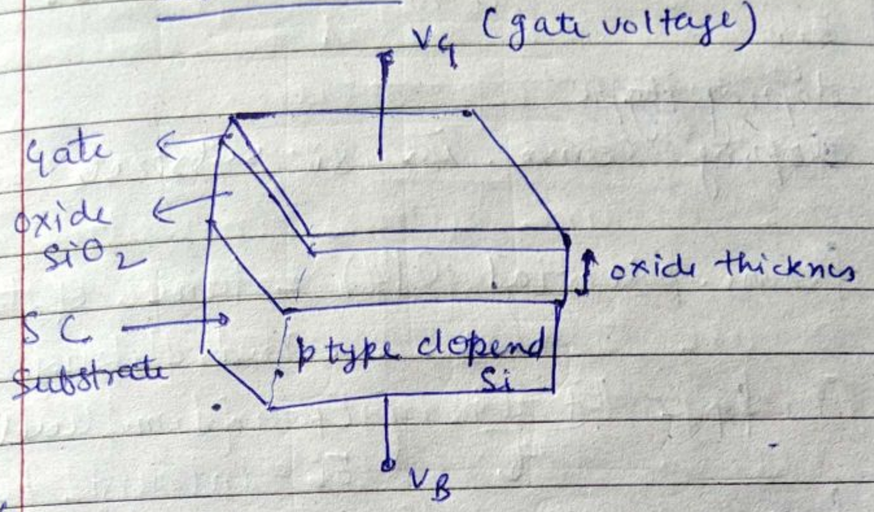
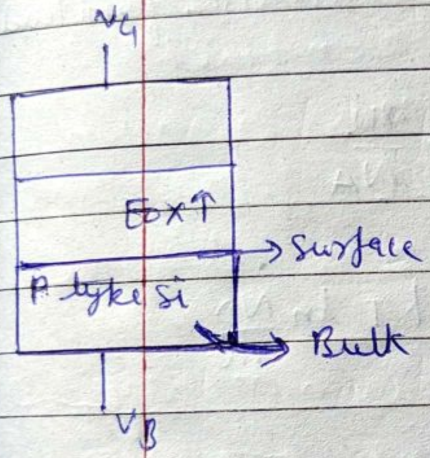
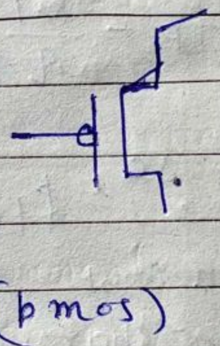
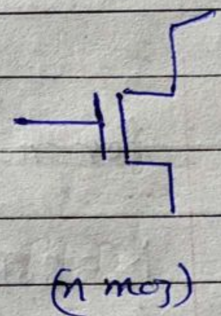
VLSI

The metal oxide semiconductor structure

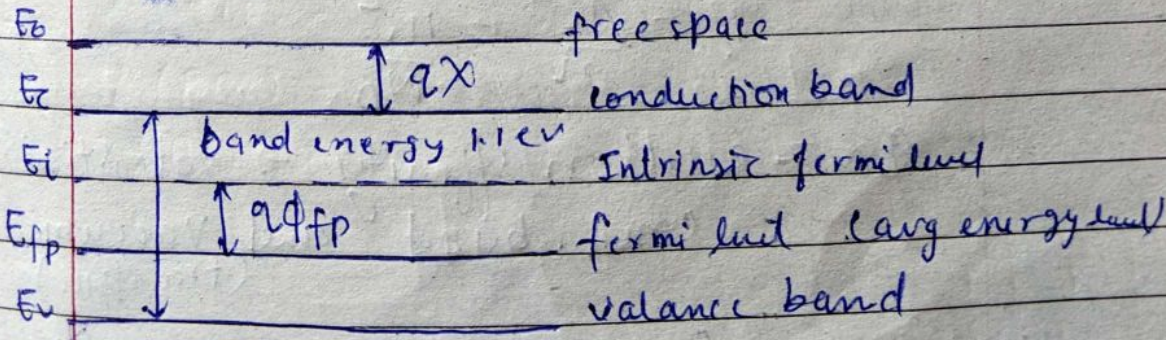








Energy band diagram of p-type Si substrate



$E_f = \frac{1}{2}$ (intrinsic)

Date
Page No.

Location of equilib fermi level within band gap is determined by
(i) doping type
(ii) doping conc. in Si substrate

fermi potential (ϕ_f) = func. of temp and doping

$$\phi_f = \frac{E_f - E_i}{q} \quad \left(\begin{array}{l} E_f = \text{fermi level} \\ E_i = \text{intrinsic fermi level} \end{array} \right)$$

for p-type sc,

$$\phi_{fp} = \frac{KT}{q} \ln \frac{n_i}{N_A}$$

for n-type sc, $\phi_{fn} = KT \ln \frac{N_D}{n_i}$

K = Boltzman const
q = unit (e⁻ charge)

$$n \cdot p = n_i^2$$
$$n = N_D$$
$$p = N_A$$
$$p = \frac{n_i^2}{n} = \frac{n_i^2}{N_D}$$

$q\chi$ = electron affinity → potential b/w cond. band and vaccum level (free space)

work function ($q\phi_s$) → energy required for an e⁻ to move from fermi level to free space

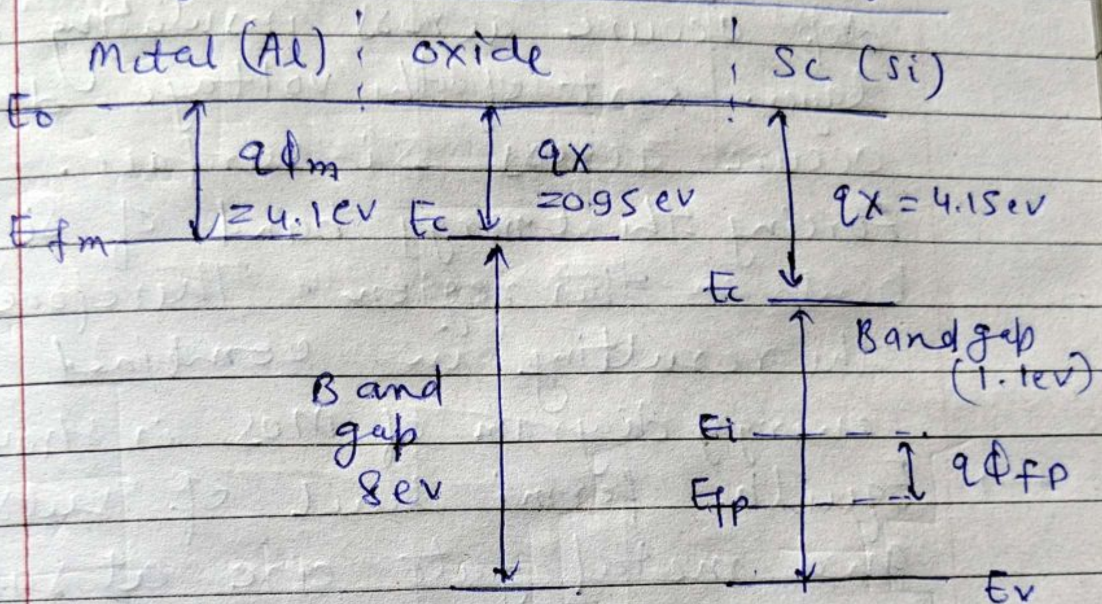
Date | Page No.

$\therefore q\phi_s = q\chi + (E_c - E_f)$

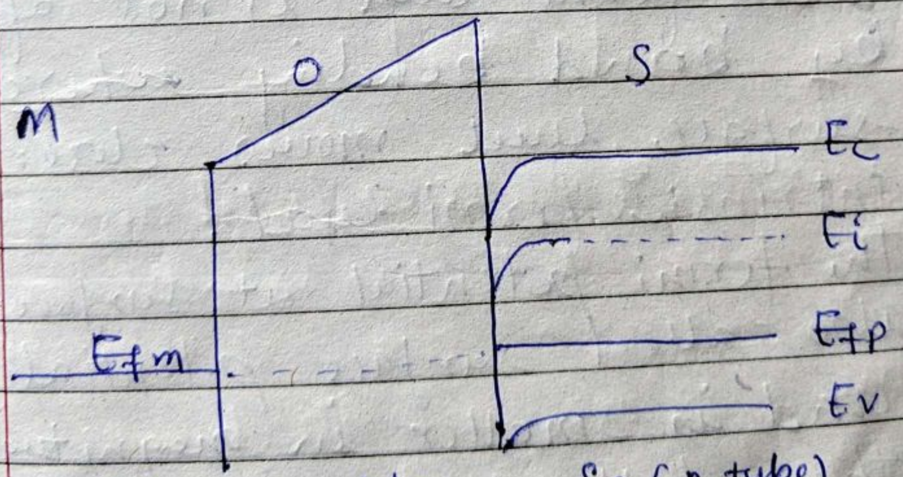
Band gap E_g of $SiO_2 = 8.8$ ev

$q\chi$ (Al gate) $= 0.95$ ev

Enogy band diagram of component of MOS system



const



energy band diagram of combined mos system

→ Consider a 3 comp of ideal MOS system because of work func difference b/w metal & semiconductor a voltage drop occures across MOS system. Built in voltage drop occure across insulating oxide layer. Rest of the voltage drop occure across Si surface. Forcing the Energy band of Si to bent in this region. Therefore the resulting in combined energy diagram of MOS is shown.

→ Equilb. fermi level of substrate and metal gate are at same potential.

→ Bulk fermi level is not affected by band bending whereas surface level moves closer to intrinsic fermi level.

→ The fermi potential at surface is also called surface potential ϕ_s. And is smaller in magnitude than bulk fermi potential ϕ_f.

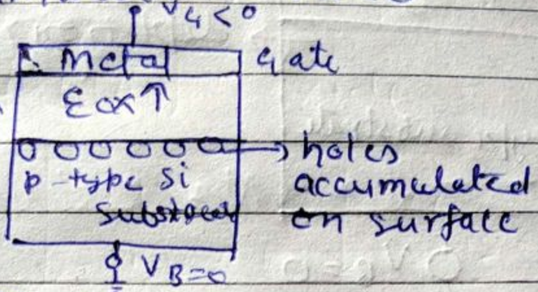
$$\phi_s < \phi_f$$

Scanned by CamScanner

MOS system under external bias

Assumption → $V_B = 0$
→ Gate voltage → V_G ⇒ controlling parameter

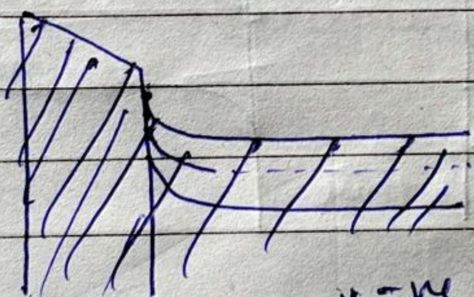
(1) Accumulation $V_G < 0$



3 Regions:

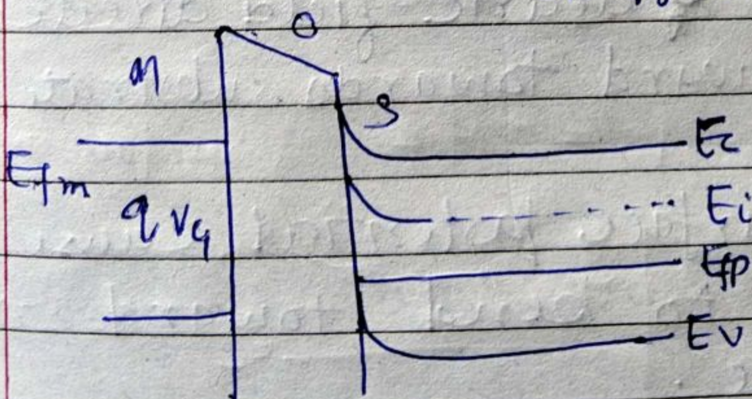
1. Accumulation region
2. Depletion region
3. Inversion region

(V)

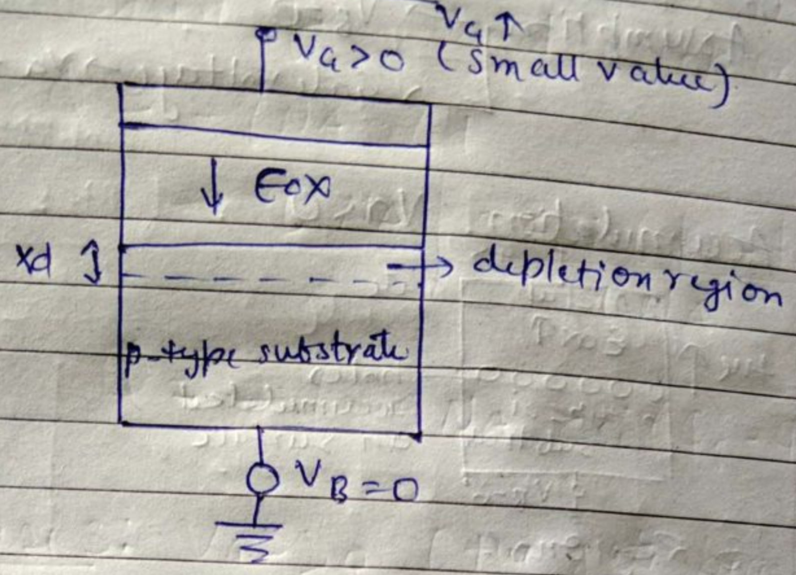


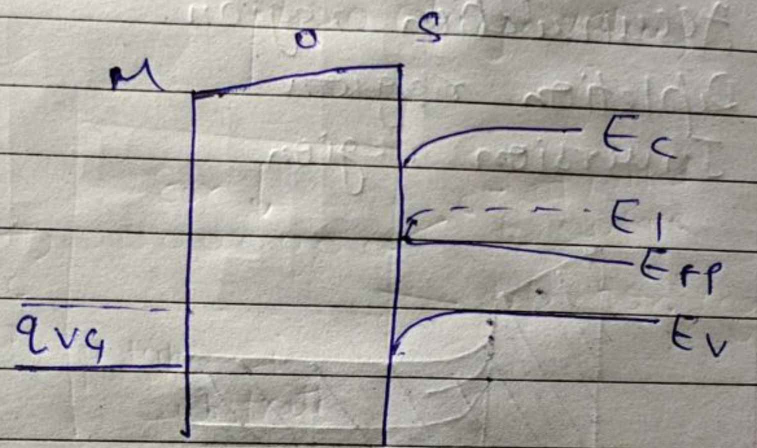
* -ve surface potential cause energy bond to

(1)



② <u>Depletion region</u>





$\varepsilon_{ox} \Rightarrow$ electric field directed downward towards substrate

the surface potential cause energy band to bend toward near surface.

Date
Page No.

~~The~~ Thickness x_d of depletion region?

Assume mobile hole charges in a thin horizontal layer ∥ to surface

$$dQ = -qN_A\,dx \quad -(1)$$

N_A = acceptor ion conc

q = unit (e^-) charge

change in surface potential ($d\phi_s$) → reqd. to displace this dQ by distance x_d away from the surface (found by poisson eqn)

const.

$q = CV$

$\frac{q}{c} = V \qquad d\phi_s = \frac{-x\,dQ}{\varepsilon_{si}} = \frac{qN_A x\,dx}{\varepsilon_{si}} \quad -(2)$

ε_{si} → dielectric const. of capacitor

Integrating eq (2) along vertical dimension

$$\int_{\phi_f}^{\phi_s} d\phi_s = \int_0^{x_d} \frac{qN_A x}{\varepsilon_{si}}\,dx$$

$$\phi_s - \phi_f = \left|\frac{qN_A x^2}{2\varepsilon_{si}}\right|_0^{x_d}$$

$$= \frac{qN_A x^2_d}{2\varepsilon_{si}}$$

Depth of depletion region

$$\boxed{x_d = \sqrt{\frac{2\varepsilon_{si}(\phi_s - \phi_f)}{qN_A}}} \quad -(3)$$

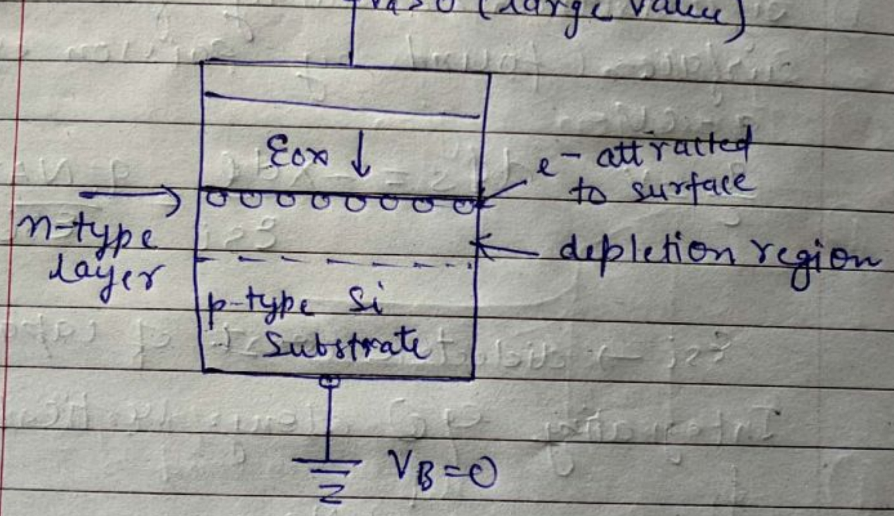
Depletion region charge (Q) →
consist of fixed acceptor ions

$$Q = -qN_A \cdot x_d$$

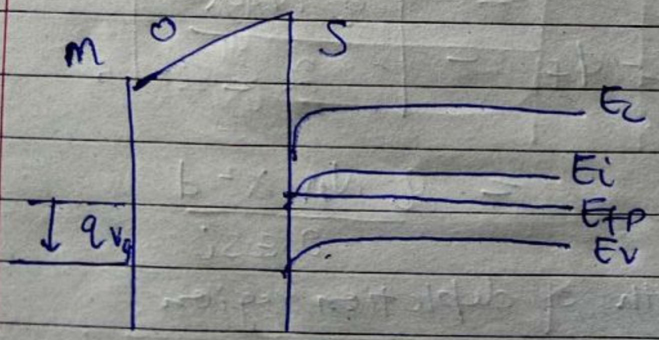
$$= -q N_A \sqrt{\frac{2\varepsilon_{si}(\phi_s - \phi_f)}{qN_A}}$$

$$Q = -\sqrt{2qN_A \varepsilon_{si}(\phi_s - \phi_f)} \quad -④$$

Case 3: $V_G >> 0$ (+ve gate bias)



$$\phi_s = -\phi_f \quad \text{(surface inversion)}$$



Depletion region depth $\phi_s = \phi_f$

$$x_{dm} = \sqrt{\frac{2\varepsilon_{si}/2\phi_f}{qN_A}}$$

Date
Page No.

→ Increase the gate bias increases surface potential downward bending of energy band increases.
Ei becomes smaller than Efp on surface.

→ Surfaces becomes n-type within this layer electron density becomes larger than hole density.

→ N-type region created near surface by the gate surface by the gate bias called inversion layer. And the condition is called as surface inversion ϕ_s, has same magnitude but reverse polarity as ϕ_f const.

i.e $\phi_s = -\phi_f$

Scanned by CamScanner