
PRAYAS
JEE 2025
Lecture - 02
Physics
[redacted] SemiConductor
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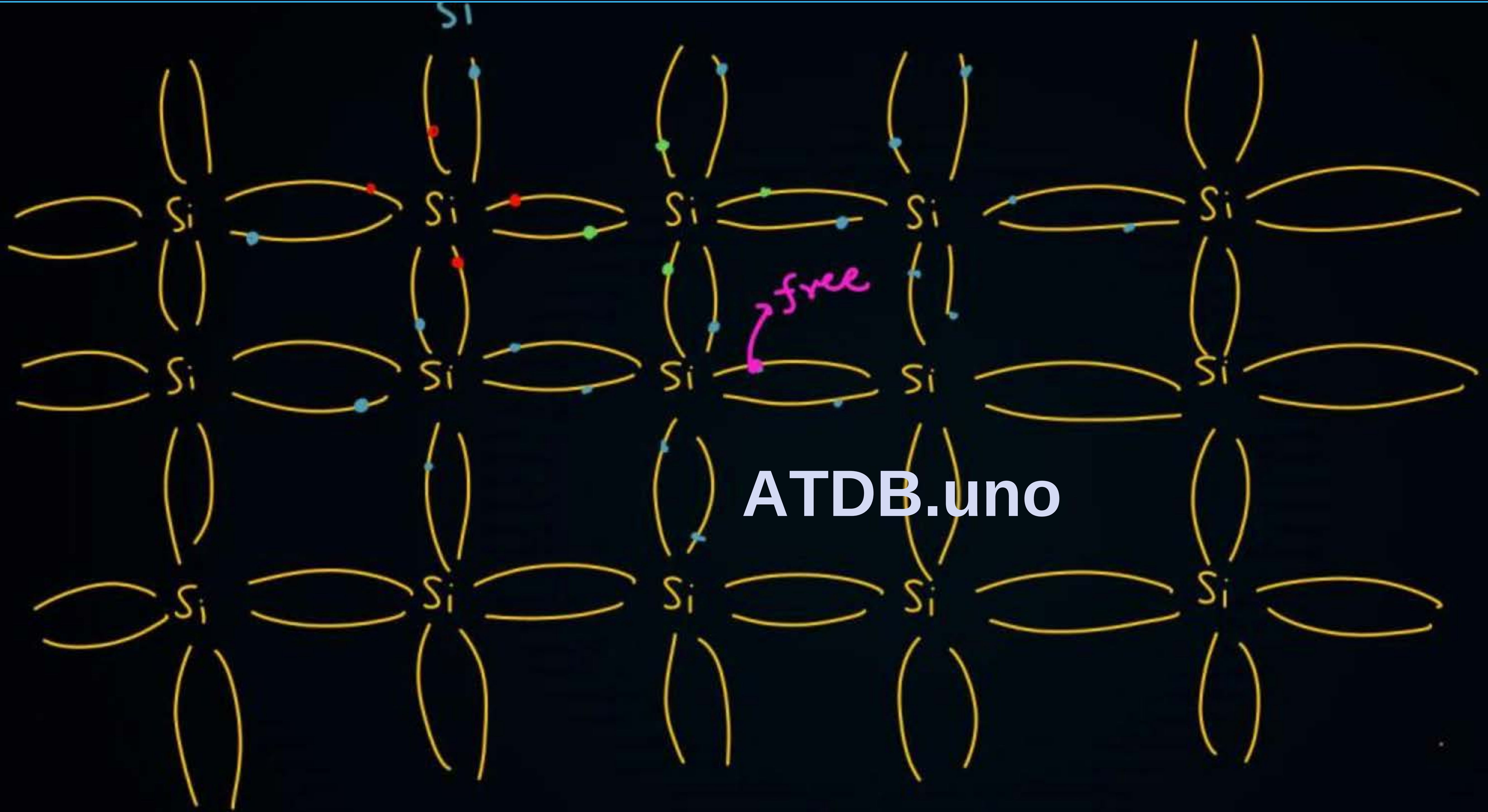
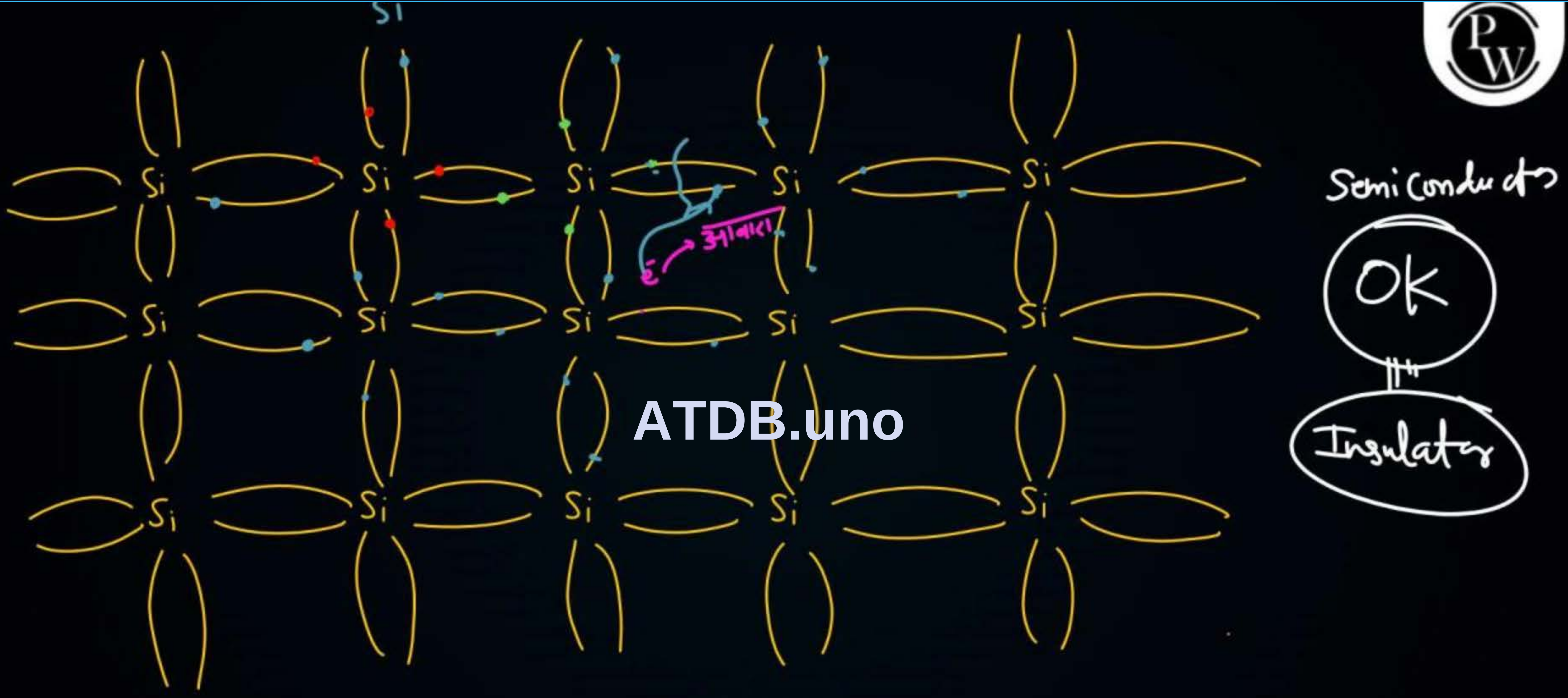
Topics to be covered

1. Semi Conductor
2. Energy band
3. Type of semi Conductor.
4.


Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
free


Si
आवारा
Semiconductors
OK
Insulator


Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si
Si

Classification of conductors, insulators and semiconductor : -

On the basis of the relative values of electrical conductivity and energy bands the solids are broadly classified into three categories

(i) Conductor

(ii) Semiconductor ⟶ Conductivity of S.C. can be heavily controlled by external factor.

(iii) Insulator

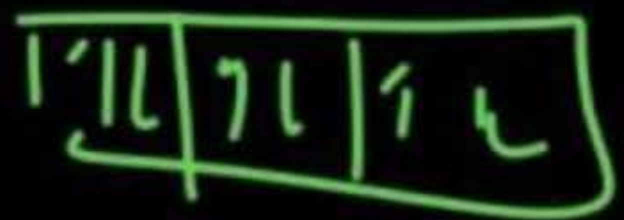
- Electron in outermost shell of an atom are called Valence e^- and this shell called Valence shell.

Na ⟶ $1s^2, 2s^2, 2p^6, 3s^1$

valence band ($2p^6$)

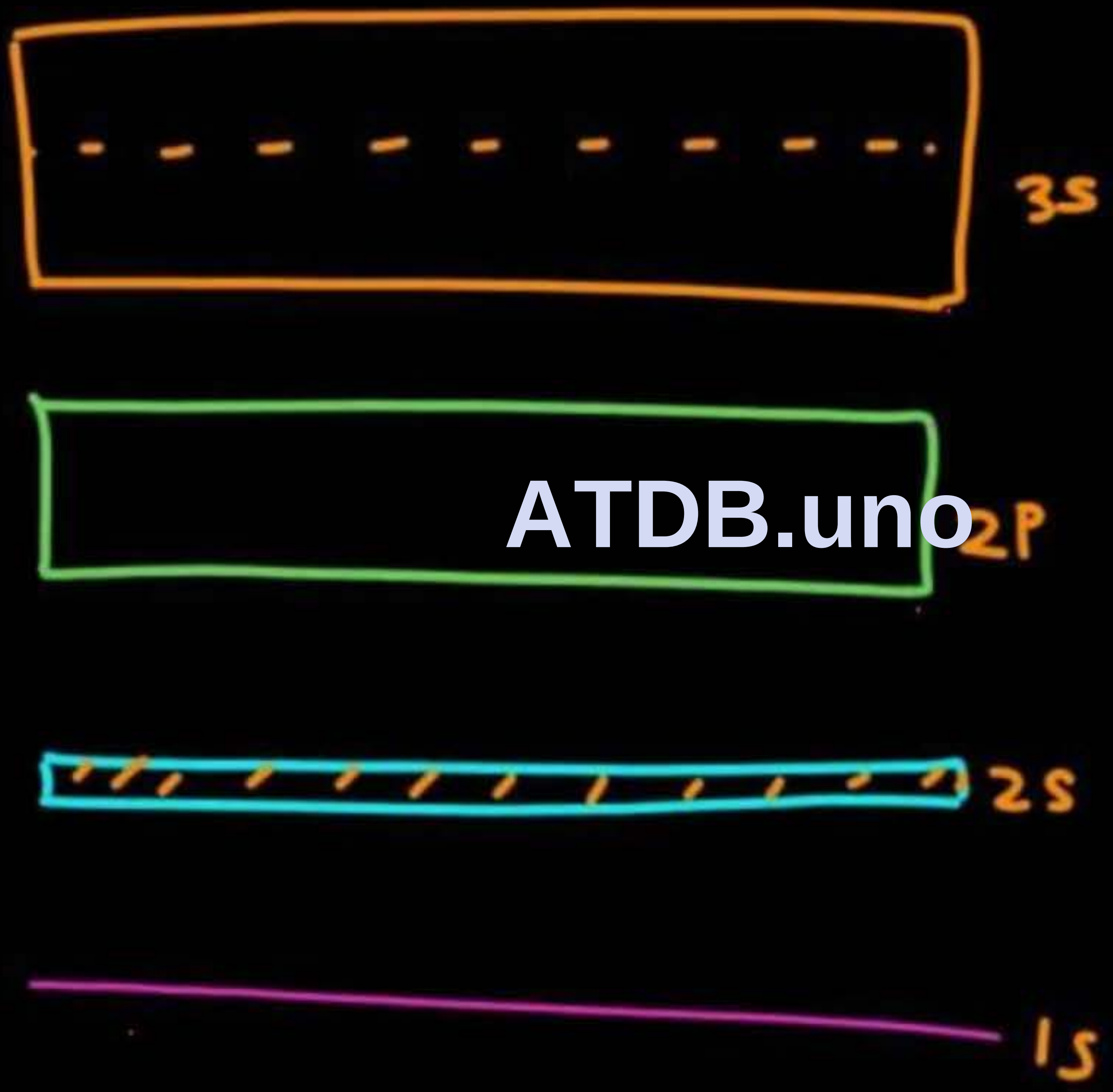
$1s^2, 2s^2, 2p^6$ ⟶ Completely filled

$3s^1$ ⟶ half filled incomplete ✓



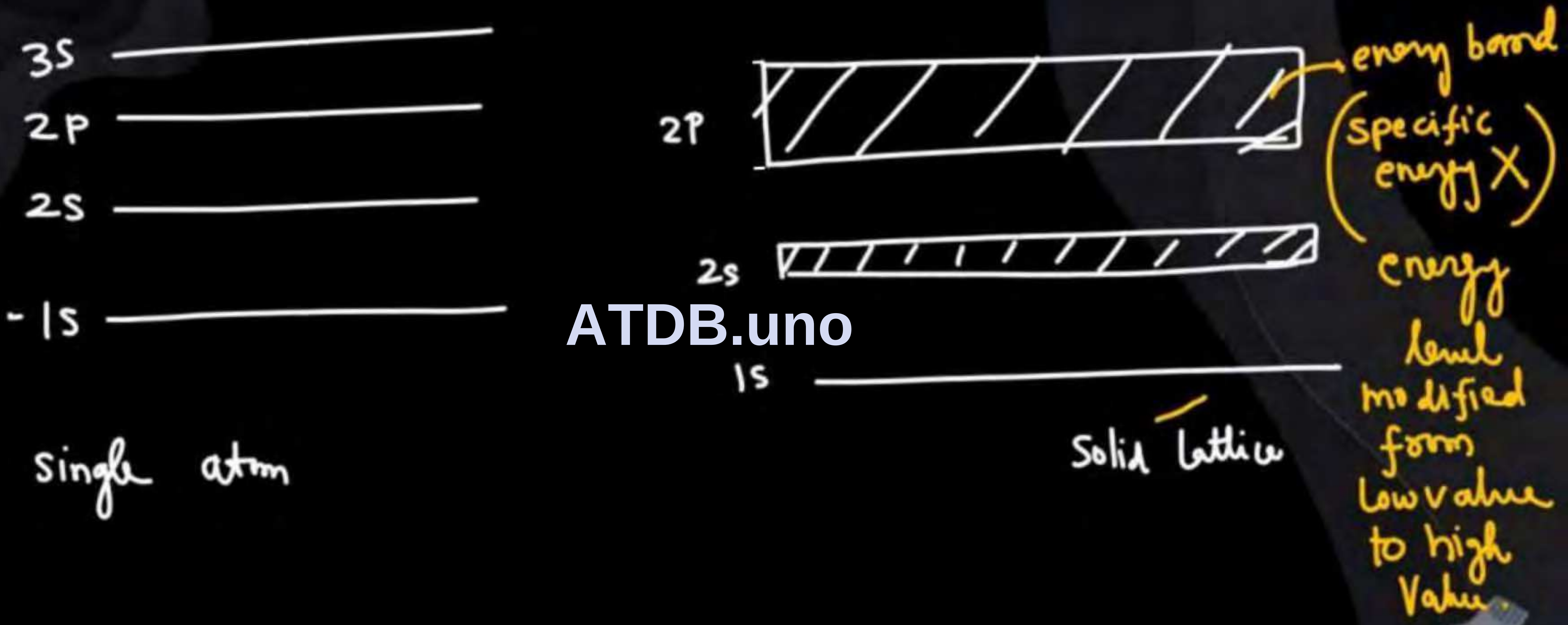
- In an isolated atom there are well define energy level of e^-.
- But in case of solid state, when atoms are very close to each other, their energy values slightly changes. hence in large no. of atoms in a sample we will have a continous range of energy level for particular energy state.

- Range of energy possesed by e^- in a solid is known as energy band.

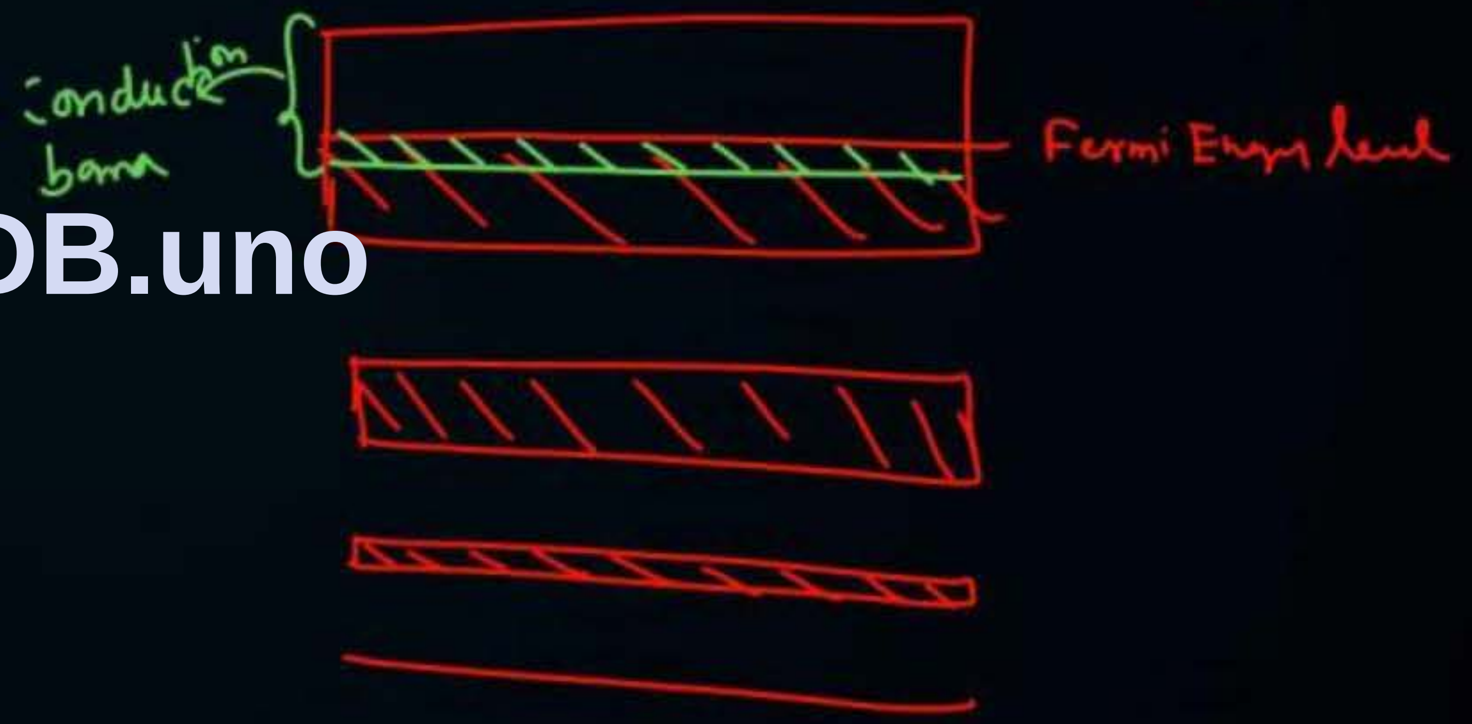


* 1s orbital has very thin energy band, bcz 1s is very closed to nucleus so that effect of sorrounding e^- & atom are negligible

* As we move to higher orbital or away from nucleus modification in energy band thickness increases due to more affected from sorrounding atom


3s
2p
2s
1s
single atom
2P
2s
1s
Solid lattice
energy band
(specific energy X)
energy level modified from low value to high value

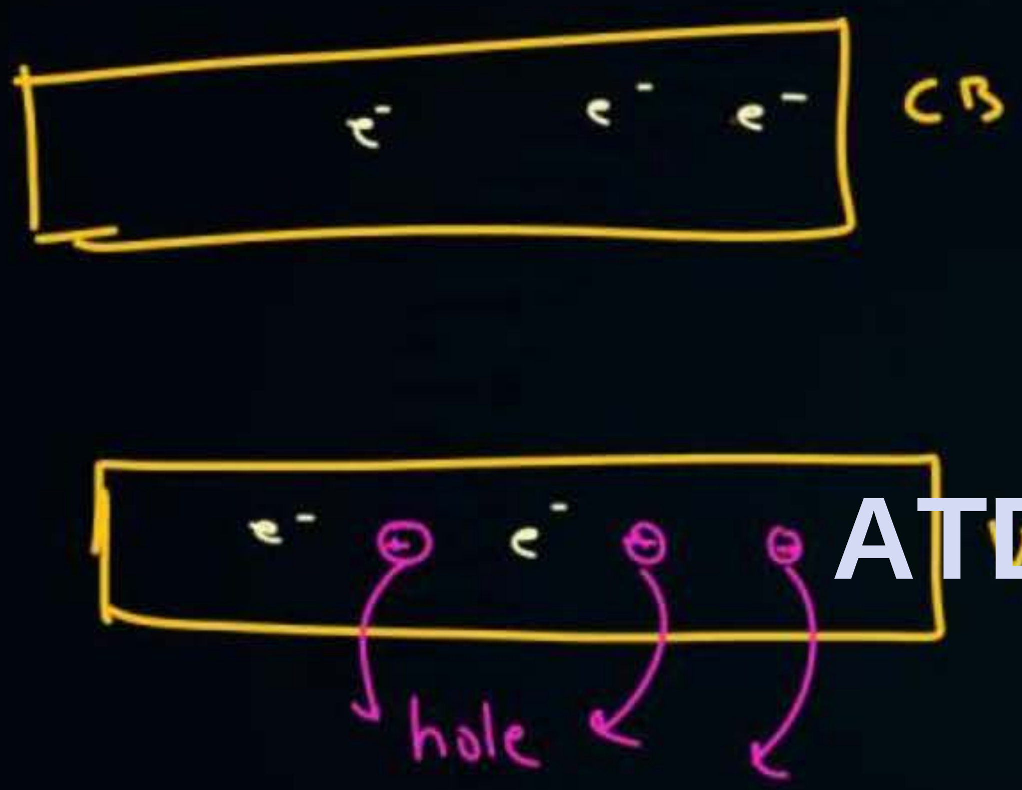
- Fermi Energy Level → Top most energy level where e^- are filled in Valence band. (at 0 K Define)

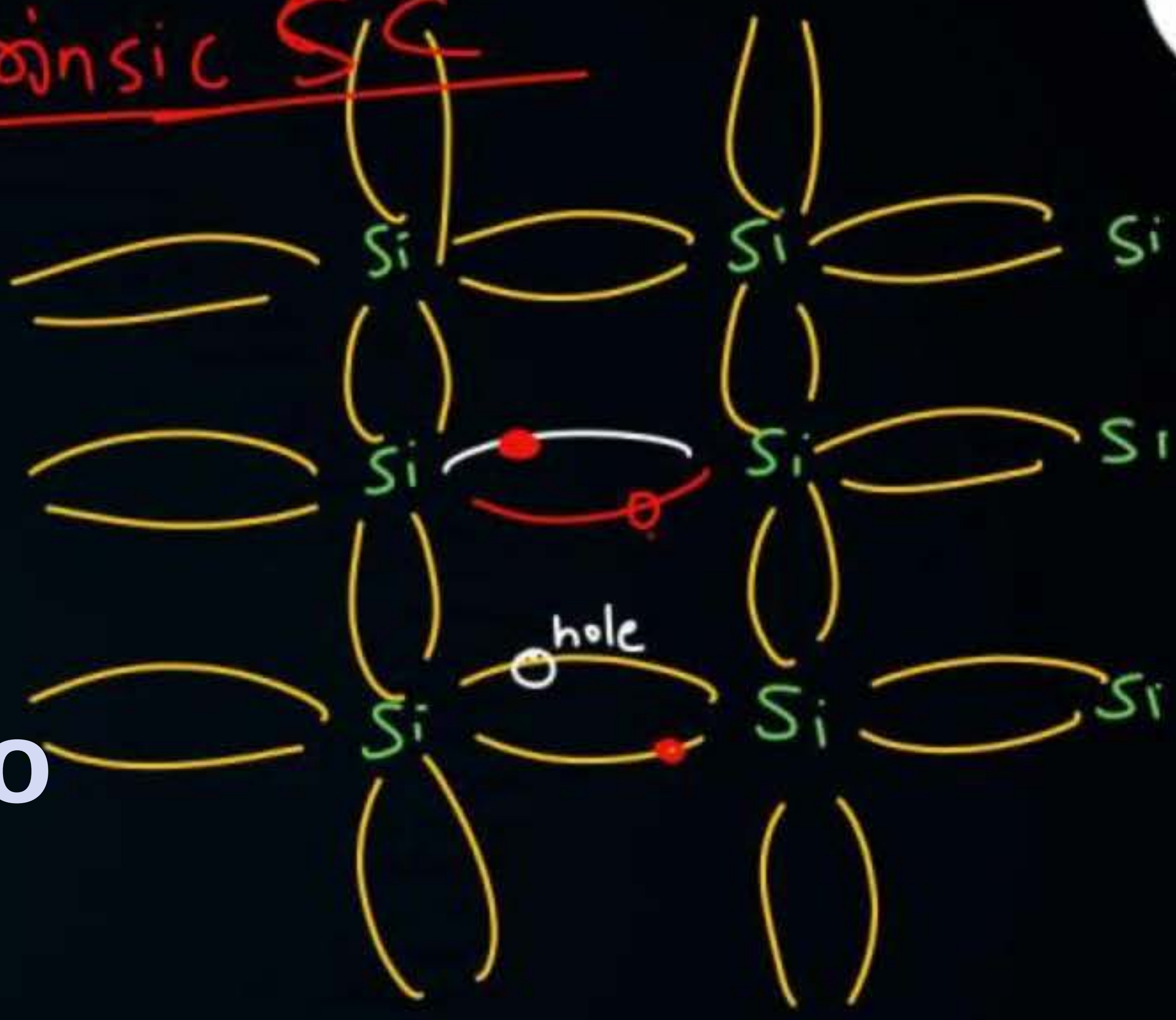


Valence Band → which are completly filled with e^- at 0K
(इतर)
→ never empty
→ e^- are not capable of gaining energy from Ex. E.F.
they donot contribute to electric current.
→ bounded e^-

Conduction Band → Band which are partially filled or completely (↑ vacant)
(KOTA/PATNA)
→ e^- gains energy from Ex. E.F. (आवारा)
- they contribute to electric current.

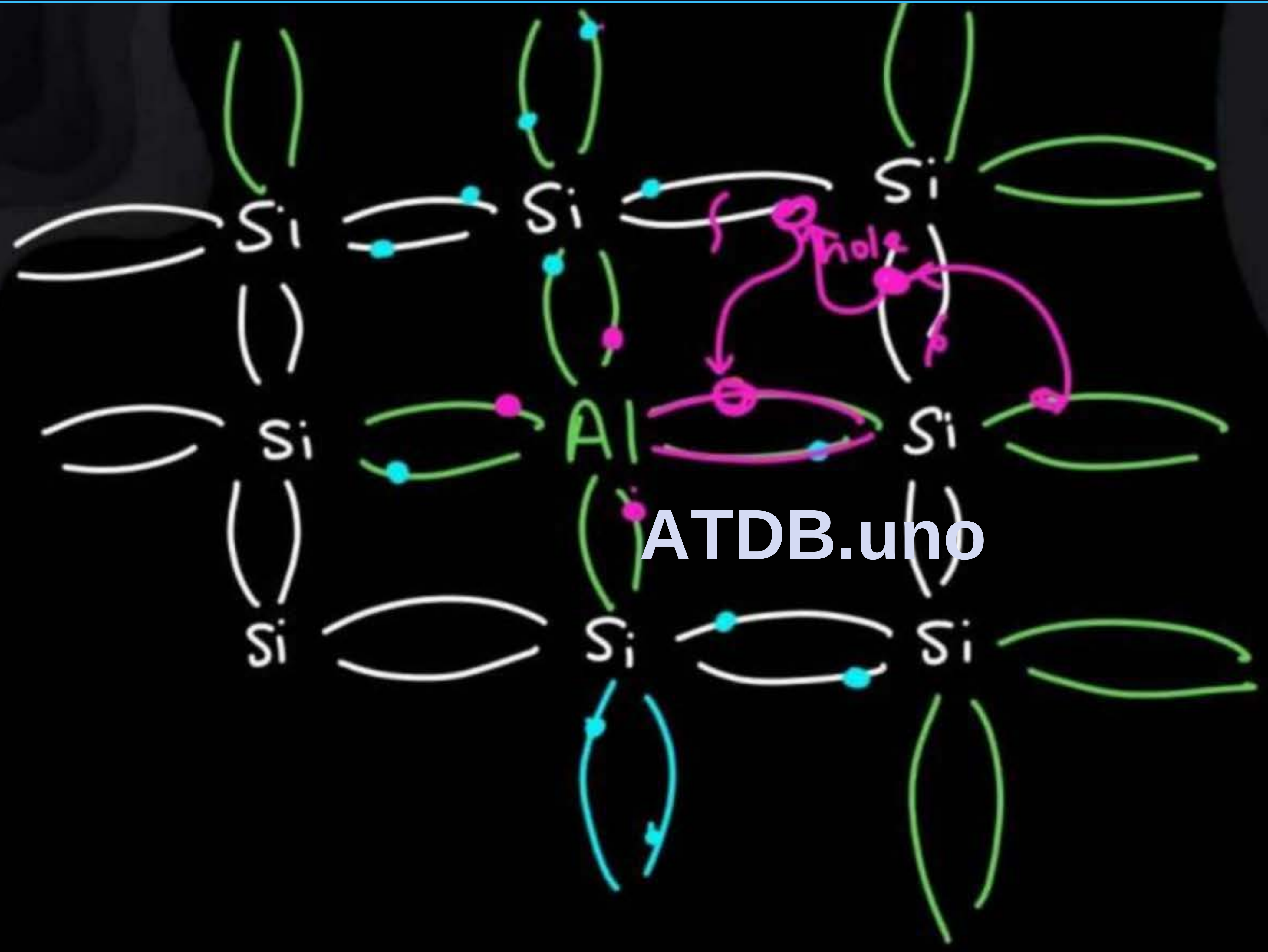
Intrinsic SC






Si
Si
Si
free e⁻
Si
Si
hole
Si
Si
Si
Si
e⁻
CB
VB


Si
As


Si
Si
Si
hole
Si
Al
Si
Si
Si
Si

Classification of conductors, insulators & semiconductor

On the basis of the relative values of electrical conductivity and energy bands the solids are broadly classified into three categories

(i) Conductor

(ii) Semiconductor

(iii) Insulator

Energy bands

Range of energy possessed by electron in a solid is known as energy band.

Valence Band (VB):

Range of energies possessed by valence electron is known as valence band.

(a) Have bonded electron.

(b) No flow of current due to such electron.

(c) Always fulfill by electron.

Conduction Band (CB):

Range of energies possessed by free electron is known as conduction band.

(a) It has conducting electrons.

(b) Current flows due to such electrons.

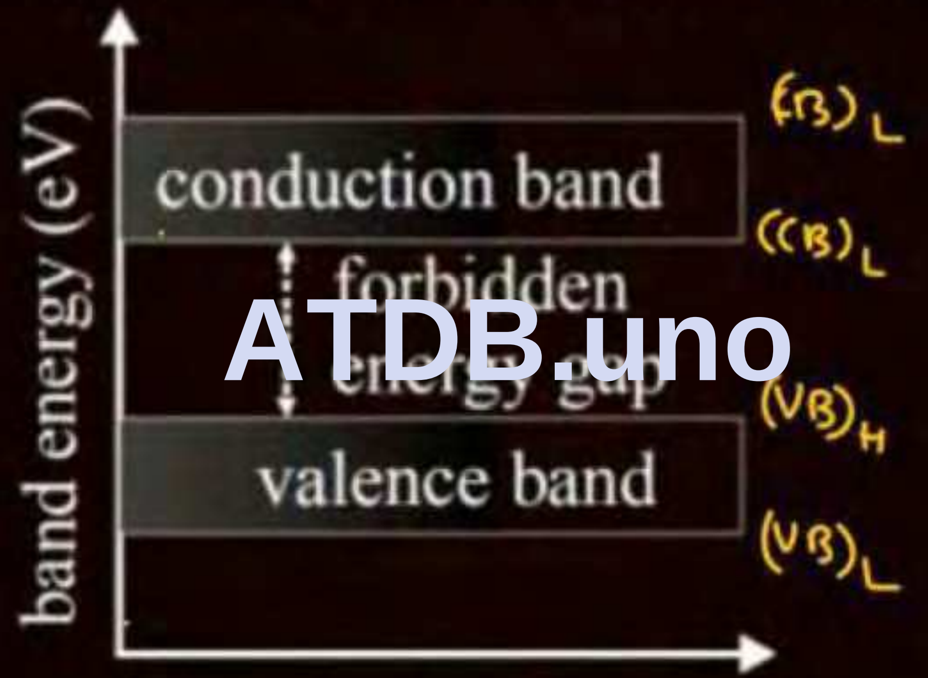
(c) If conduction band is fully empty then current conduction is not possible.

(d) Electrons may exist or not in it.

Forbidden Energy gap (FEG) (ΔEg)

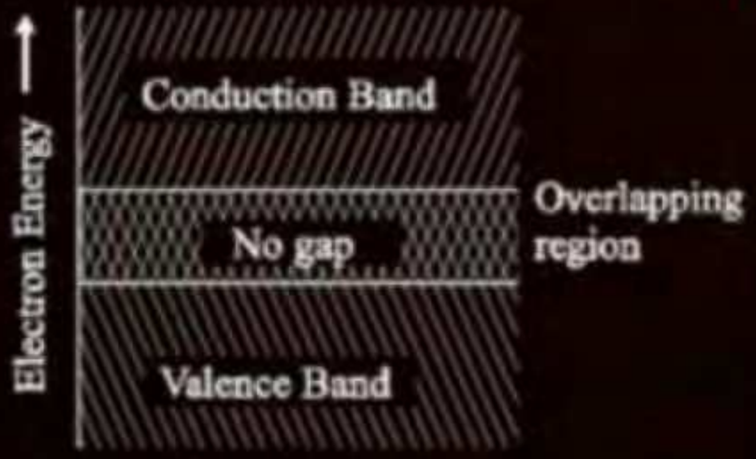
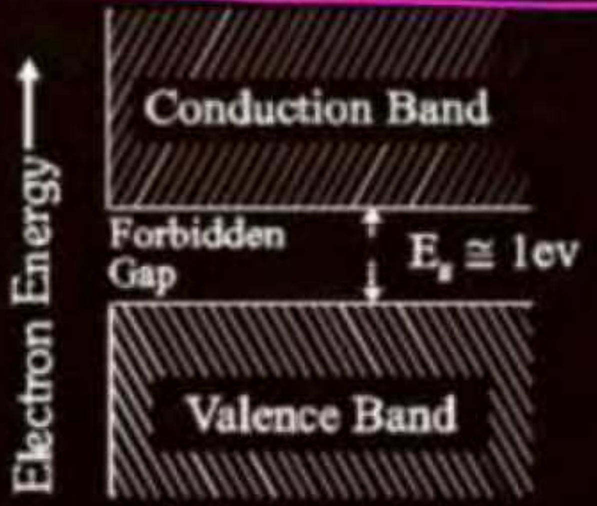
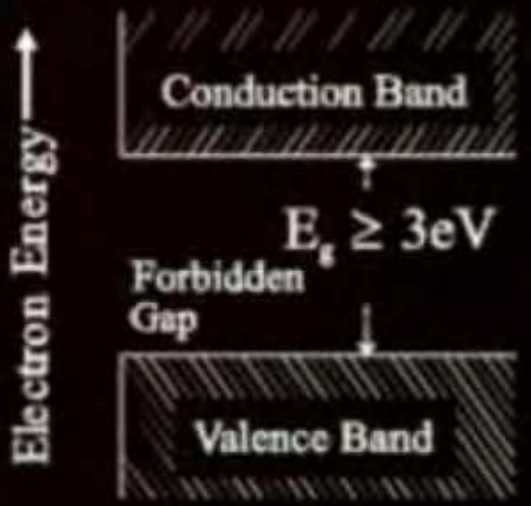
$\Delta E_g = (CB)_{min} - (VB)_{max}$

Energy gap between conduction band and valence band, where no free electron can exist.



- Width of forbidden energy gap depends upon the nature of substance.
- Width is more, then valence electrons are strongly attached with nucleus
- Width of forbidden energy gap is represented in eV.
- As temperature increases forbidden energy gap decreases (very slightly).

Comparison between conductor, semiconductor and insulator

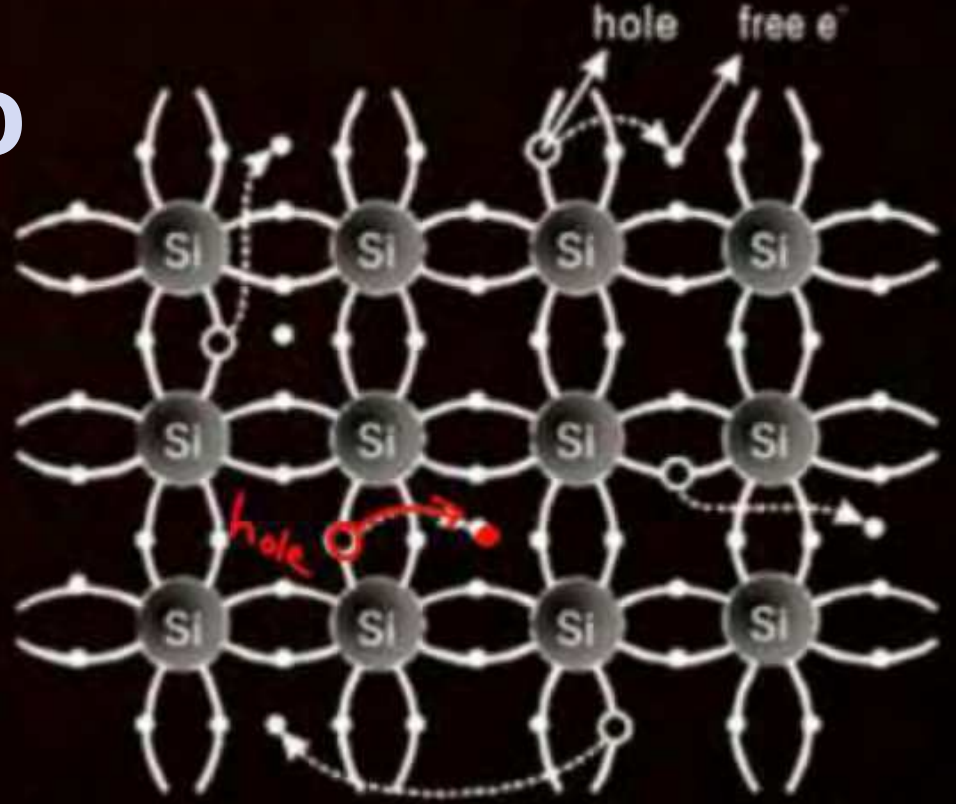
Properties	Conductor	Semiconductor	Insulator
Resistivity ρ	$10^{-2} - 10^{-8}$ Ωm	$10^{-5} - 10^{6}$ Ωm	$10^{11} - 10^{19}$ Ωm
Conductivity	$10^{2} - 10^{8}$ mho/m	$10^{5} - 10^{-6}$ mho/m	$10^{-11} - 10^{-19}$ mho/m
Temp. Coefficient of resistance (α)	Positive $R = R_0(1+\alpha\Delta T)$, $\alpha > 0$, T↑ R↑	Negative, $\alpha < 0$	Negative
Current	Due to free electrons	Due to electrons and holes	No current
Energy band diagram			
Forbidden energy gap Example:	÷ 0 eV Pt, Al, Cu, Ag	÷ 1 eV Ge, Si, GaAs, GaF_2	≥ 3 eV Wood, plastic, Diamond, Mica

Concept of "holes" in semiconductors

Due to external energy (temp. or radiation) when electron goes from valence band to conduction band (i.e. bonded electrons becomes free) a vacancy of free e⁻ creats in valence band,

which has same charge as electron but positive. This positively charged vaccancy is termed as hole and shown in figure.

- It is deficiency of electron in VB.
- It acts as positive charge carrier.
- It's effective mass is more than electron.
- It's mobility is less than electron.



Note : Hole acts as virtual charge carrier, although it has no physical significance.

Effect of temperature on semiconductor

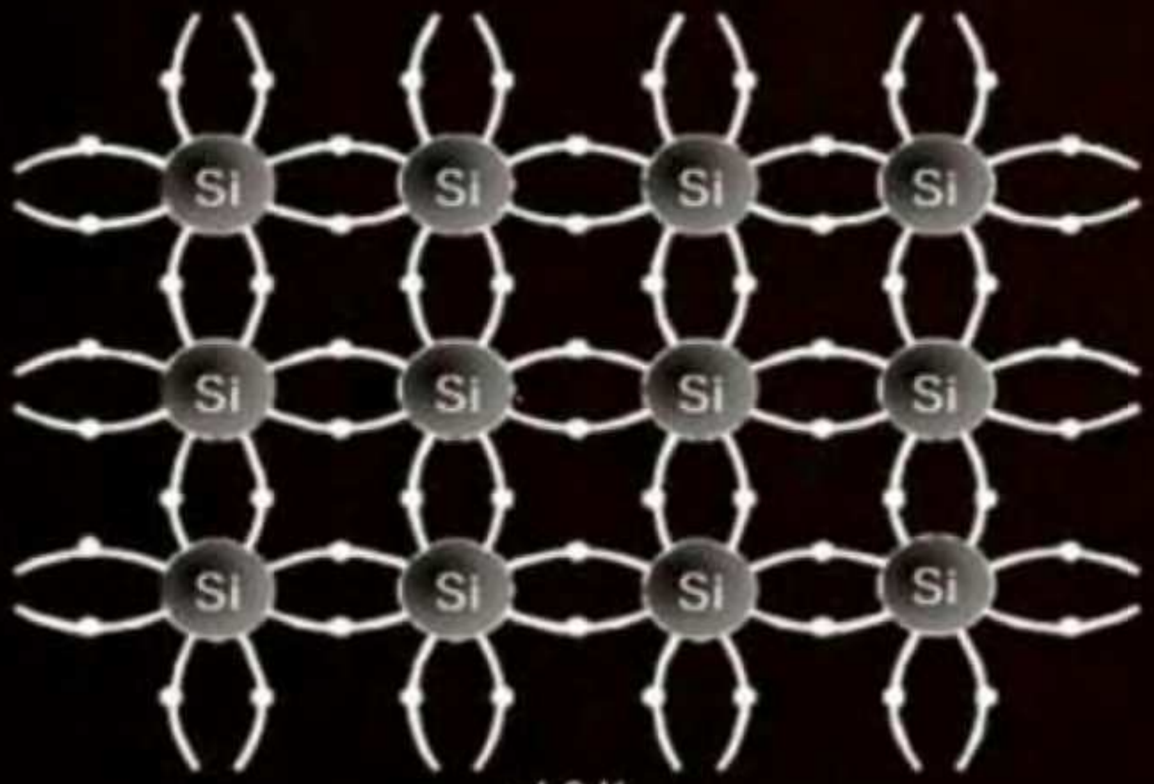
0K ≡ (Semiconductor ≡ Insulator)

At absolute zero kelvin temperature

At this temperature covalent bonds are very strong and there are no free electrons and and hence semiconductor behaves as perfect insulator.

Above absolute temperature

With increase in temperature few valence electrons jump into conduction band and hence it behaves as poor conductor.



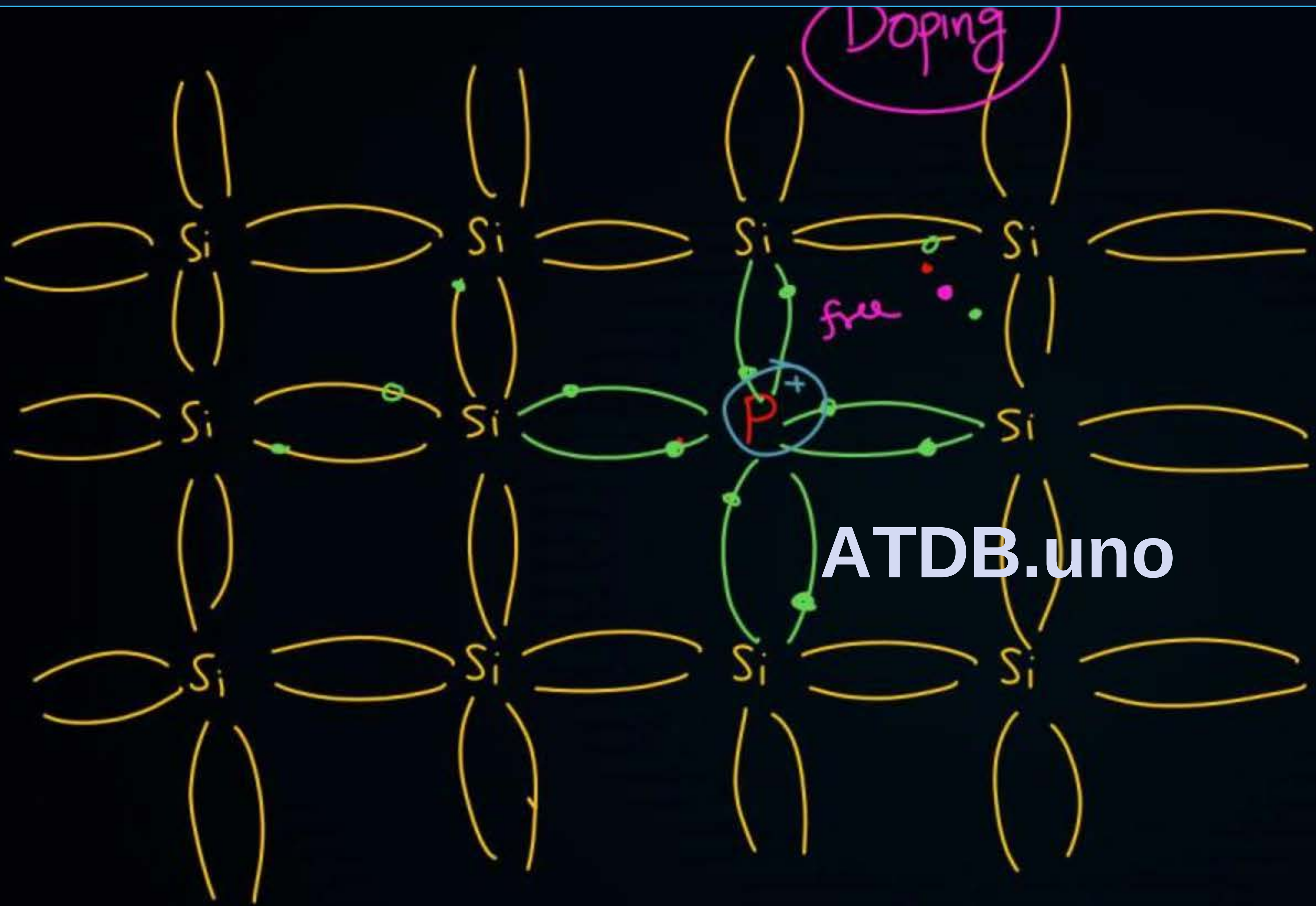
at 0 K
Valence band fully filled

at high temperature
Valence band partially empty

Pure semi conductor

no. of free e^- in CB = no. of holes VB

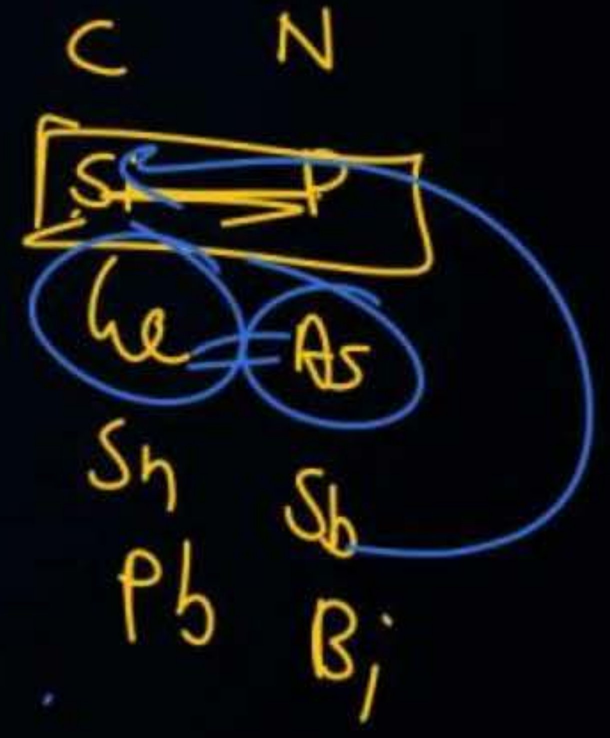
$$n_e = n_h$$



n type Semi Conductors

$(n_e >> n_{holes})$

e⁻ are



Intrinsis Semi Conductor ⟶ Pure

Extrensic Semi Conductor ⟶ Doping. $\left(\begin{matrix} Si + P \\ 10^5 : 1 \end{matrix}\right)$, impurity.

Effect of impurity in semiconductor

Extrinsic SC

Doping is a method of addition of "desirable" impurity atoms to pure semiconductor to increase conductivity of semiconductor. or

Doping is a process of deliberate addition of a desirable impurity atoms to a pure semiconductor to modify its properties in controlled manner.

Added impurity atoms are called dopants.

The impurity added may be ≈ 1 part per million (ppm).

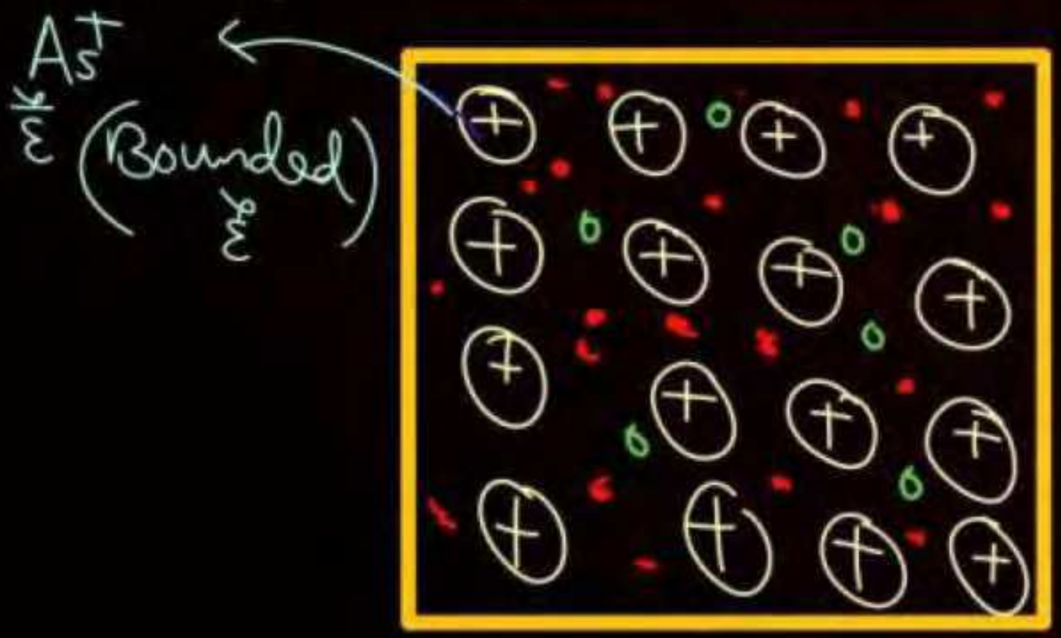
- The dopant atom should take the position of semiconductor atom in the lattice.
- The presence of the dopant atom should not distort the crystal lattice.
- The size of the dopant atom should be almost the same as that of the crystal atom.
- The concentration of dopant atoms should not be large (not more than 1% of the crystal atom).

It is to be noted that the doping of a semiconductor increases its electrical conductivity to a great extent.

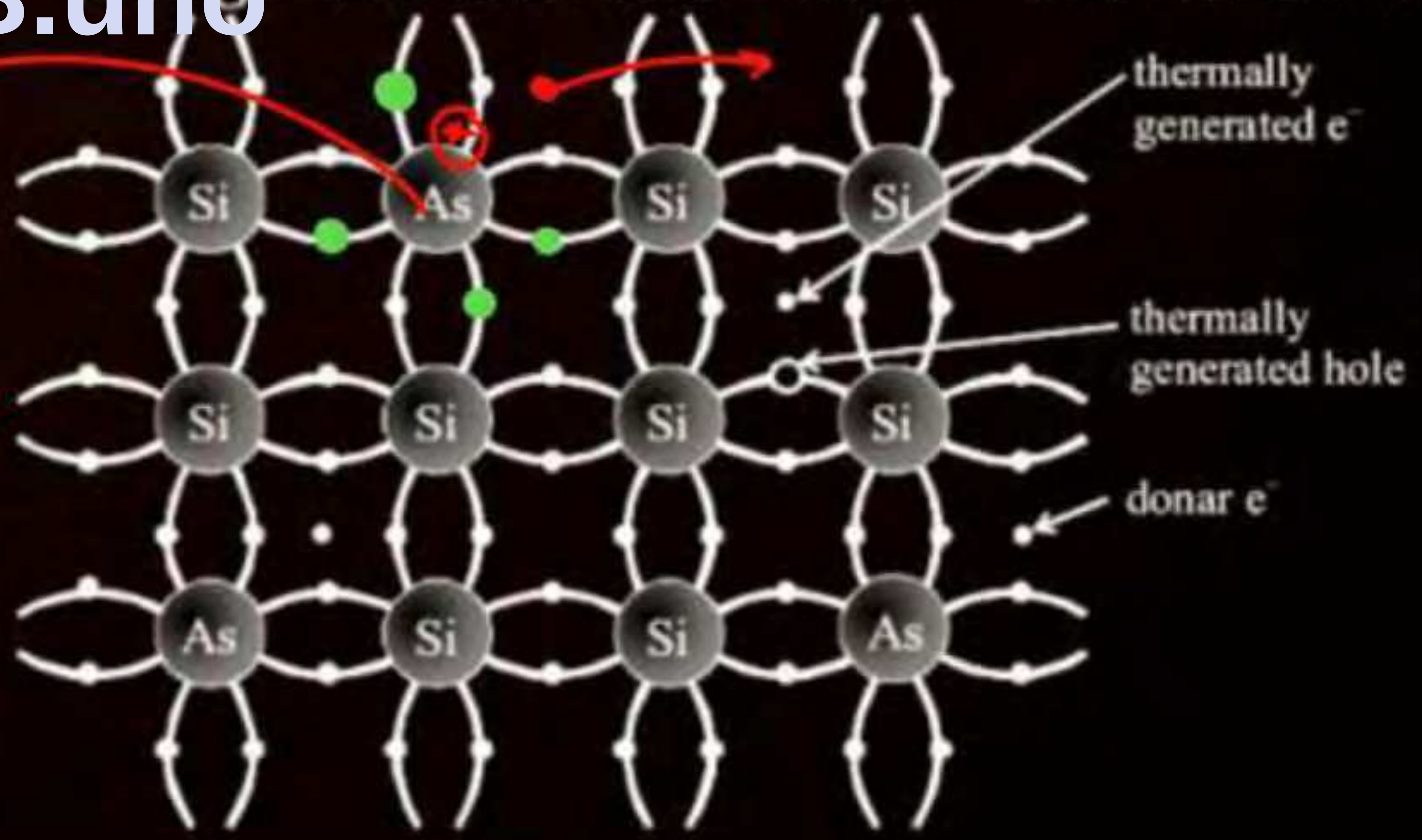
- The concentration of dopant atoms be very low, doping ratio is vary from impure : pure :: $1 : 10^6$ to $1 : 10^{10}$ In general it is $1 : 10^8$

N – type semiconductor

When a pure semiconductor (Si or Ge) is doped by pentavalent impurity (P, As, Sb, Bi) then four electrons out of the five valence electrons of impurity take part, in covalent bonding, with four silicon atoms surrounding it and the fifth electron is set free. These impurity atoms which donate free e⁻ for conduction are called as Donar impurity (N_D). Due to donar impurity free e⁻ increases very much so it is called as "N" type semiconductor. By donating e⁻ impurity atoms get positive charge and hence known as "Immobile Donar positive Ion". In N-type semiconductor free e⁻ are called as "majority" charge carriers and "holes" are called as "minority" charge carriers.



As ≡ Bounded
+ve Charge



n type ⇒ (Si + pentavalent) ≡ $5e^-$
→ $4e^-$ Bond ✓
→ $1e^-$ free → move → चला जाता
(Extrinsic)

As^+ → immobile atom, +ve charge

* e^- are majority Carriers.
* holes : minority Carrier

$n_e >> n_{holes}$

* Overall material is neutral.
* n-type ≡ SC ⇒ Charge ≡ neutral.

Entrinsic Semiconductor —(doping / impurity Add)→ Extrensic Semiconductor

Entrinsic Semiconductor → pure, $n_e = n_h$

Extrensic Semiconductor → n type, p type

n type

$n_e >> n_{holes}$

$(Si = As)$

p type

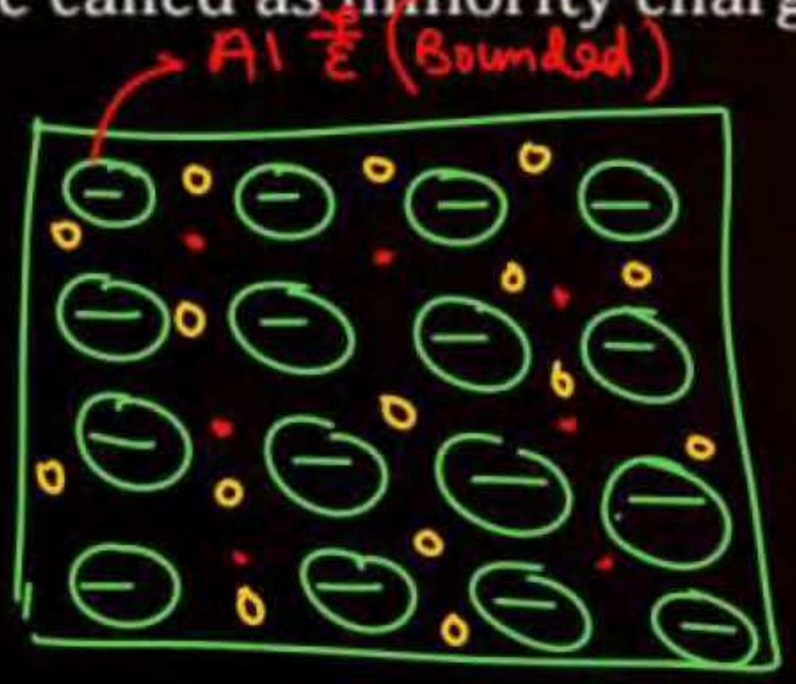
$Si \equiv Al$

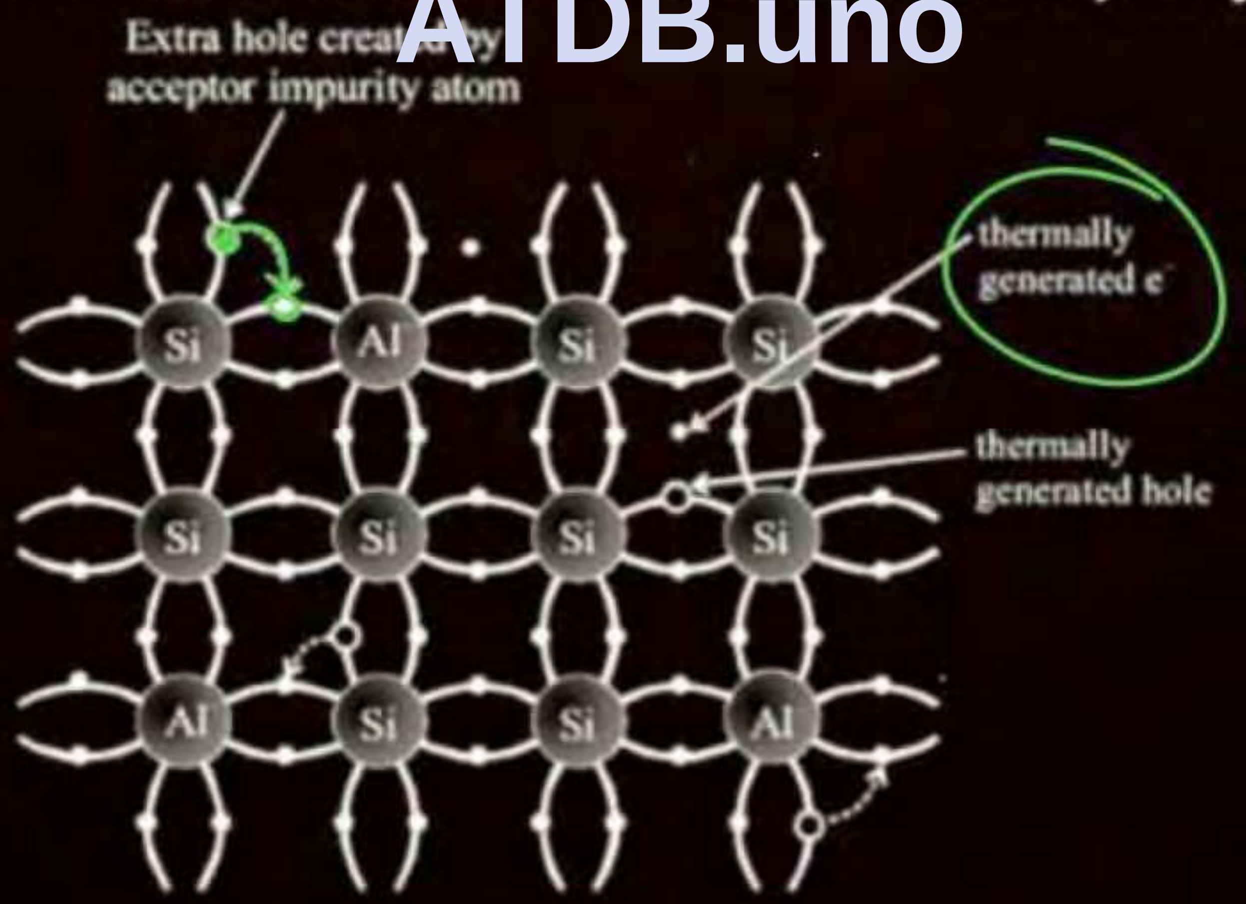
$n_h >> n_{e^-}$

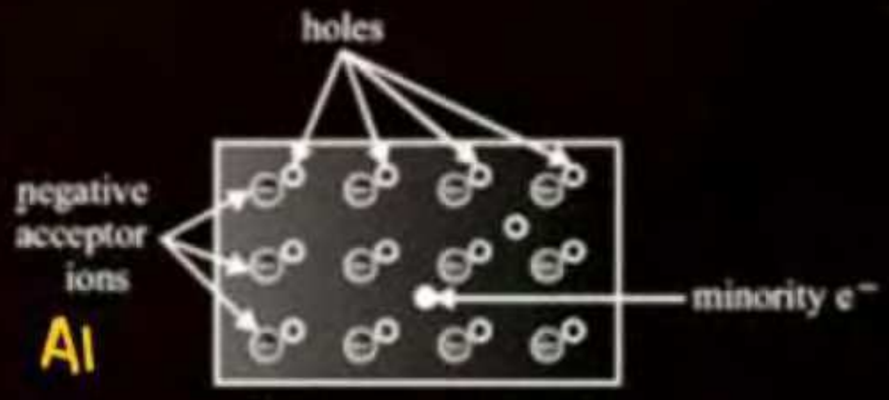

P type
Si
Al
e⁻
e⁻

P - type semiconductor

When a pure semiconductor (Si or Ge) is doped by trivalent impurity (B, Al, In, Ga) then outer most three electrons of the valence band of impurity take part, in covalent bonding with four silicon atoms surrounding it and except one electron from semiconductor and make hole in semiconductor. These impurity atoms which accept bonded e^- from valance band are called as Acceptor impurity (N_A). Here holes increases very much so it is called as "P" type semiconductor and impurity ions known as "Immobile Acceptor negative Ion". In P-type semiconductor free e^- are called as minority charge carries and holes are called as majority charge carriers.







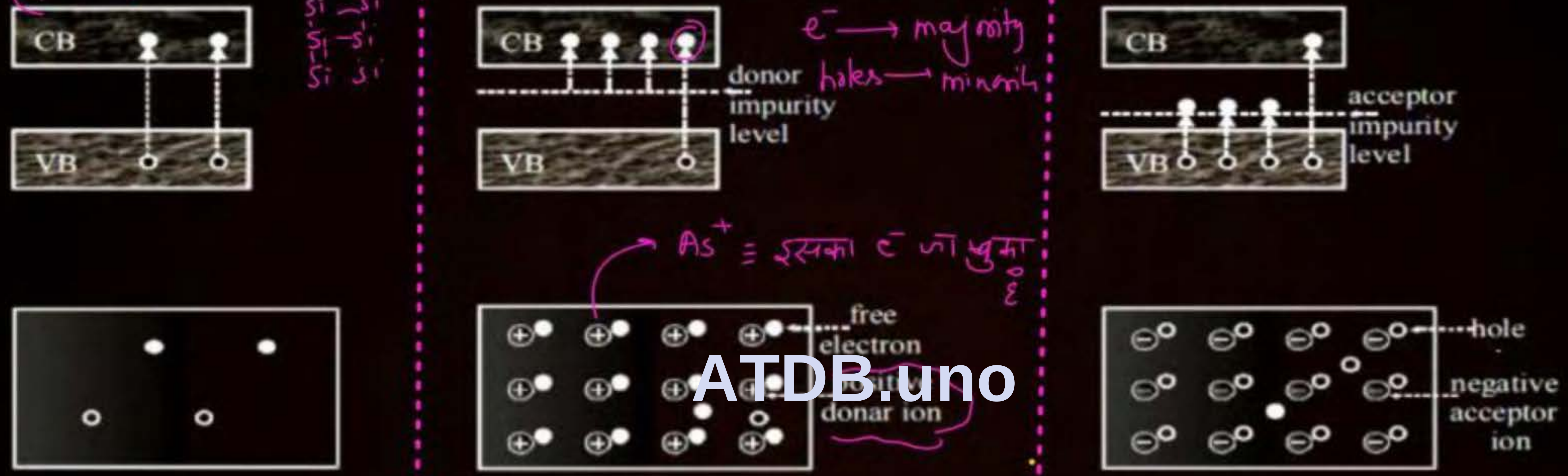
P-type semiconductor

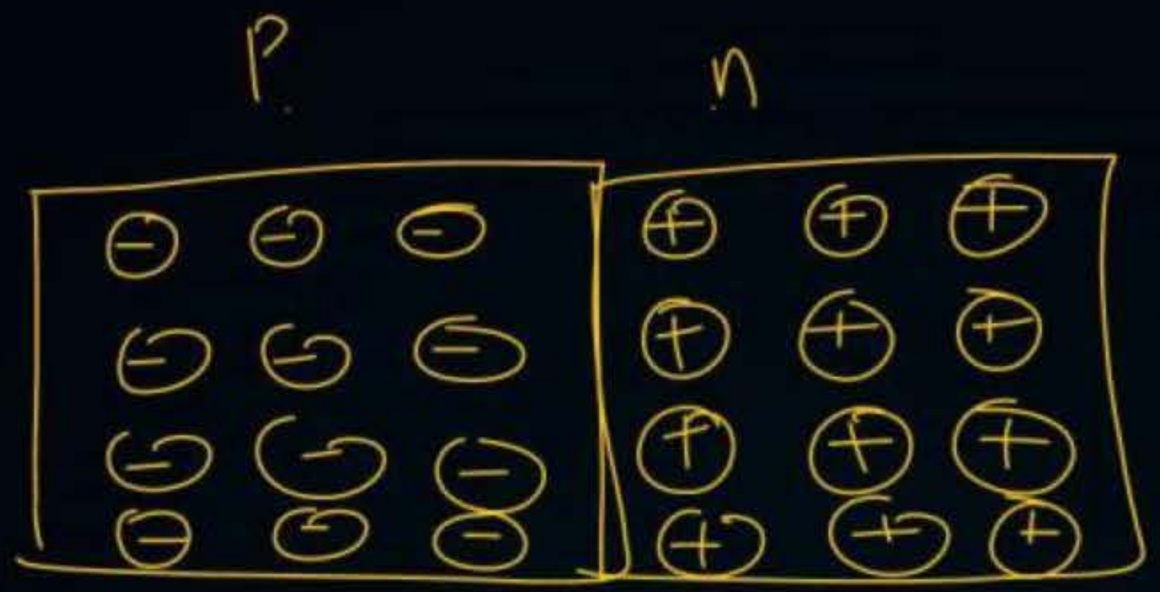
B	C	N
Al	Si	P
Ga	Ge	As
In	Sn	Sb
Th	Pb	Bi

Pentavalent
$5e^-$

$4e^-$ Bond बना लिया
$1e^-$ बचा

(n type)

	Intrinsic Semiconductor	N-type (Pentavalent impurity)	P-type(Trivalent impurity)
1.			
2.			
3.	Current due to electron and hole	Mainly due to electrons	Mainly due to holes
4.	$n_e = n_h = n_i$	$n_h << n_e$ ($N_D \simeq n_e$)	$n_h >> n_e$ ($N_A \simeq n_h$)
5.	$I = I_e + I_h$	$I \simeq I_e$	$I \simeq I_h$
6.	Entirely neutral	Entirely neutral	Entirely neutral
7.	Quantity of electrons and holes are equal	Majority – Electrons Minority – Holes	Majority – Holes Minority - Electrons



PN junction diode


THANK
YOU