UNIT-3 → MOSFET & MOS Capacitance →

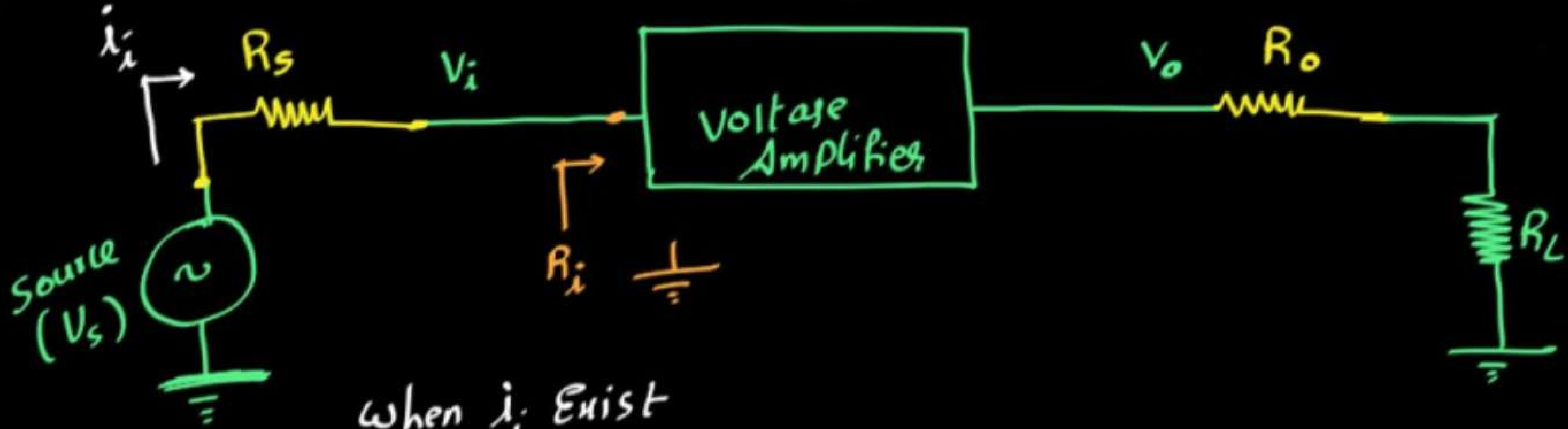
→ For GATE.

- FET
  - JFET
    - n-channel
    - p-channel
  - MOSFET
    - Depletion MOSFET
      - D-Mode
        - N-MOS
        - P-MOS
      - E-Mode
        - N-MOS
        - P-MOS
    - Enhancement MOSFET
      - Enhancement only Mode
        - N-MOS
        - P-MOS
  - ....

1). Consider voltage Amplifier $\longrightarrow$

$V_o \propto V_i$

$\Rightarrow V_o = A_v V_i$



when i_i Exist

$\Rightarrow i R_s = V_{R_s}$ drop Exist.

$\Rightarrow$ There is loss of Information.

Then what to do?

$i_i = 0 \Rightarrow V_{R_s} = 0.$

$\Rightarrow V_i = V_s.$

Find R_i of Amp., $\Rightarrow$ Choose Amplifier whose $R_i = \infty$ (Ideally) (or)

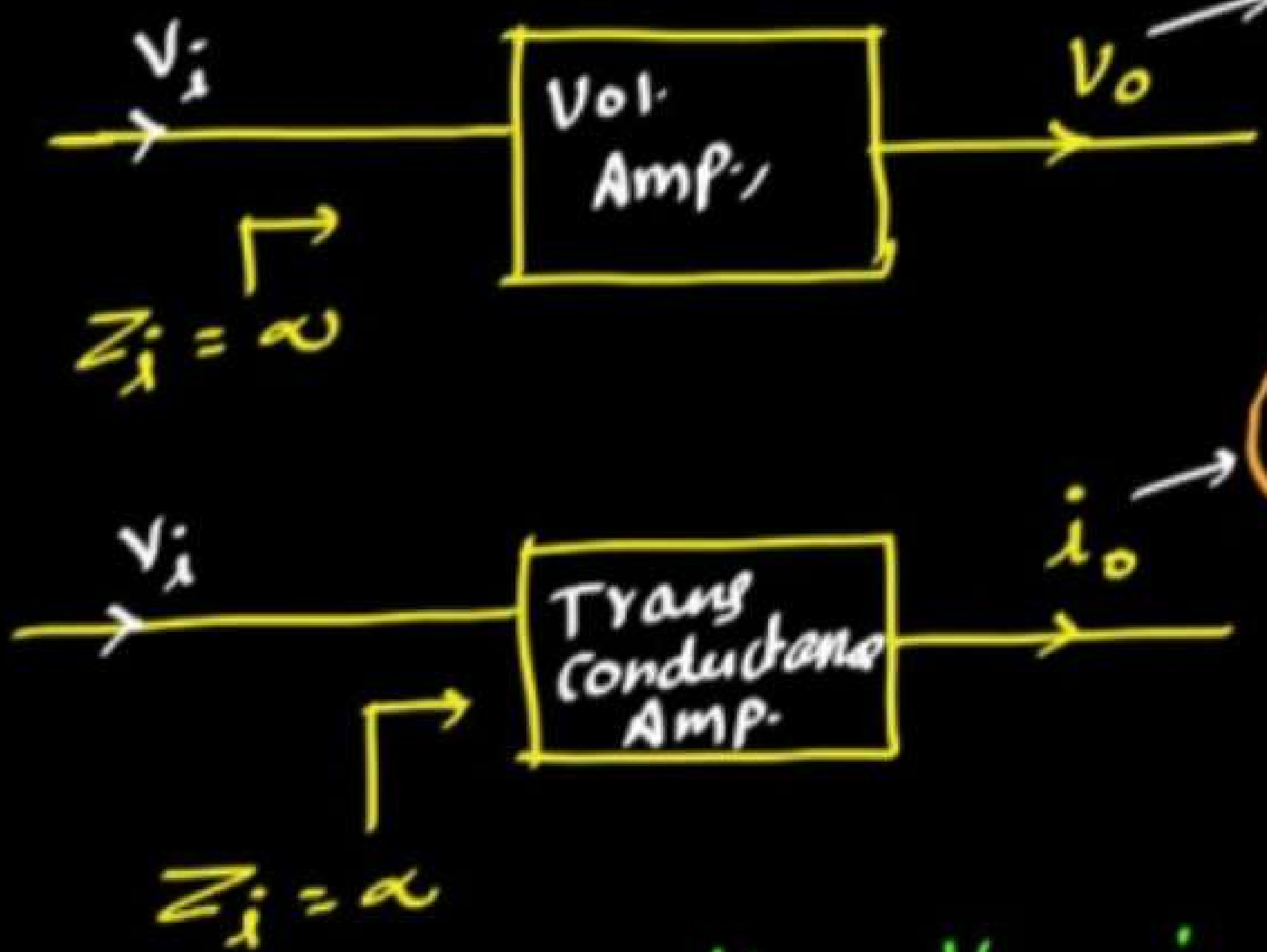
$R_i \rightarrow$ v.v.v. large (practically).

2). Now → @ I/p ∃ $\boxed{\text{only}}$ one Signal → Voltage.

∴ O/p depends on I/p ⇒ o/p depends on $\boxed{\text{Only}}$ I/p V_i.

⇒ Voltage Control device.

Voltage Control device



$V_o \propto V_i \Rightarrow V_o \propto i_o \propto V_i$

$i_o \propto V_i$

→ Trans Conductance is Default property of Voltage Control device.

↓ No I/p characteristics.

∴ Voltage Control device Also Called as Trans Conductance Device.

$$\therefore A_v = \frac{V_o}{V_i} = \frac{V_o}{i_o} \cdot \frac{i_o}{V_i}$$

$$\boxed{A_v = Z_o \cdot g_m}$$

[∵ $V_o \propto V_i \Rightarrow V_o \propto i_o \propto V_i$]

O/p characteristics ⇒ we get O/p Resistance.

Transfer char. ⇒ we get Transconductance.

3).

Voltage Control device

① $i_i = 0$, Z_i = v.v.high, $V_o \propto V_i$, $i_o \propto V_i$

② Default property is Trans conductance.

③ o/p char., & Transfer char., are importance.

④ As $i_o \propto V_i \Rightarrow$ $\boxed{\text{Only}}$ Drift Transport.
$\Rightarrow$ There Should Not be Diffusion & Recombination currents.
$\Rightarrow$ No Low level injection priciples.
No Law of Junction
$\Rightarrow I = I_0\left(\exp\left(\frac{V}{\eta V_T}\right)-1\right)$ is "INVALID".

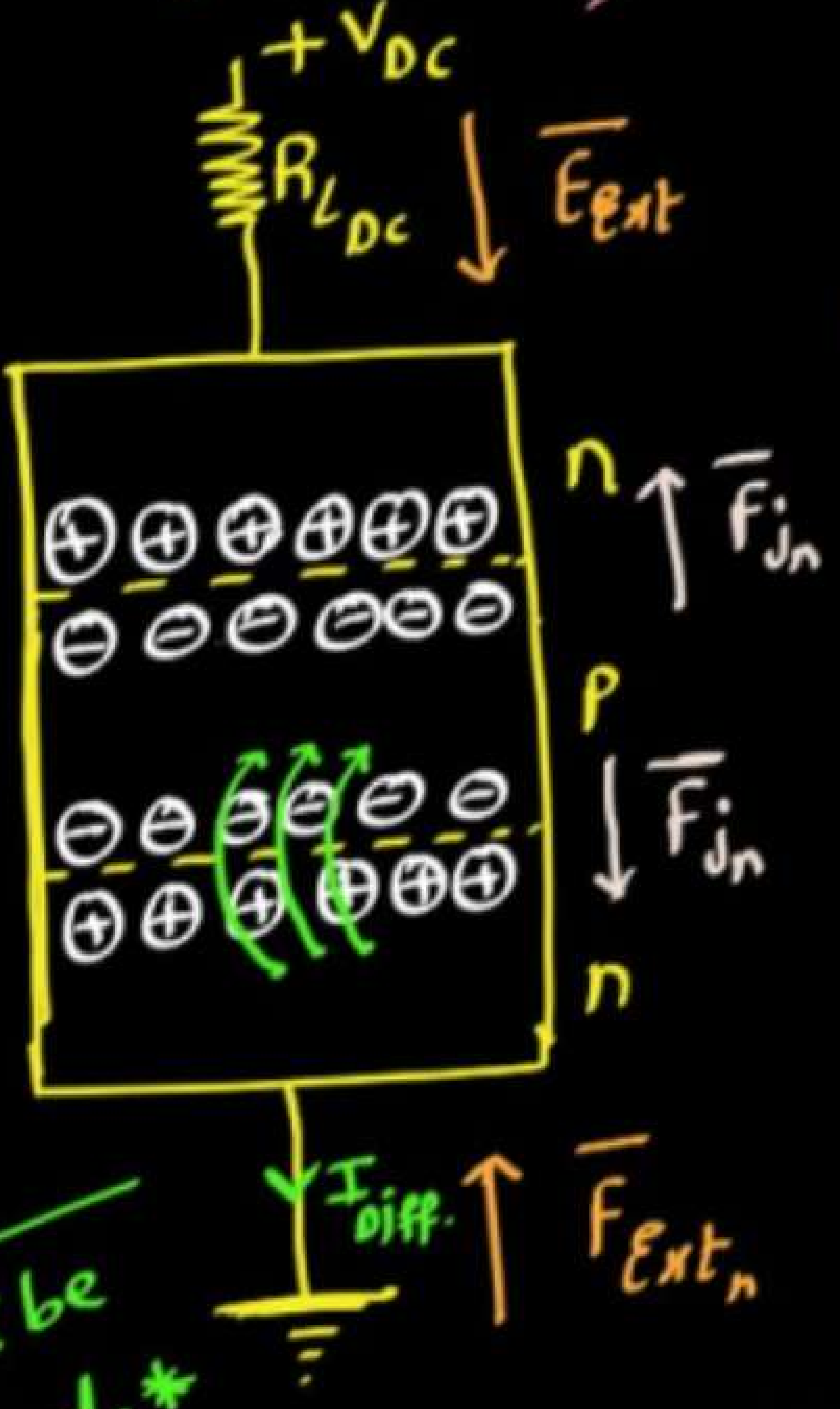
⑤ Since No Recombination current
$\Rightarrow$ Current is due to Either free Electrons (or) holes $\Rightarrow$ UNIPOLAR device.

⑥ $(\mu \propto 1/E)$
Since i_o Controlled by I/p voltage $\Rightarrow$ o/p Mobility is Controlled (or) Effected by I/p E-field
$\Rightarrow$ Field Effect Transistor.

⑦ Since UNIPOLAR
$\Rightarrow$ No minority Effect
$\Rightarrow$ No Thermal Noise
$\Rightarrow$ No Thermal RunAway.

4).

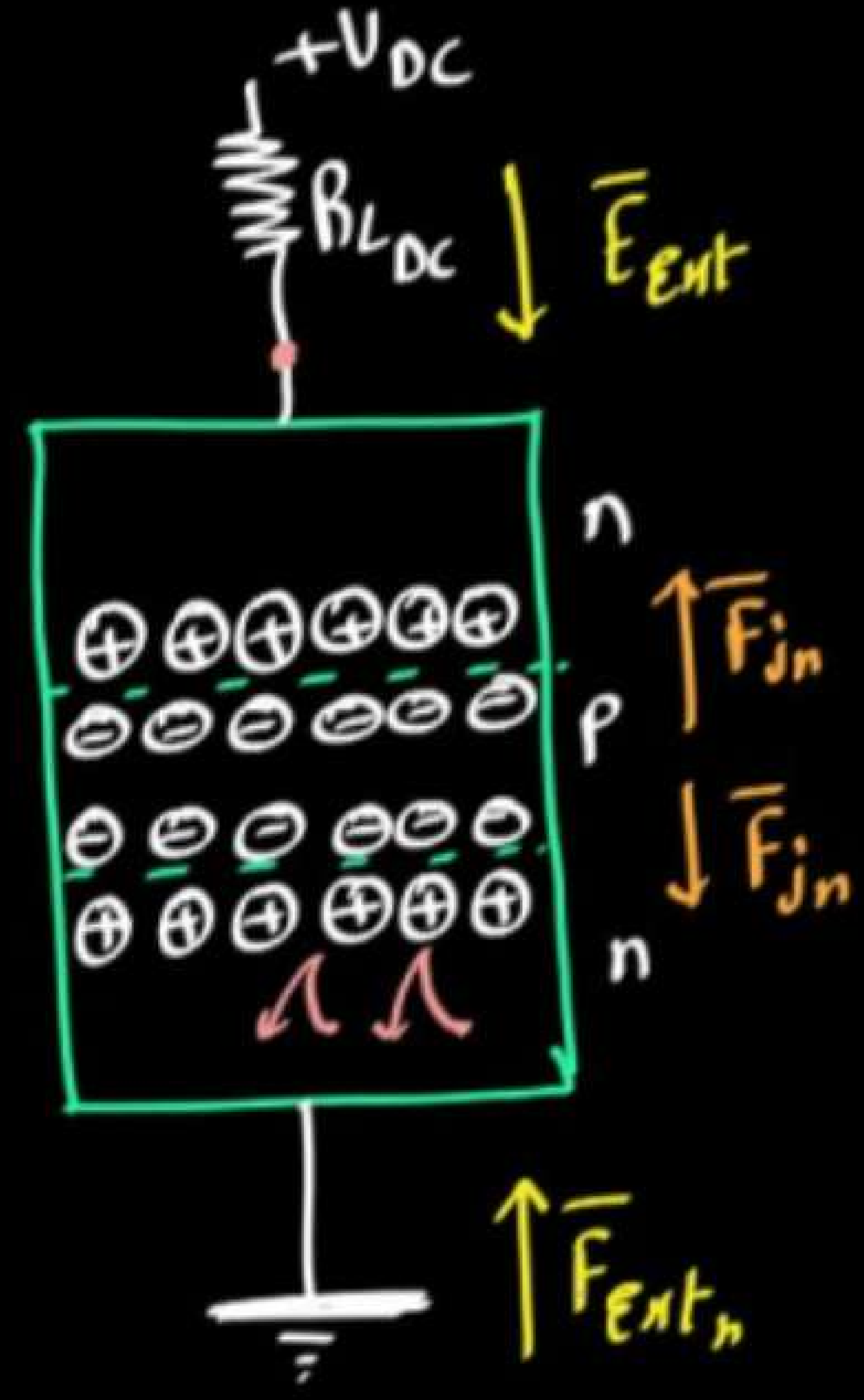
How Can we Impliment Above Properties?



→ Then what to Do?

Diff., &
ReComb.,
* Should Not be
happend.*

5).



Either p (or) n

Dop heavily.

$\hookrightarrow \because V_{bi} = \frac{KT}{q} \log_e \left| \frac{N_D N_A}{n_i^2} \right|$

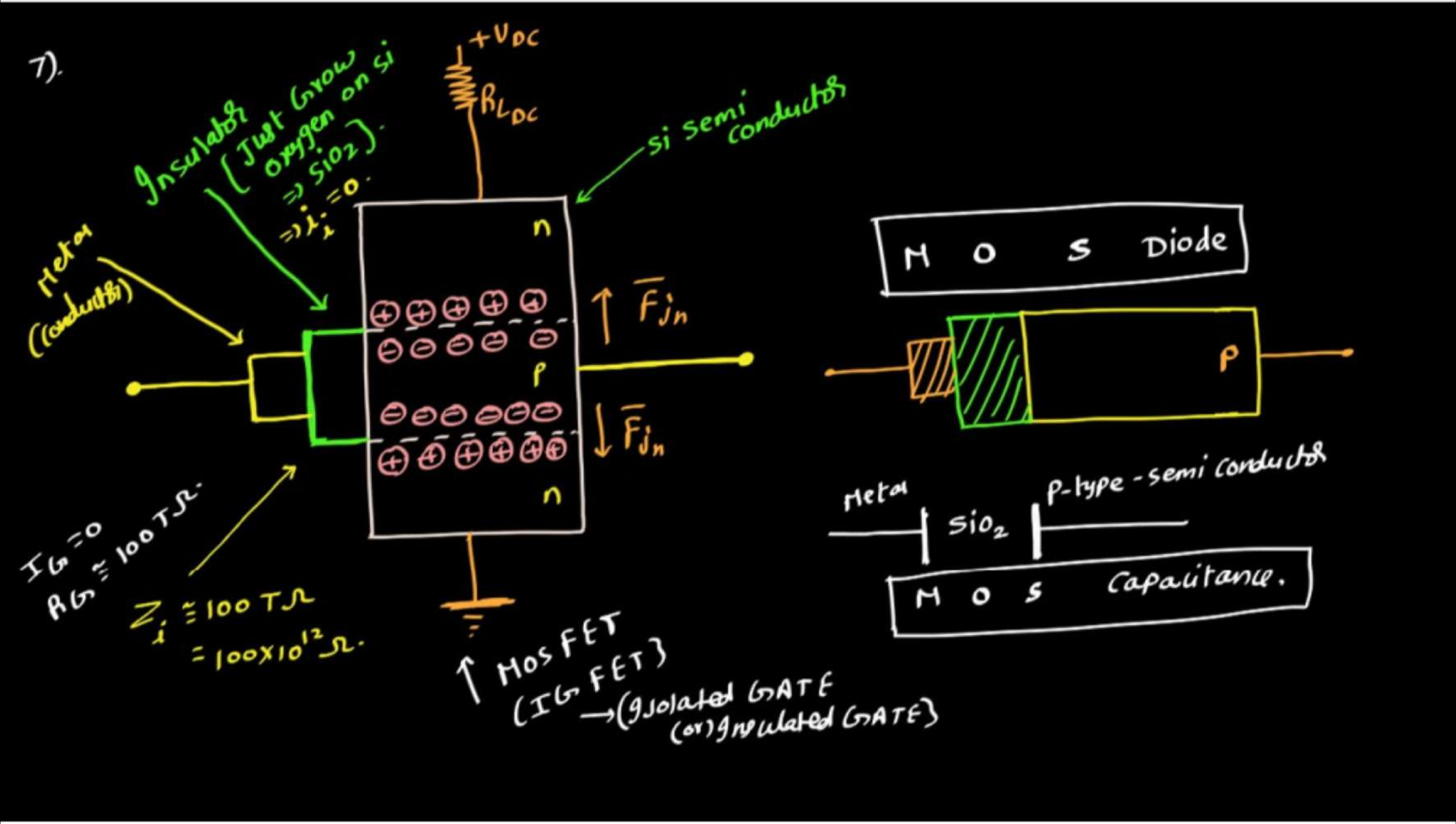
$\Rightarrow$ higher Doping $\Rightarrow$ higher V_{bi}

$\Rightarrow$ higher $\bar{F}_j$.

$\longrightarrow$ problem resolved.

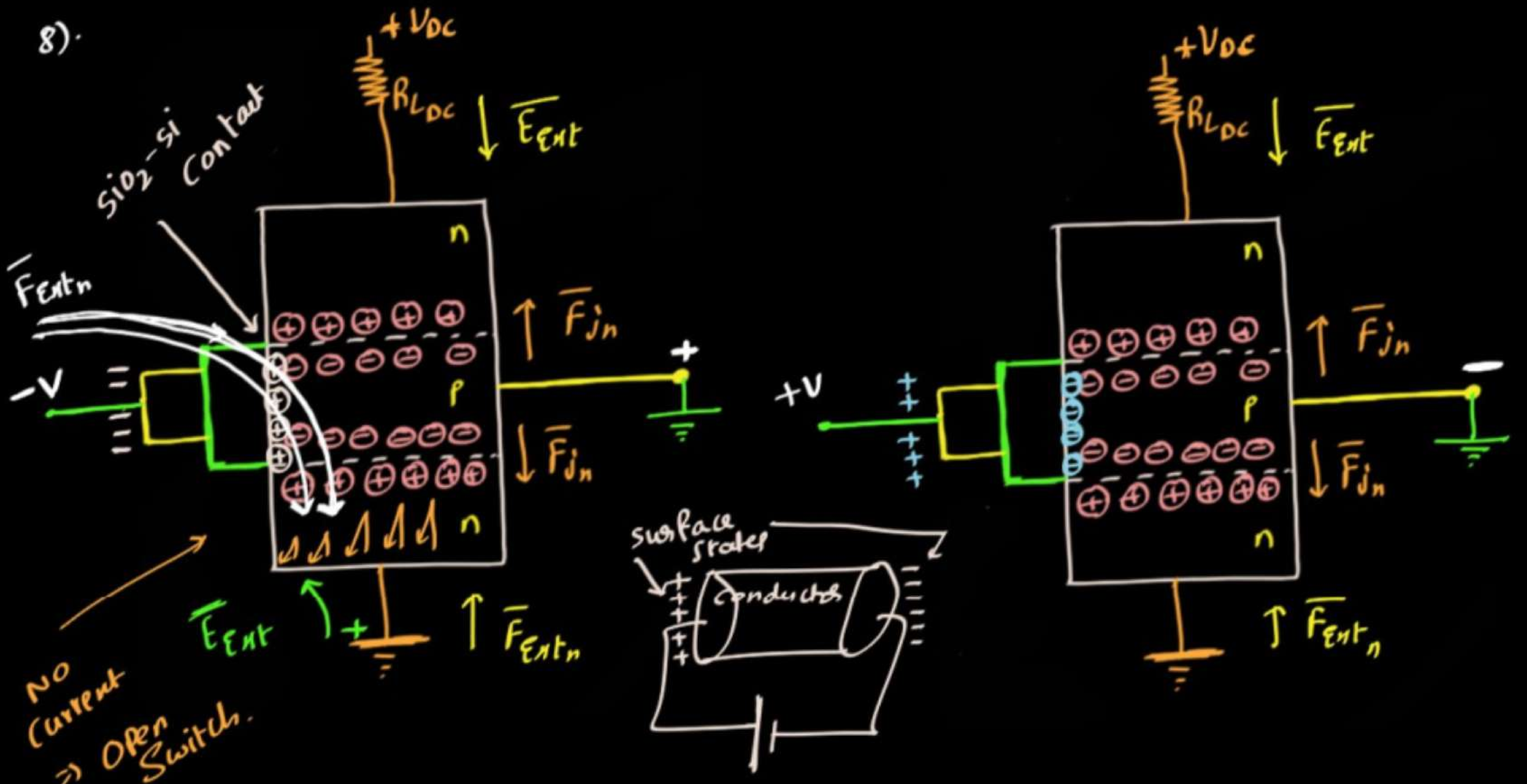
$\rightarrow$ But No current in the device ......

How to Solve this?

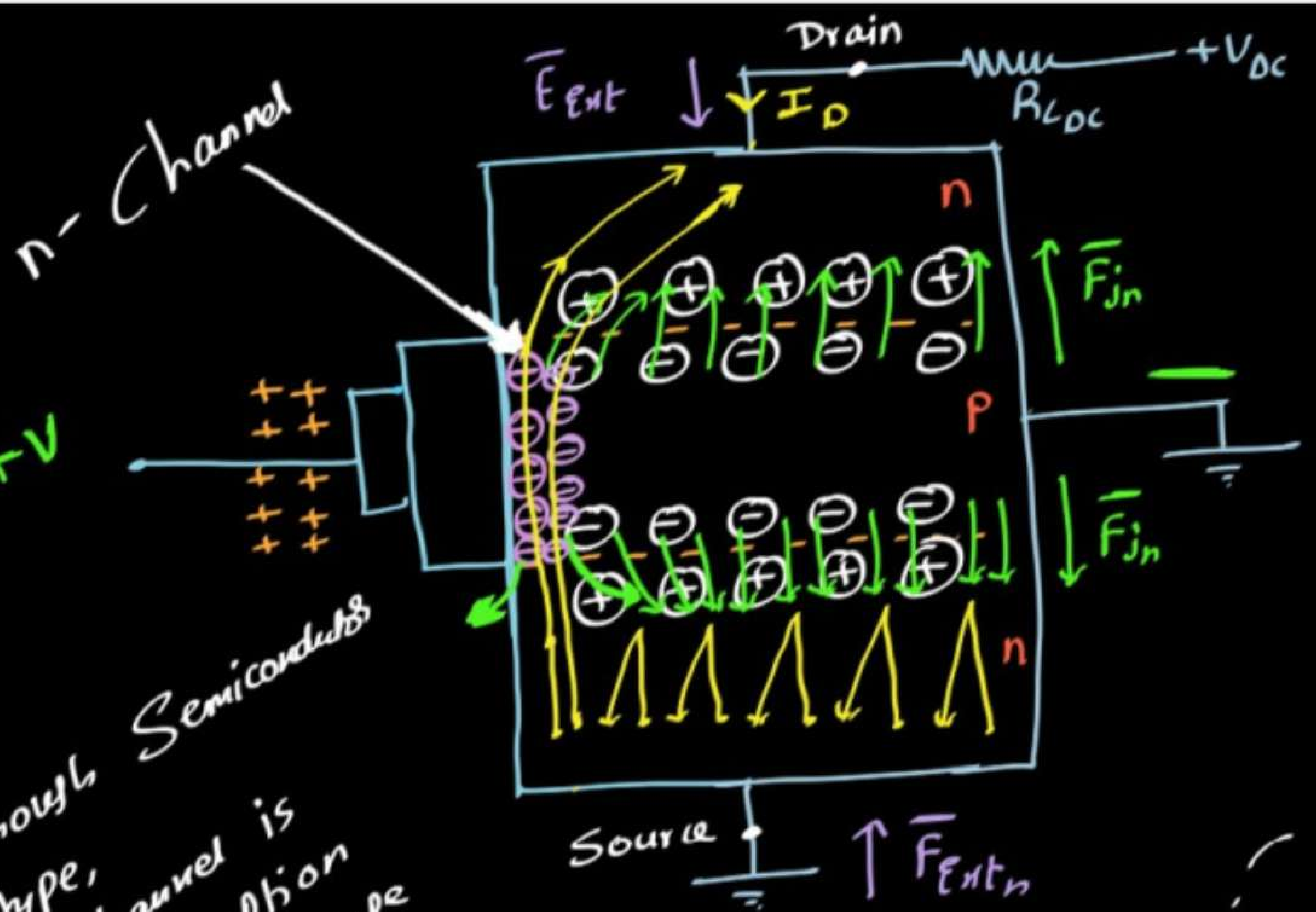


7).
+V_DC
R_L_DC
Insulator (Just Grow oxygen on si ⇒ SiO2).
⇒ i_i = 0.
si semi conductor
Metal (conductor)
n
p
n
F̄_jn
F̄_jn
I_G = 0
R_G ≈ 100 TΩ.
Z_i ≈ 100 TΩ
= 100×10^12 Ω.
MOS FET
(IG FET)
→ (Isolated GATE
(or) Insulated GATE)
M O S Diode
P
Metal
SiO2
p-type-semi conductor
M O S Capacitance.

8).



+VDC
RLDC
EExt
SiO2-Si Contact
FExtn
-V
n
p
n
Fjn
Fjn
+
EExt
FExtn
NO current
=> Open Switch.
surface states
conductor
+V
+VDC
RLDC
EExt
n
p
n
Fjn
Fjn
-
FExtn



Even though Semiconductor is p-type, But channel is Acception Negative type carriers (Electrons) with out Recombination ⇒ Behaving like n-type ⇒ It is not minority current.

Electrons Travel from Source to Drain ⇒ ∃ current with out Recombination & with out Diffusion.

⇒ Only Drift Transport.

⇒ It is Called Inversion Mode.

∴ N-channel → NMOS → Only one current
↓
i.e., Electron Current.
↓
Enhancement Carriers Transport.
↓
Enhancement MOSFET.

∴ The I/P vol., Controls O/P current.
The I/P vol., Controls flow of Carriers (Mobility) from Source to Drain.

∴ I/P Terminal → GATE.
∴ $I_{O/P} \propto V_{I/P}$ → Trans conductance device.

9).

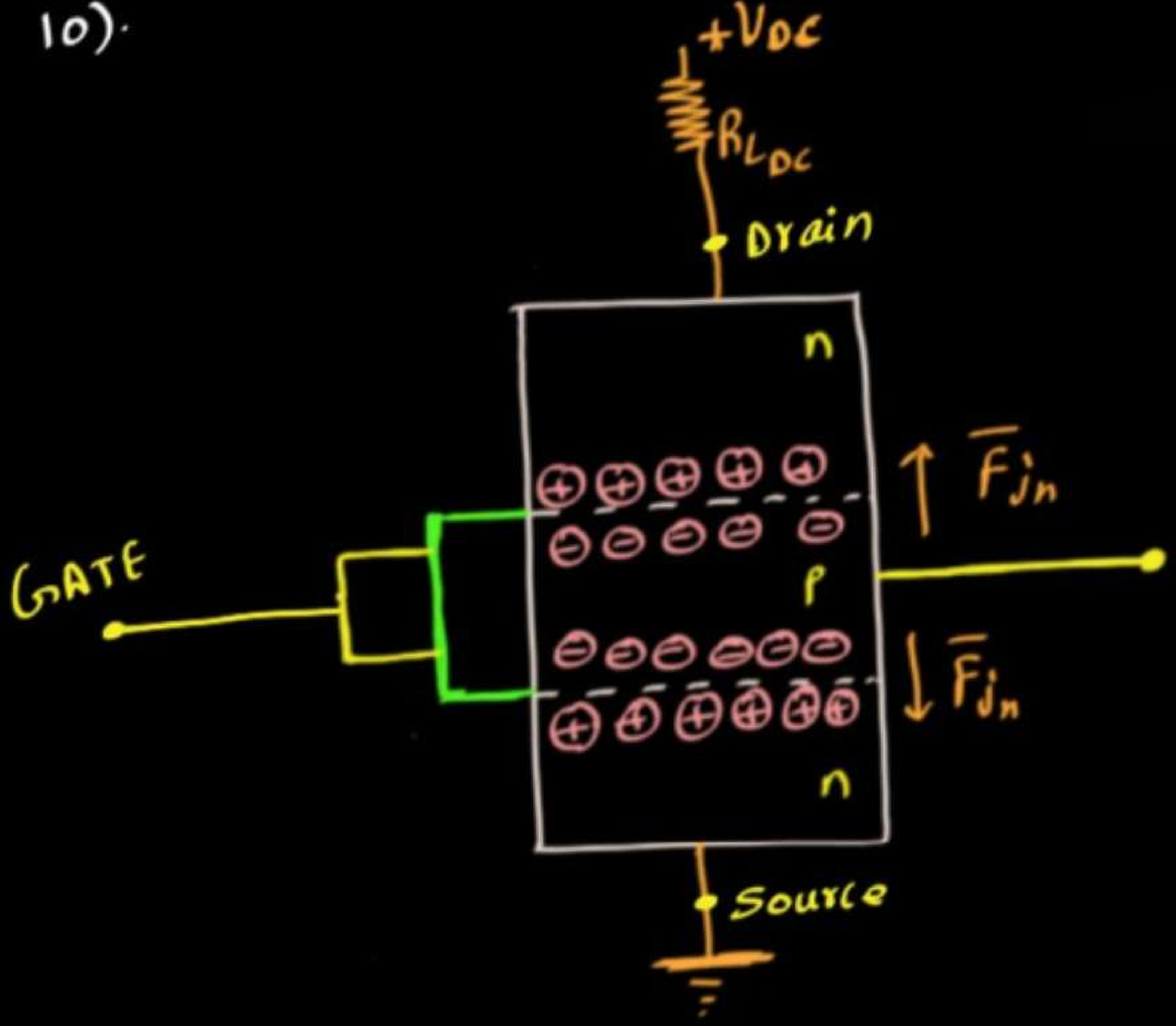
From Above Analysis $\longrightarrow$

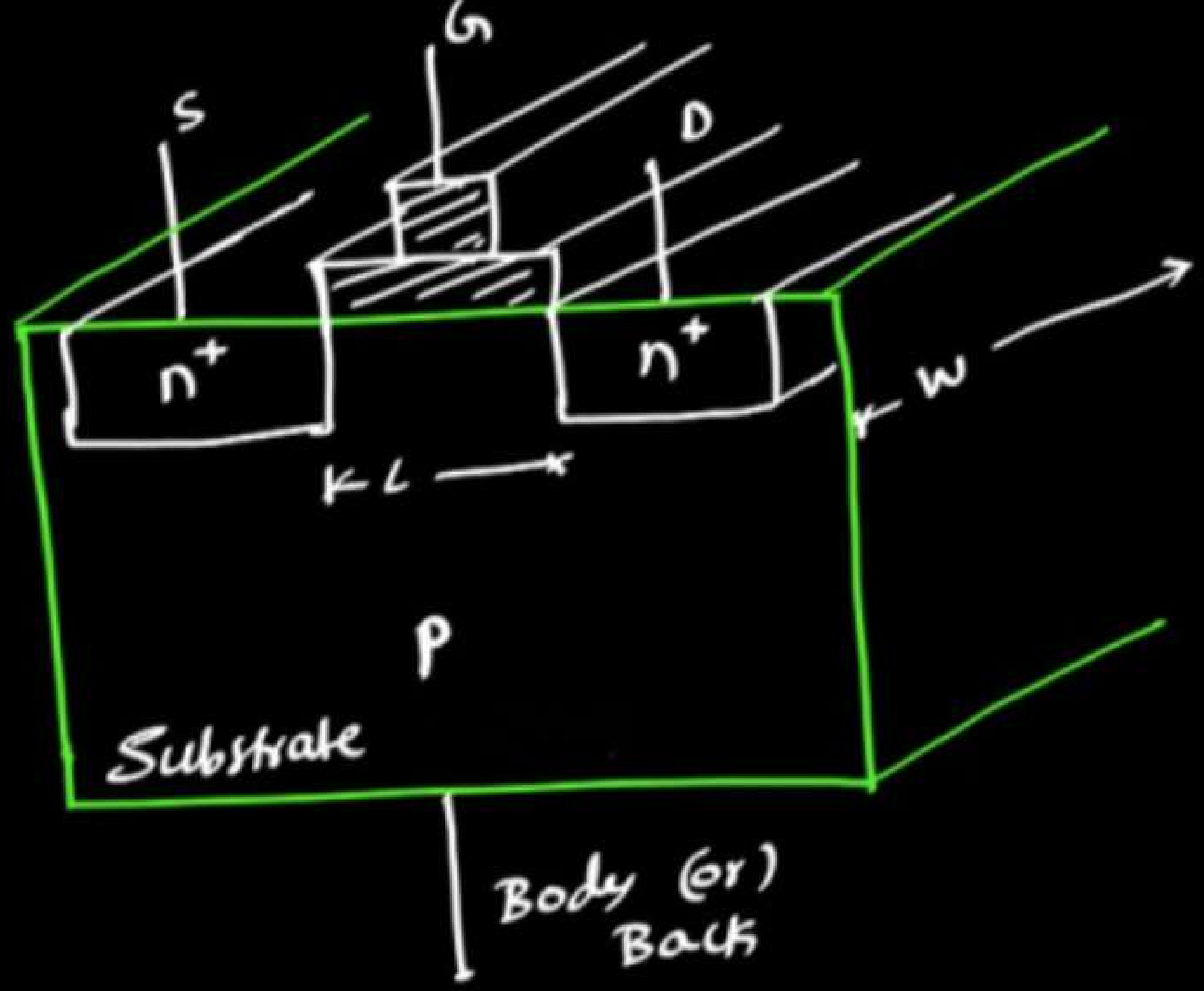
where current is generated
where current is controlled
where mobility controlled
where chance of getting more heat
where Inversion channel exist

$\Bigg\}$ p-region in Above Example

$\Rightarrow$ Increase the size of p-region in N-MOS.

10).





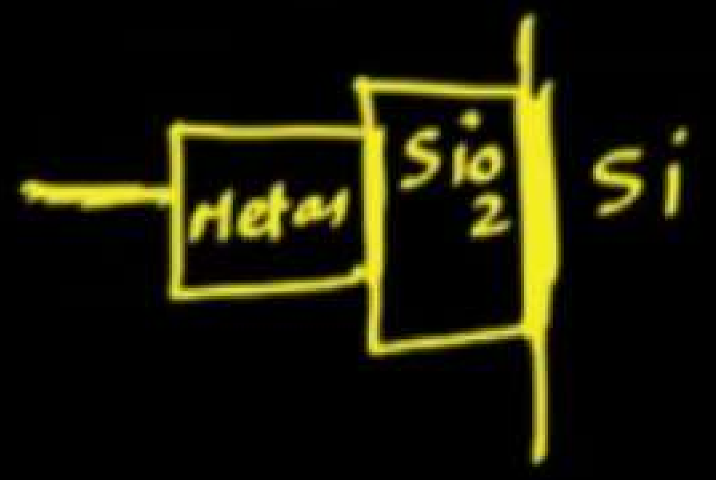
$L \rightarrow$ Channel length
$W \rightarrow$ Channel width

(11).

Challenges

→ We are Adding SiO_2 on Si

$$\underbrace{\text{Lattice} \qquad \text{Lattice}}_{\text{Different}}$$



→ We are Adding Metal to SiO_2

$$\underbrace{\text{Lattice} \qquad \text{Lattice}}_{\text{Different}}$$

→ Metal is Conductor
⇒ No E_c, No E_v

SiO_2 is Insulator ⇒ No E_F

Si → S·Conductor which has E_c, E_v, E_G, E_F

Then How can we draw Energy band diagram? Which Energy is reference in All three bodies.

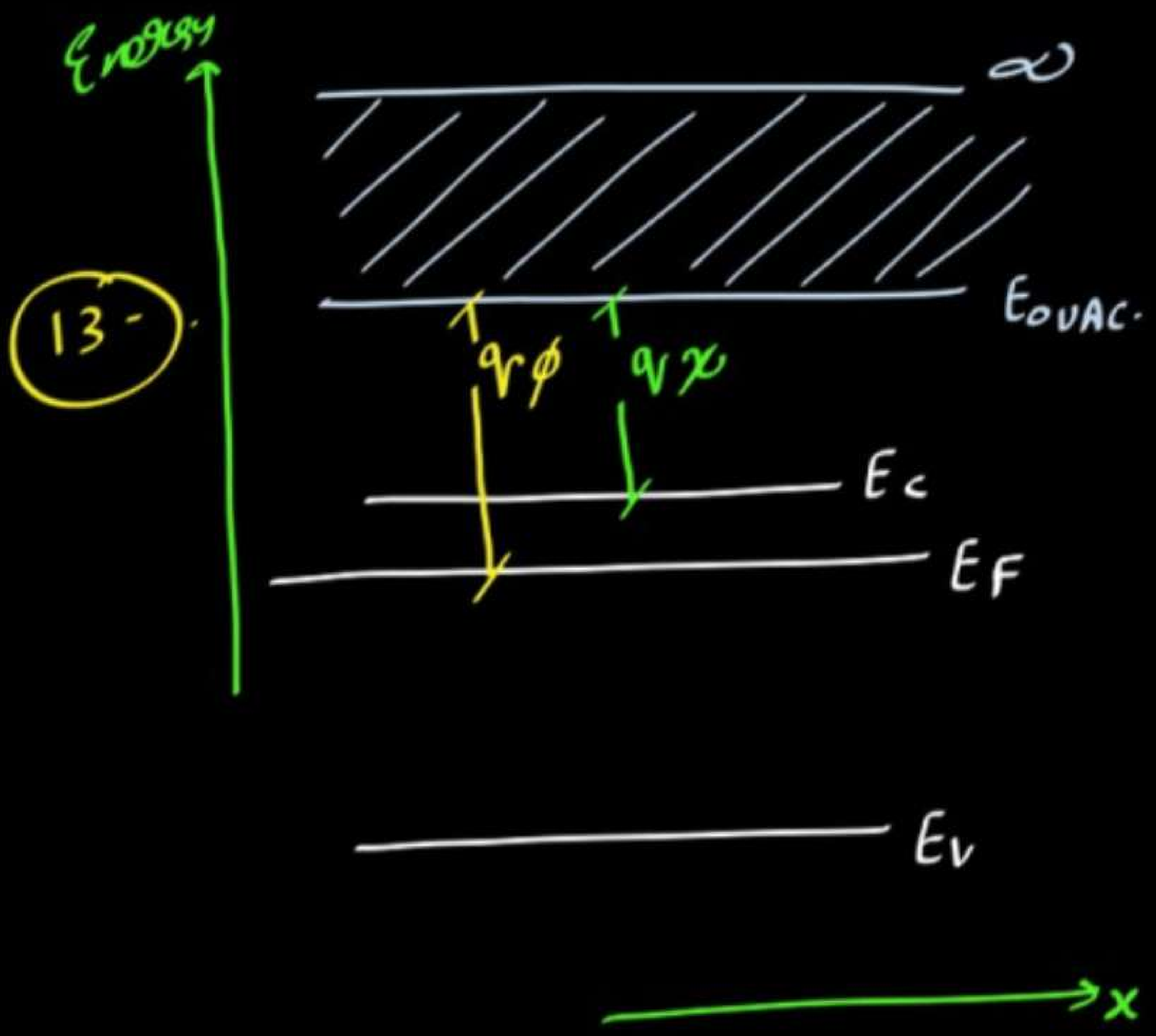
(12) The Energy states that occur @ the boundaries of the Material (or) Surfaces of the Material → "Surface States".

These occur because of the other Material starting @ the surface (or) boundary.

Surface States can Act as Traps which Effect charge Transport in Semiconductors, Can influence band bending.

Because Si has different Lattice, SiO_2 has diffent Lattice, → ∃ dangling bonds, As In MOSFET ∃ channel @ Interface itself, ∃ Major impact on device Operation.

"Surface Passivation techniques can be Used to reduce density of Surface States".

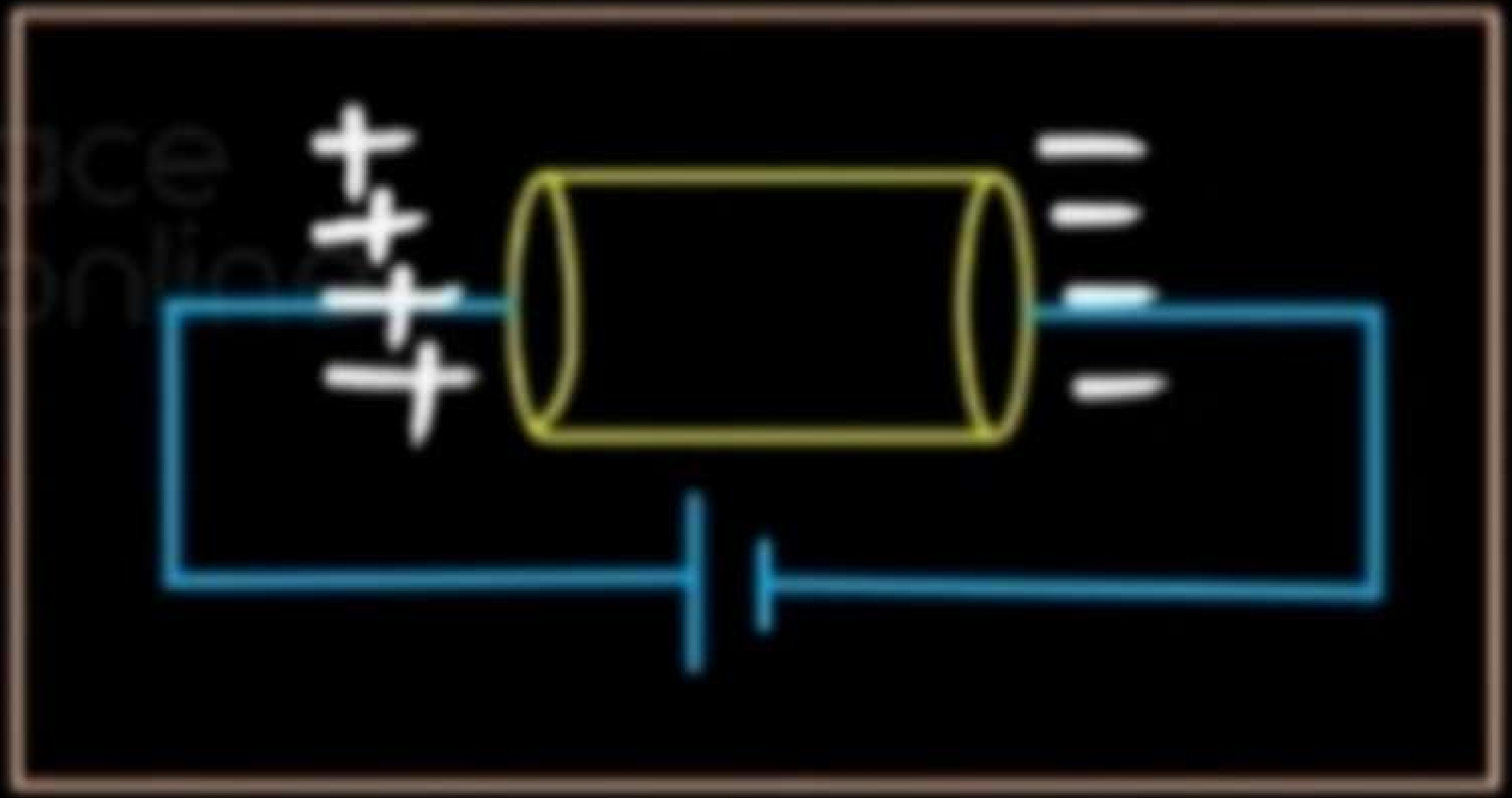


$E_{0_{VAC}}$ → Common Ref. Energy level for Conductors, Insulators & Semiconductors.

ϕ → Work function

χ → Electron Affinity

Also we know a metal always accumulate surface states for metal the (ions) states are outside (surface of metal), inside metal there is e^- movement only when excited, where as for S.C the states are inside the S.C only.



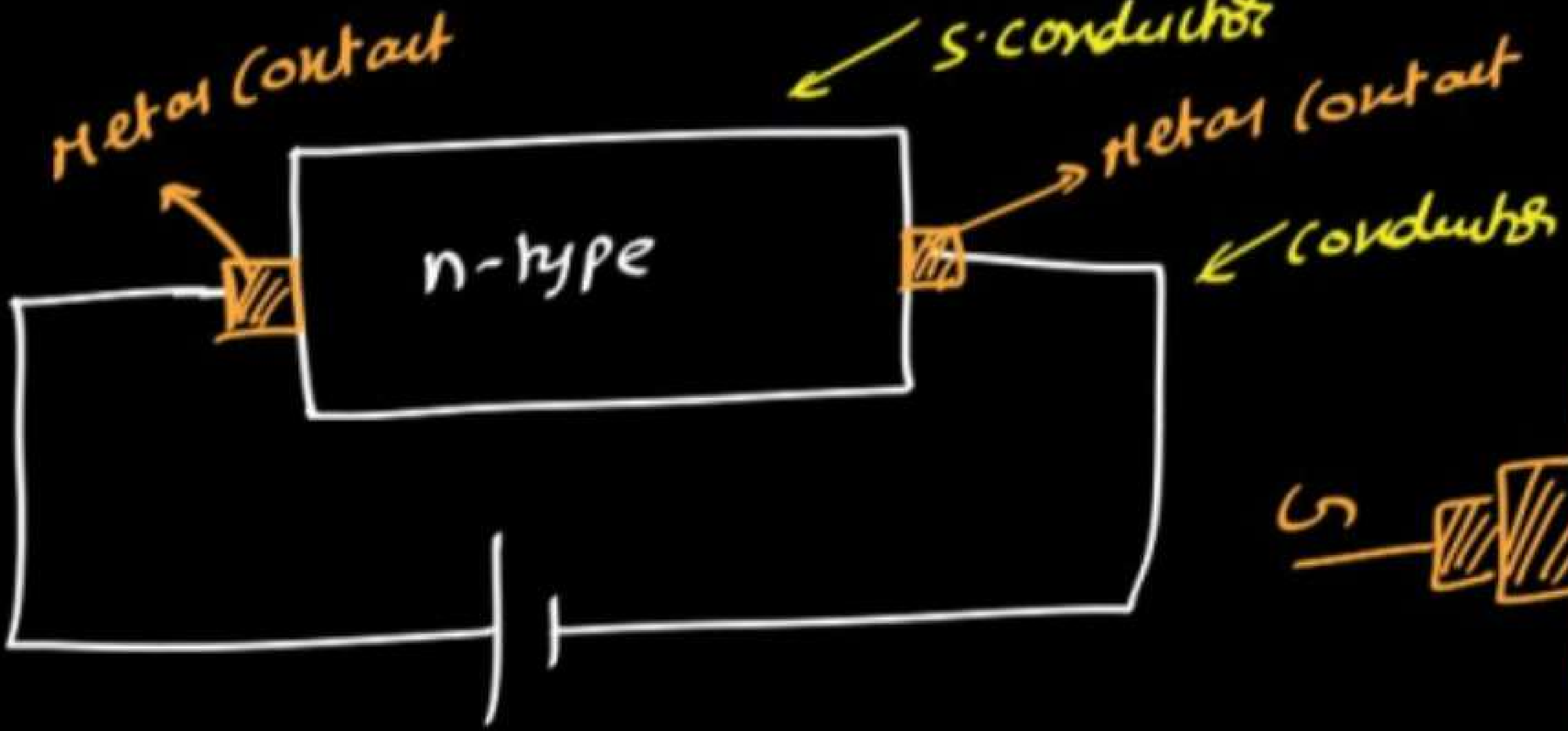
Metal Contact (Metal to S.C. Contact) →

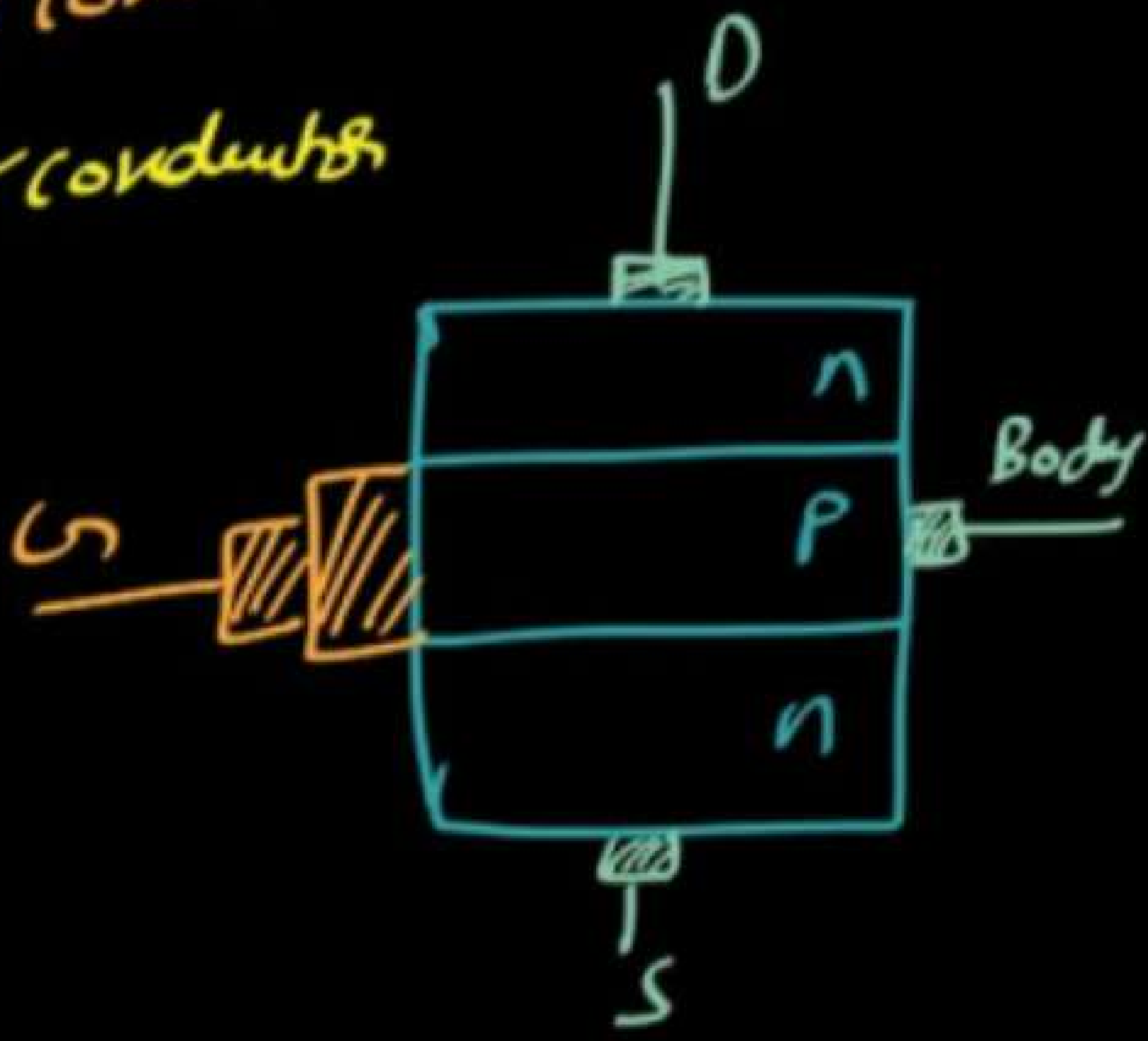
Energy Required to take an Electron from E_F to Vaccum → Work function (ϕ).

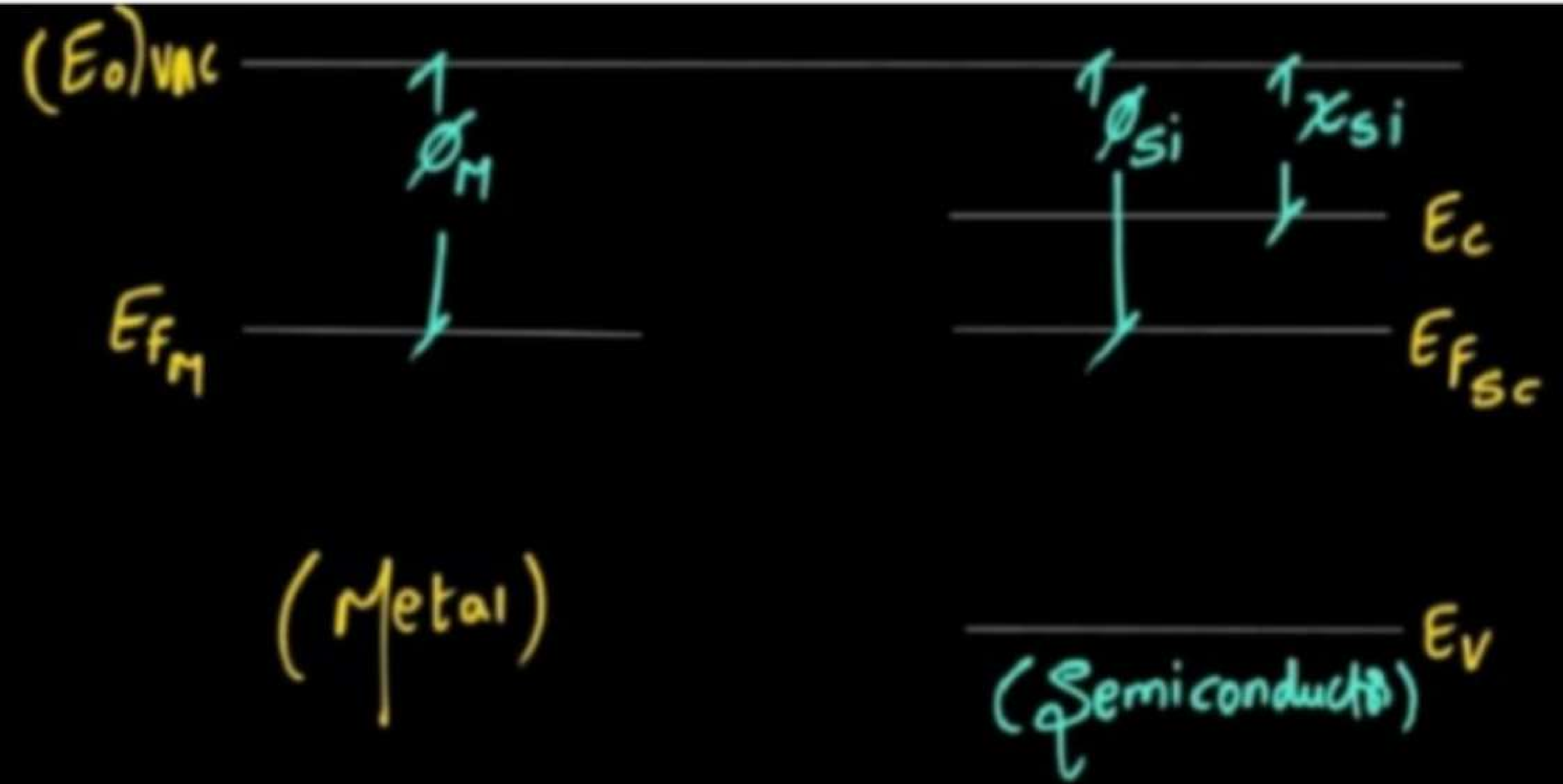
Energy Required to take an Electron from E_c to Vaccum → Electron Affinity (χ)

For Example → Let Metal & Semiconductor has a Contact.
[Join Metal & Semiconductor].

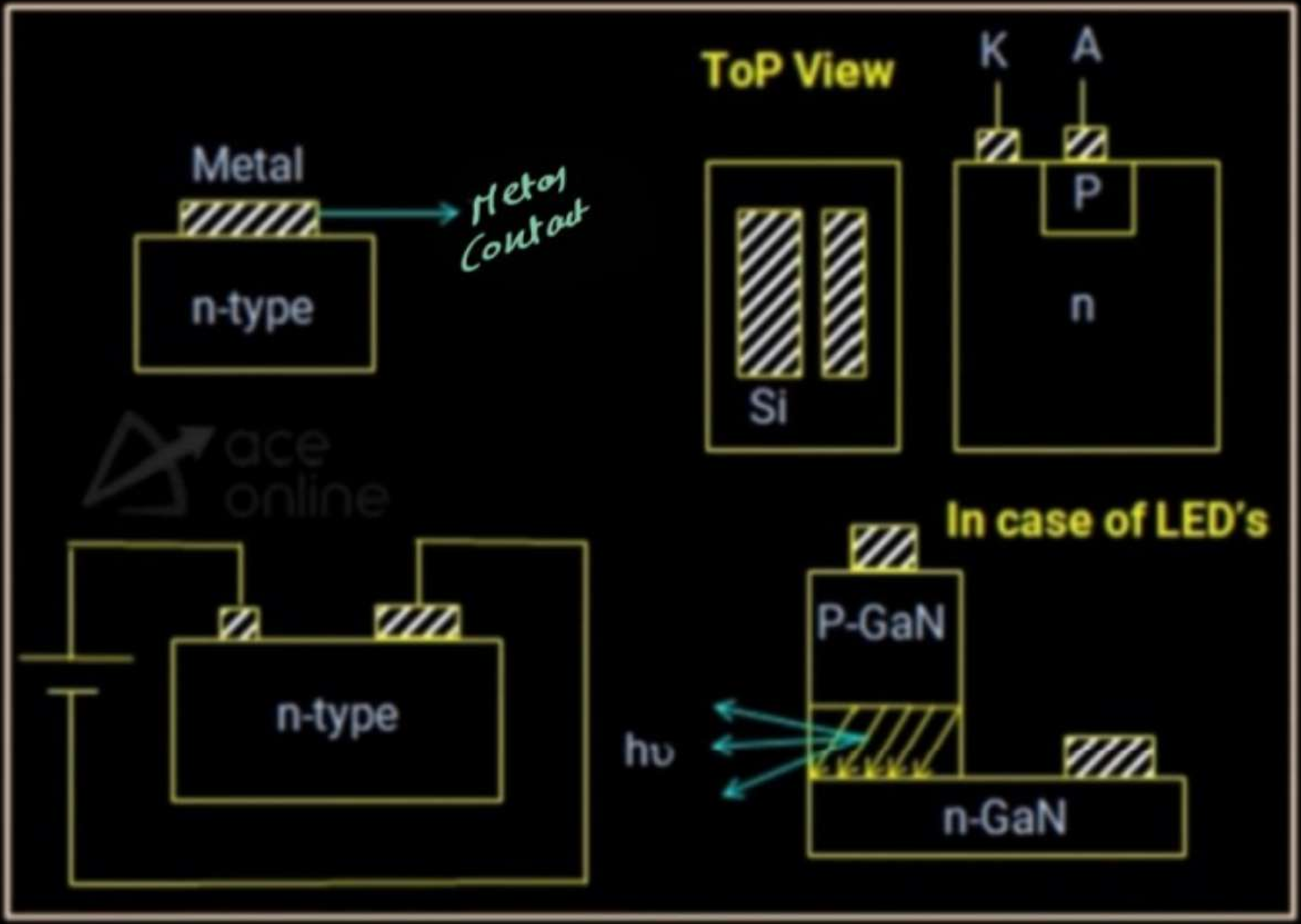
[As Already we Know Metal contacts are Must if Semiconductor Wants to Communicate with External World].





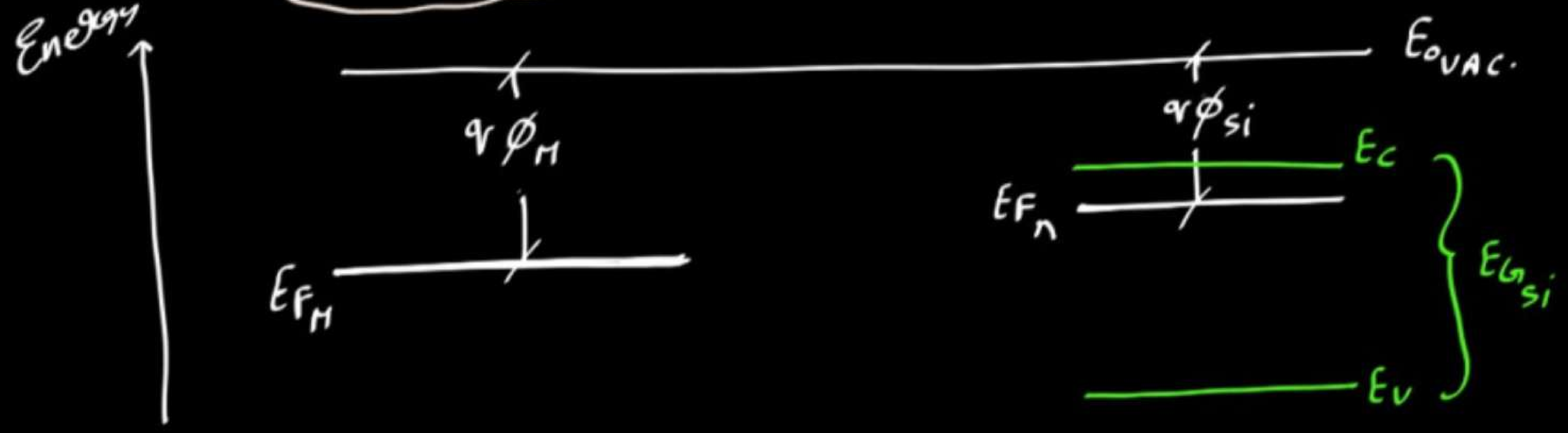


- e^- energy will be filled up to fermi level hence conductors need work function to bring e^- energy to vacuum.
- Similarly metal contacts are very important to make conduction from S.C to be propagated to external world.
- Metal like titanium, platinum, gold mix etc. will be used as metal contacts.



Metal
Metal Contact
n-type
ToP View
K
A
Si
P
n
In case of LED's
P-GaN
hυ
n-GaN
n-type

Let $\phi_M > \phi_{si}$ → n-type → **Schottky Barrier Diode** →

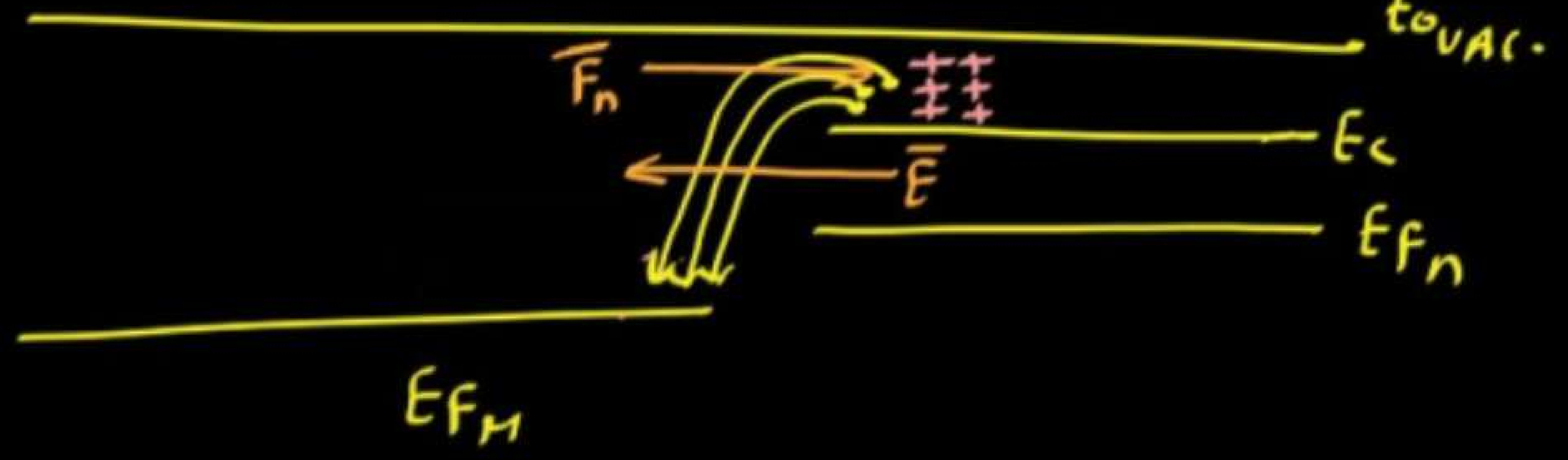


Isolated Metal & n-type Energy bands.

$\longrightarrow x$

When we Join Metal & n-type.

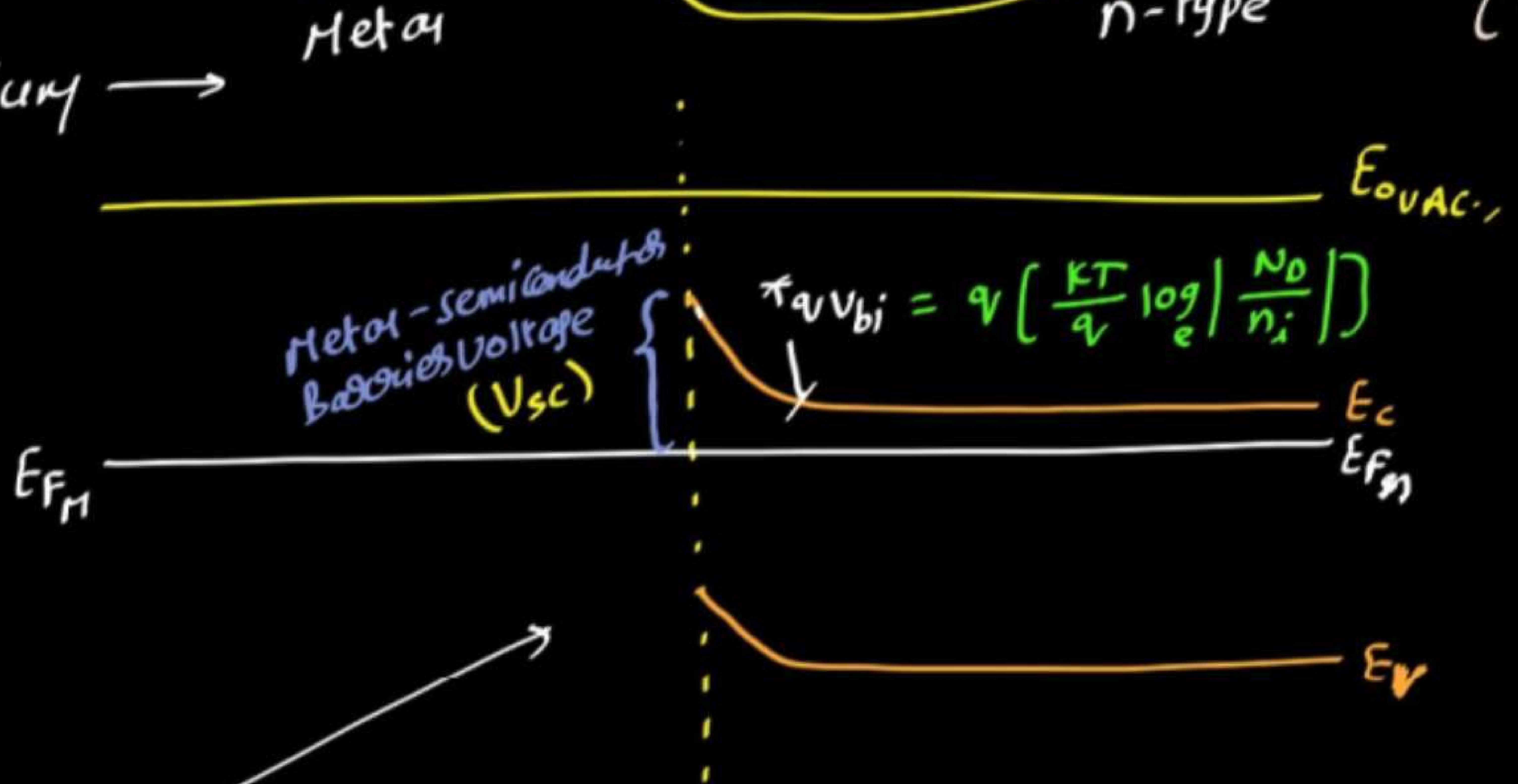
⇒



When Joined Together → Schottky Diode
Schottky Barrier
Diode

(Non linear)

@ Equilibrium →



$$*\,qV_{bi} = q\left(\frac{KT}{q}\log_e\left|\frac{N_D}{n_i}\right|\right)$$

∃ barrier
∃ depletion } behaves like a Diode

→ Metal to Semiconductor Diode.

$$qV_{sc} = qV_{bi} + (E_C - E_F)$$

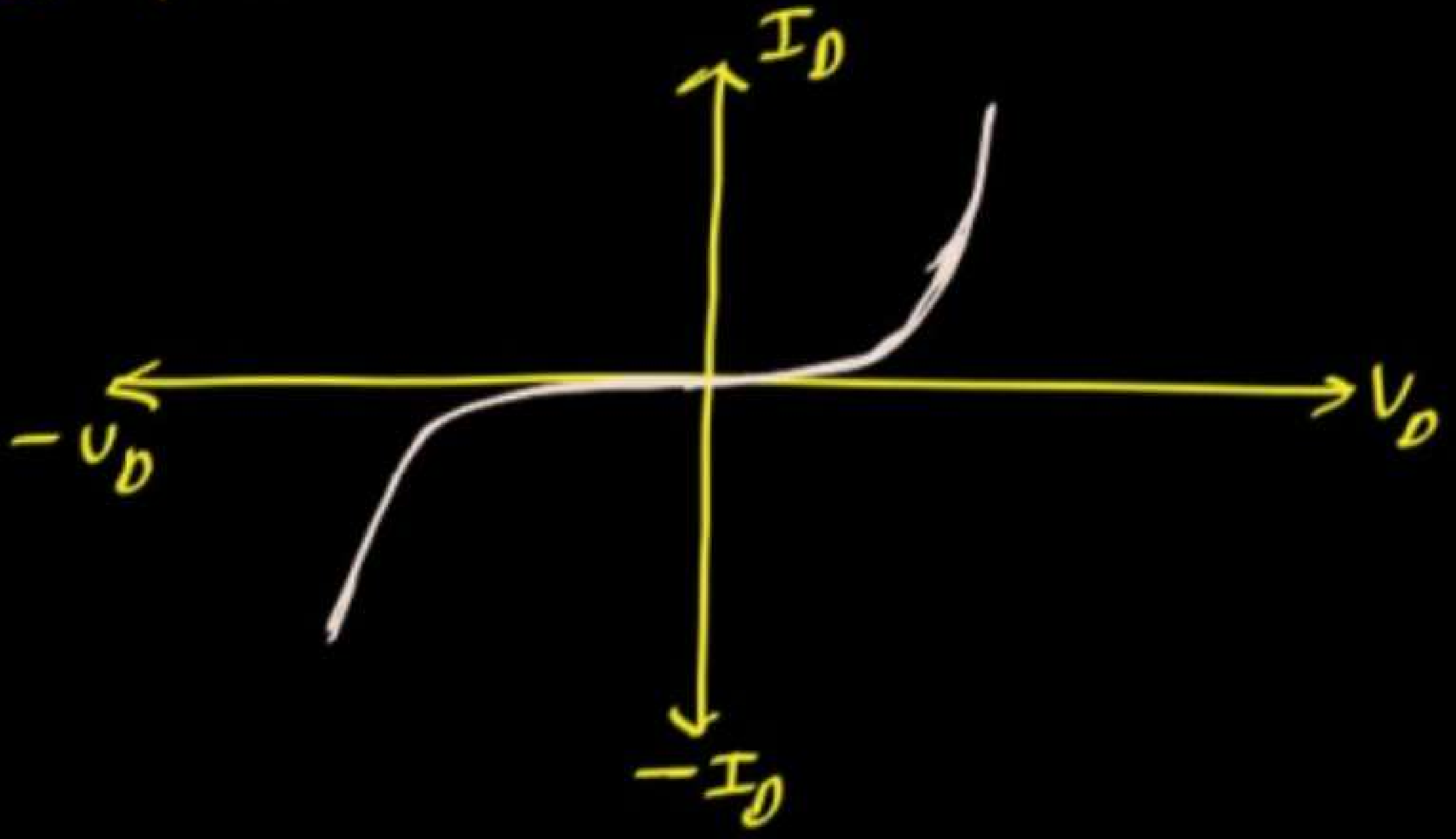
$$\boxed{V_s = V_{bi} + \frac{KT}{q}\log_e\left|\frac{N_C}{N_D}\right|}$$

→ Schottky barrier Potential.

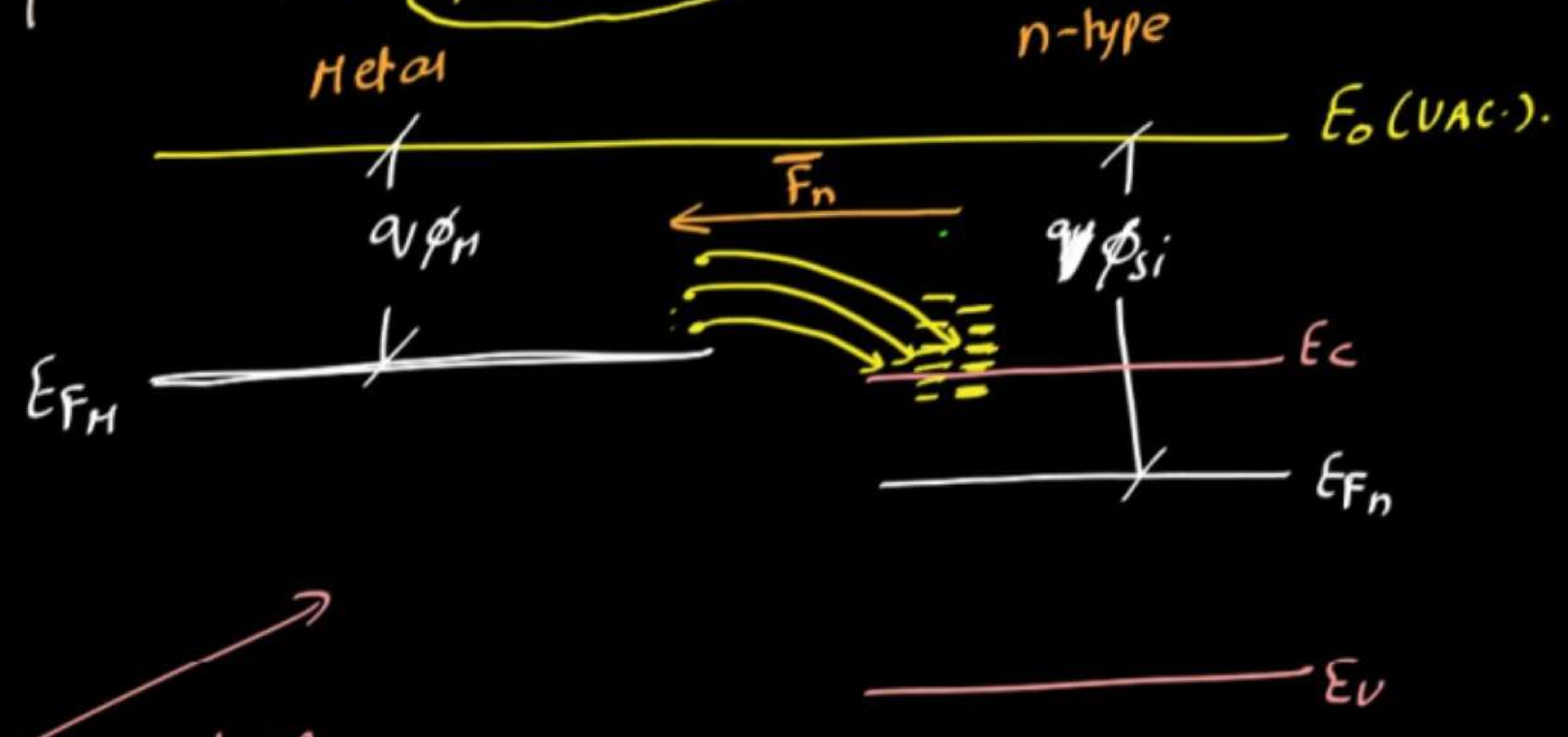
→ Hot Carriers Diode.

Capacitance Effect is Small.

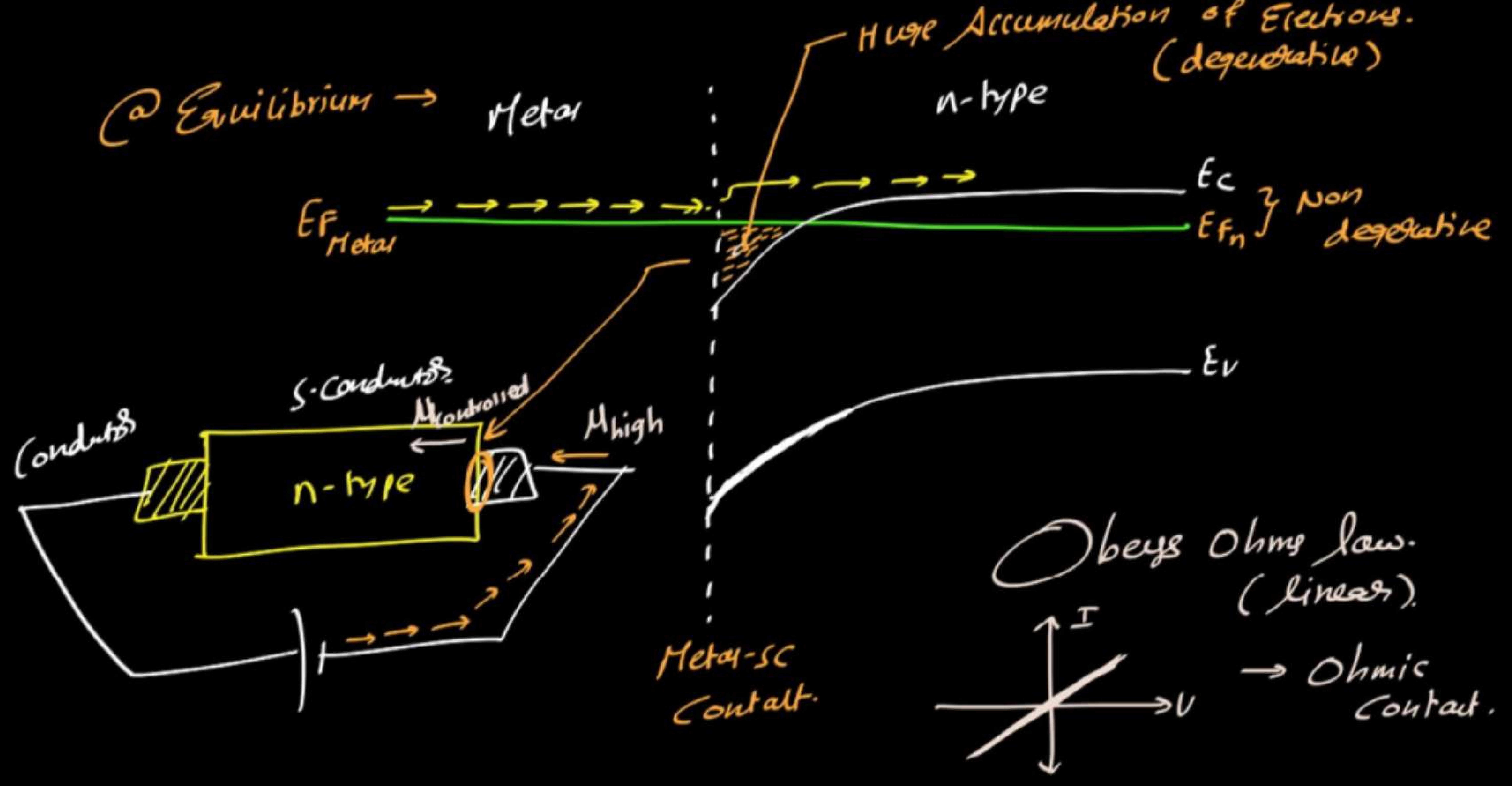
→ fastest Switching.



Similarly Let $\phi_M < \phi_{si}$ → n-type



when Joined.

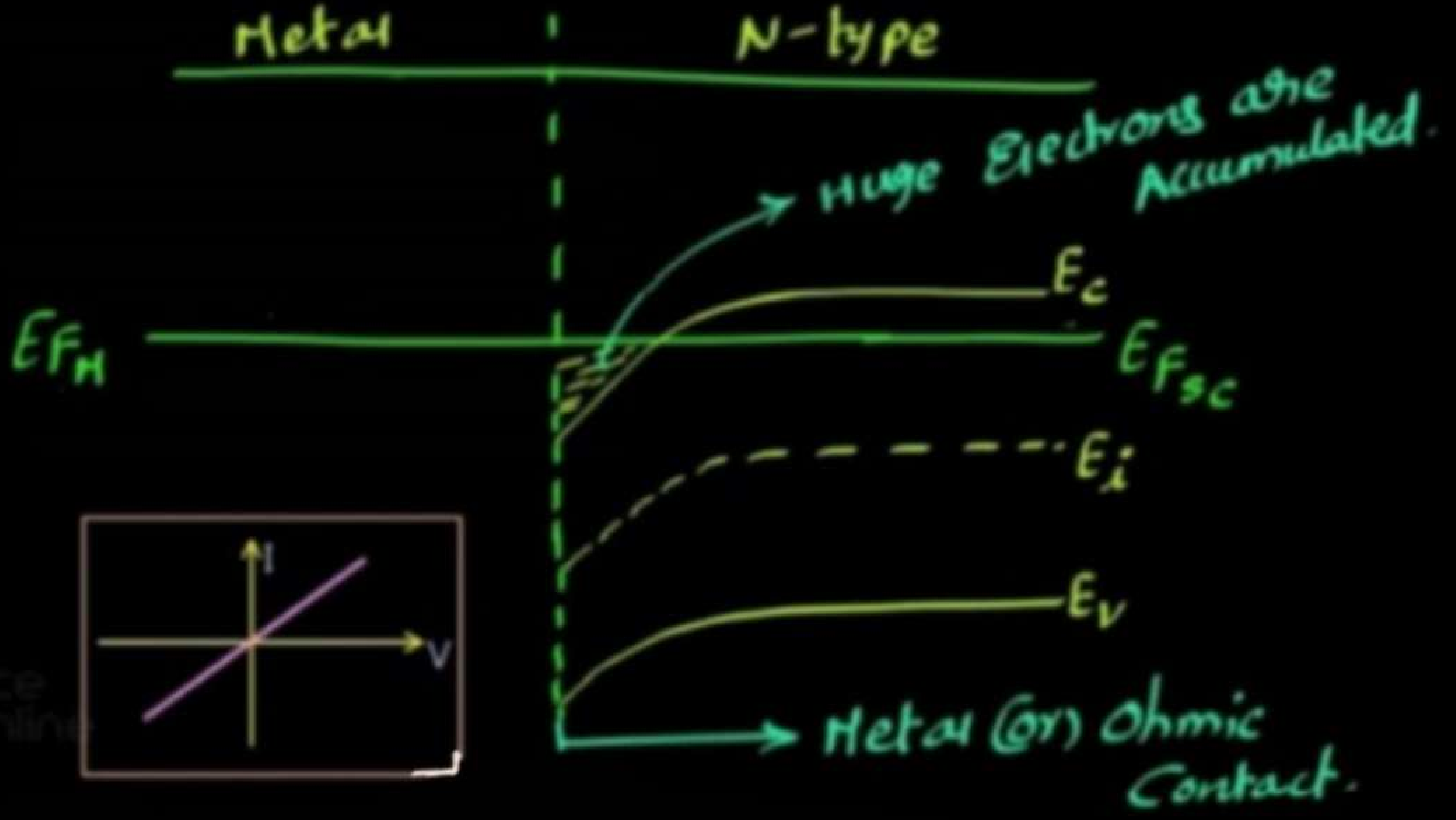


Huge Accumulation of Electrons.
(degenerative)
@ Equilibrium → Metal
n-type
$E_{F_{Metal}}$
E_C
E_{F_n}
Non degenerative
E_V
S-Conductor
Conductor
$\mu_{controlled}$
μ_{high}
n-type
Metal-SC Contact.
Obeys Ohms law.
(linear).
I
V
→ Ohmic Contact.

Now Let $\phi_M < \phi_{Si} \rightarrow$

Here Carriers Can propogate from $L \rightarrow R$ & $R \rightarrow L$ with Out disturbing Lattice & Obeys Ohm's Law.

$\Rightarrow$ Ohmic Contact.



$\rightarrow$ Default Metal Contact in Electronic devices.

Hence from Above Analysis $\rightarrow$

Metal	N-type
$\phi_M < \phi_{Si}$	$\rightarrow$ Ohmic
$\phi_M > \phi_{Si}$	$\rightarrow$ Schottky

Metal	P-type
$\phi_M < \phi_{Si}$	$\rightarrow$ Schottky
$\phi_M > \phi_{Si}$	$\rightarrow$ Ohmic