



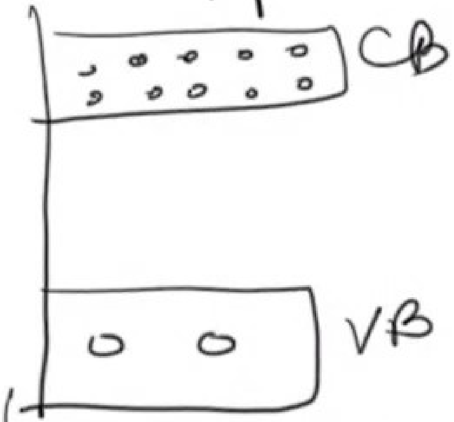
$p >> n$

$p = N_A$

acceptor impurity concentration

$np = n_i^2$

N Type



$n >> p$

$n = N_D$

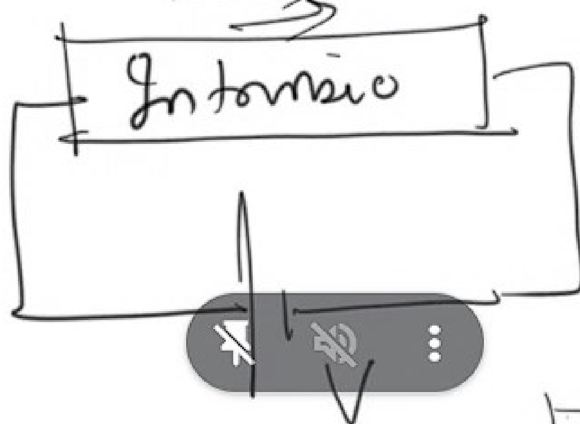
Donor impurity concentration

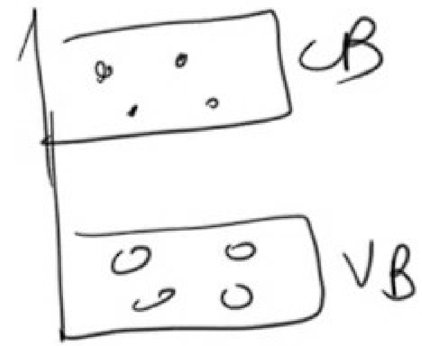
$np = n_i^2$

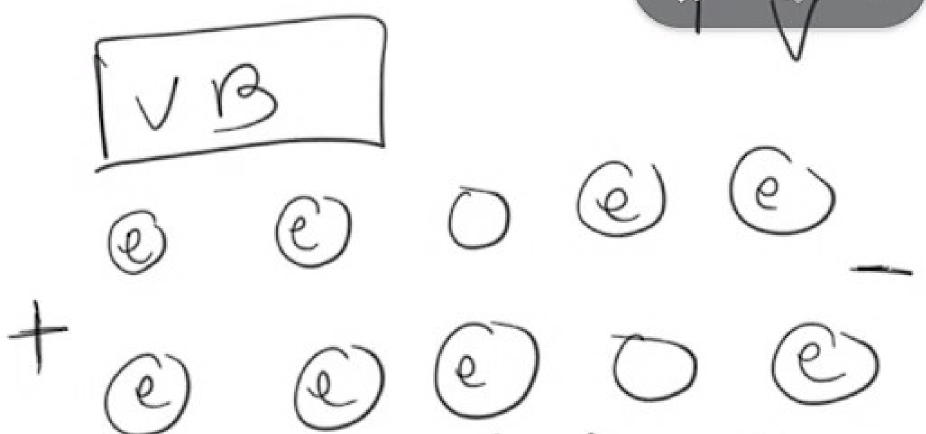
Mass action law states that hole e^- conc product is constant at given temp and is equal to n_i^2

(6) Conduction in semiconductor.

hole current   ele current







hole →

$$\boxed{J = J_n + J_p}$$

$\frac{A}{m^2}$ $\frac{A}{m^2}$

ele current → cond Band

hole current → val Band

(7) Current

Drift

(1) flow of electrons under the influence of applied E field

(2) A steady state velocity attained by e^-s under the influence of applied E field is called as drift velocity

$$\boxed{v = \mu E}$$

→ μ = mobility v^2/ms

E = applied E field V/m

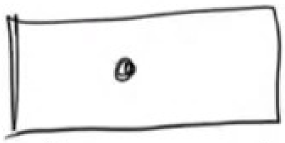
v = drift velocity

Diffusion

flow of e^-s due to non uniform doping

$$\boxed{\mu_p < \mu_e}$$

Drift current



N el's move from a pt in Time T

Current $I = \dfrac{Nq}{T} \rightarrow (1)$

But $v = \dfrac{L}{T}$ where L is the length of conductor

velocity

$\dfrac{1}{T} = \dfrac{v}{L}$

$I = \dfrac{Nqv}{L}$ But $v = \mu E$

Current $I = \dfrac{Nq\mu E}{L}$

current density $J = \dfrac{I}{A} = \dfrac{Nq\mu E}{LA}$

$\boxed{J = nq\mu E}$

n = Electron density/cm^3

Layer Editor

Normal

Background

Intrinsic S C

$J = J_n + J_p$

$= nq\mu_n E + pq\mu_p E$

μ_n = mobility of e^-

μ_p = " " holes

n → e^- concentration

p = hole concentration

E applied electric

$\sigma_n = nq\mu_n$ → conductivity of e^-s

$\sigma_p = pq\mu_p$ → conductivity of holes

resistivity $\boxed{\rho_n = 1/\sigma_n}$ $\boxed{\rho_p = 1/\sigma_p}$

Intrinsic

$$\boxed{J = \sigma_n E + \sigma_p E}$$

↓

conductivity of e^-

Extrinsic

n type

$J \simeq \sigma_n E$

$= nq\mu_n E$

p type

$J \simeq \sigma_p E$

$= pq\mu_p E$

ENG 14:17

10. Calculate majority & minority carrier conc in a silicon at room temp; if it is doped with

Case I $N_A = 10^{17}/cm^3$ **Case 2** $N_D = 5 \times 10^{15}/cm^3$

What is the type of semiconductor you get

Given $n_i = 1.5 \times 10^{10}/cm^3$

Find current density if $\mu_n = 0.14\ m^2/VS$

$E = 10\ V/m$ $\quad \mu_p = 0.05\ m^2/VS$

MA law

$np = n_i^2$

$n = \frac{n_i^2}{p}$

case 1 $N_A = 10^{17}/cm^3 \rightarrow$ p type

majority carriers $\boxed{p = N_A = 10^{17}/cm^3}$

minority carrier concentration $n = n_i^2/p$

$\boxed{n = 2.25 \times 10^3/cm^3}$

$\boxed{J = p q \mu_p E}$

In the previous numerical

case ③ → No doping

↳ intrinsic semicond

$$n = p = n_i = 1.5 \times 10^{10} / cm^3$$

$$J = J_n + J_p$$

$$= n q \mu_n E + p q \mu_p E$$

$$\sigma_n E + \sigma_p E$$

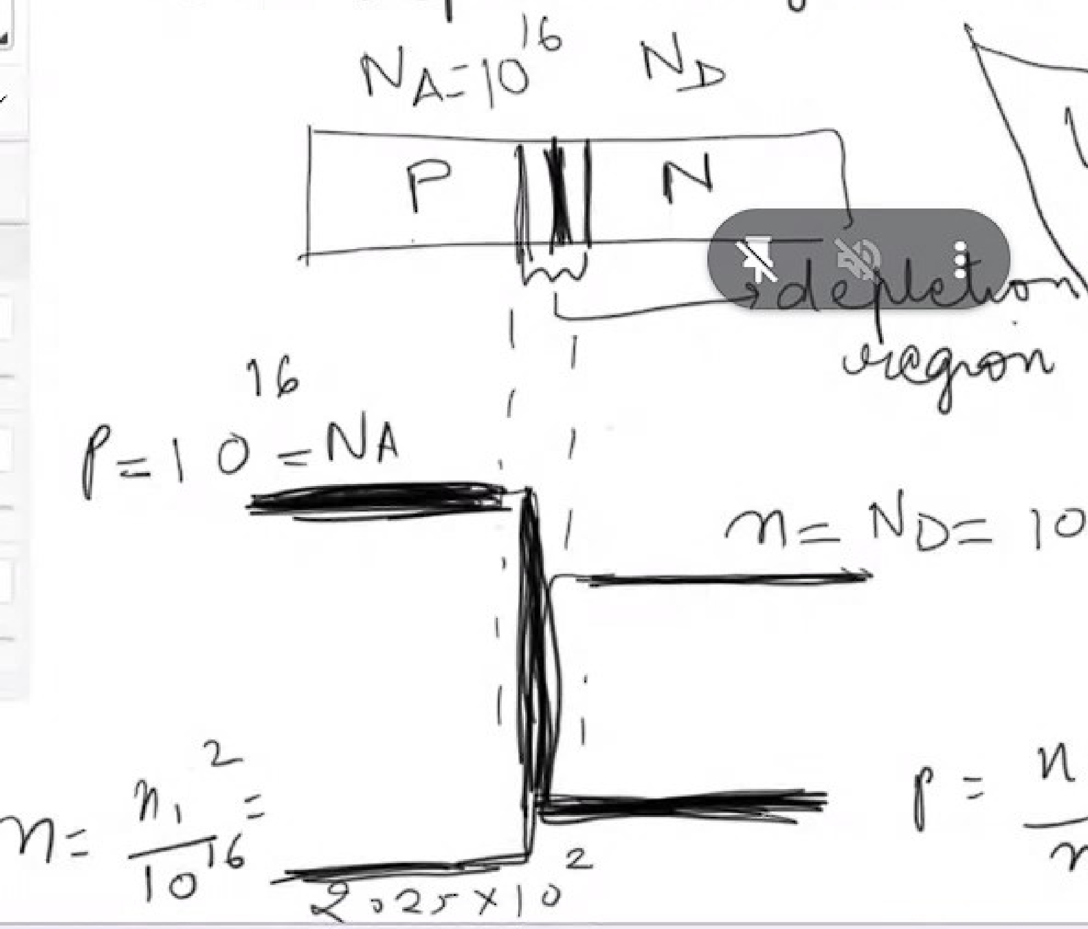
Layer Editor

Normal

Background

42. Sketch a plot of carrier concentration against distance for an abrupt Si junction $N_D = 10^{15}/cm^3$ $N_A = 10^{16}$ atoms/cm^3 label N, P and depletion region. Find Barrier potential

$n_i = 1.5\times10^{10}/cm^3$



$$V_B = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

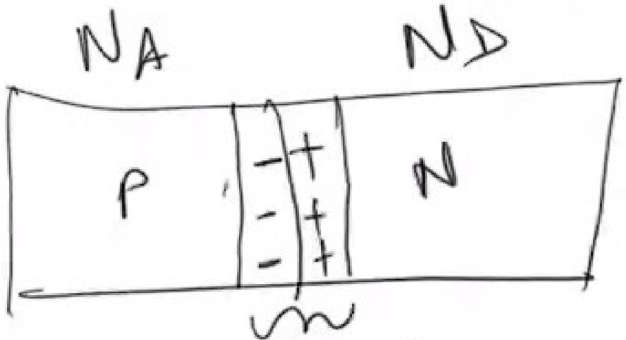
V_T = volt equivalen of temp = 26 mV at RT

$$p = \frac{n_i^2}{n} = 2.25\times10^{3}$$

$$\boxed{V_B = 0.637V}$$

13

P N Junction Diode



depletion region has no mobile Charge carriers

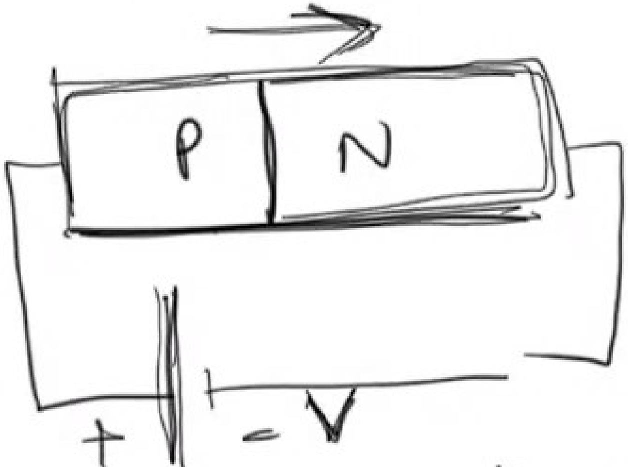
Charge carriers have a tendency to move from higher to lower concentration

$$\boxed{V_B = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)}$$

In order that majority carriers cross the junction and external voltage is to be applied which is greater than equal to Barrier potential V_B

14

FB



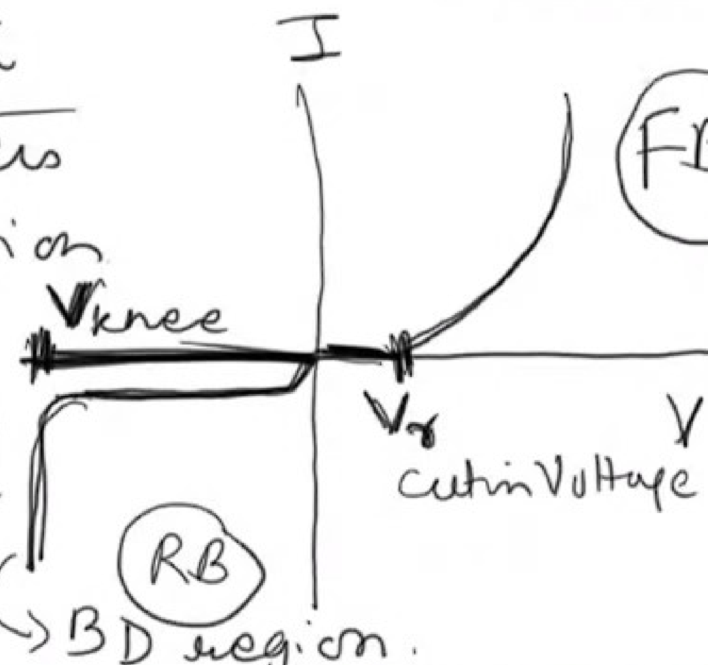
V_B = 0.2 to 0.3V for Ge

= 0.6 to 0.7 V for Si

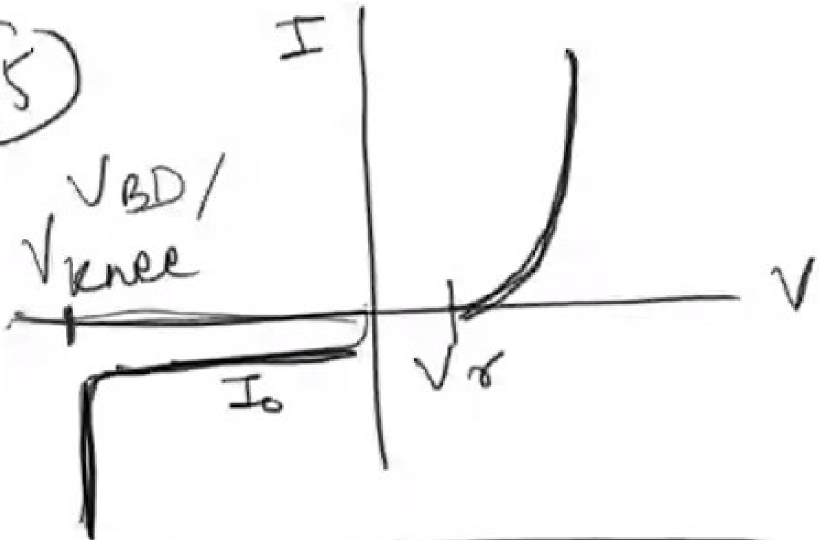
(1) In FB majority carrier cross the junction constituting current

(2) In RB majority carriers cannot cross the junction

But we get current due to minority carriers called leakage current or reverse saturation current



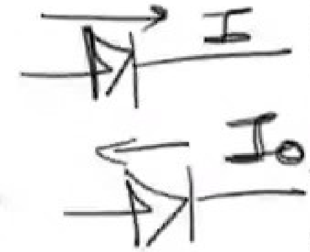
15



$\boxed{\text{V I characteristics of Diode}}$

Forward current } → majority carriers

Reverse current } → minority carriers.

FB 

I forward curve

RB I_o → leakage current

When

Reverse voltage ↑

kinetic energy ↑ of minority carrier

rupture covalent bonds ↑

hole electron pairs are formed

Hence minority carriers ↑

This process is multiplicative and gives ~~rise to~~ excessively large current

This is called as <u>Avalanche BD</u>.