

PRAYAS

JEE 2025



Lecture - 02

Physics

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SemiConductor



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Topics *to be covered*

1

Semi Conductor

2

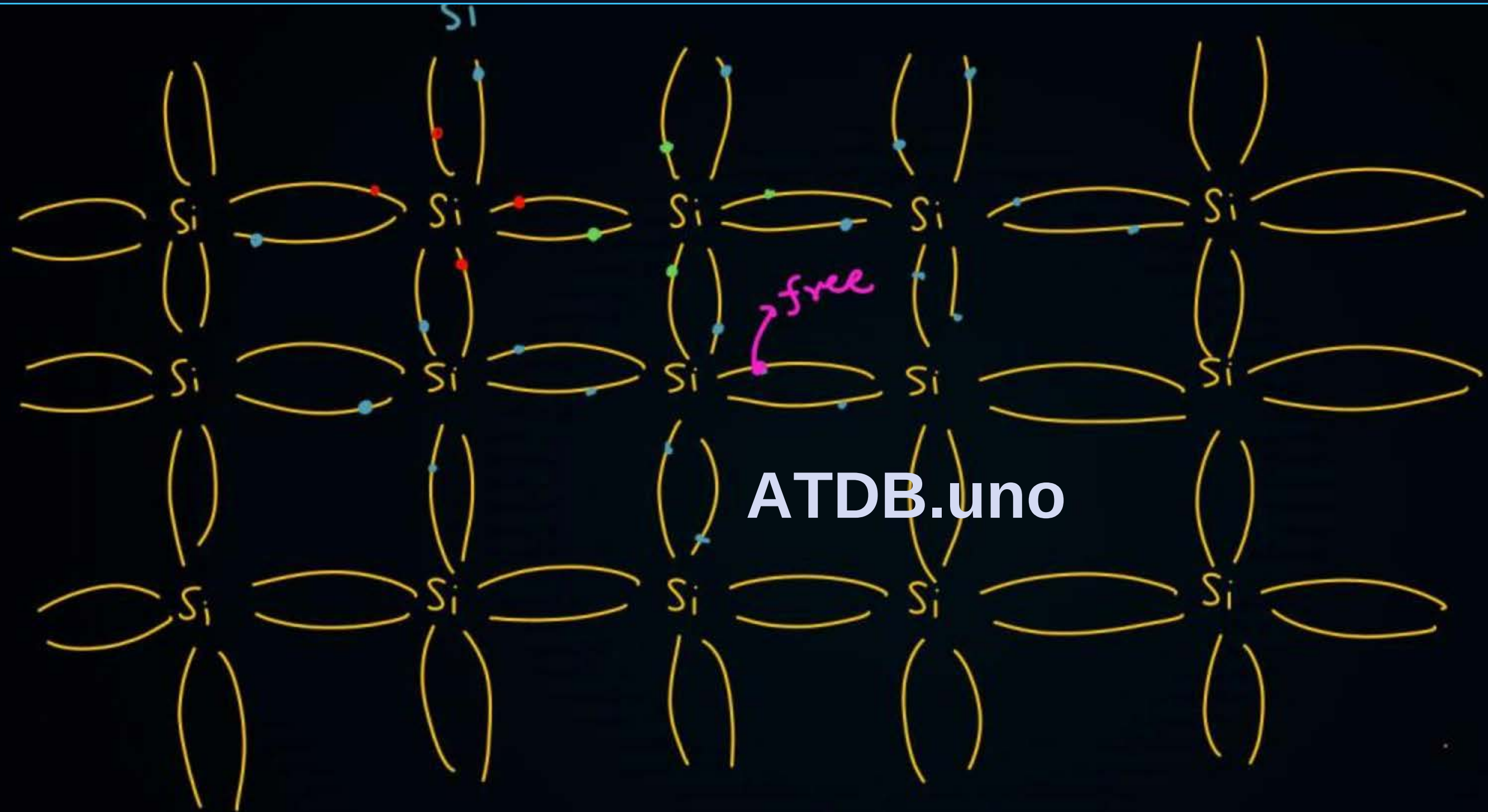
Energy band

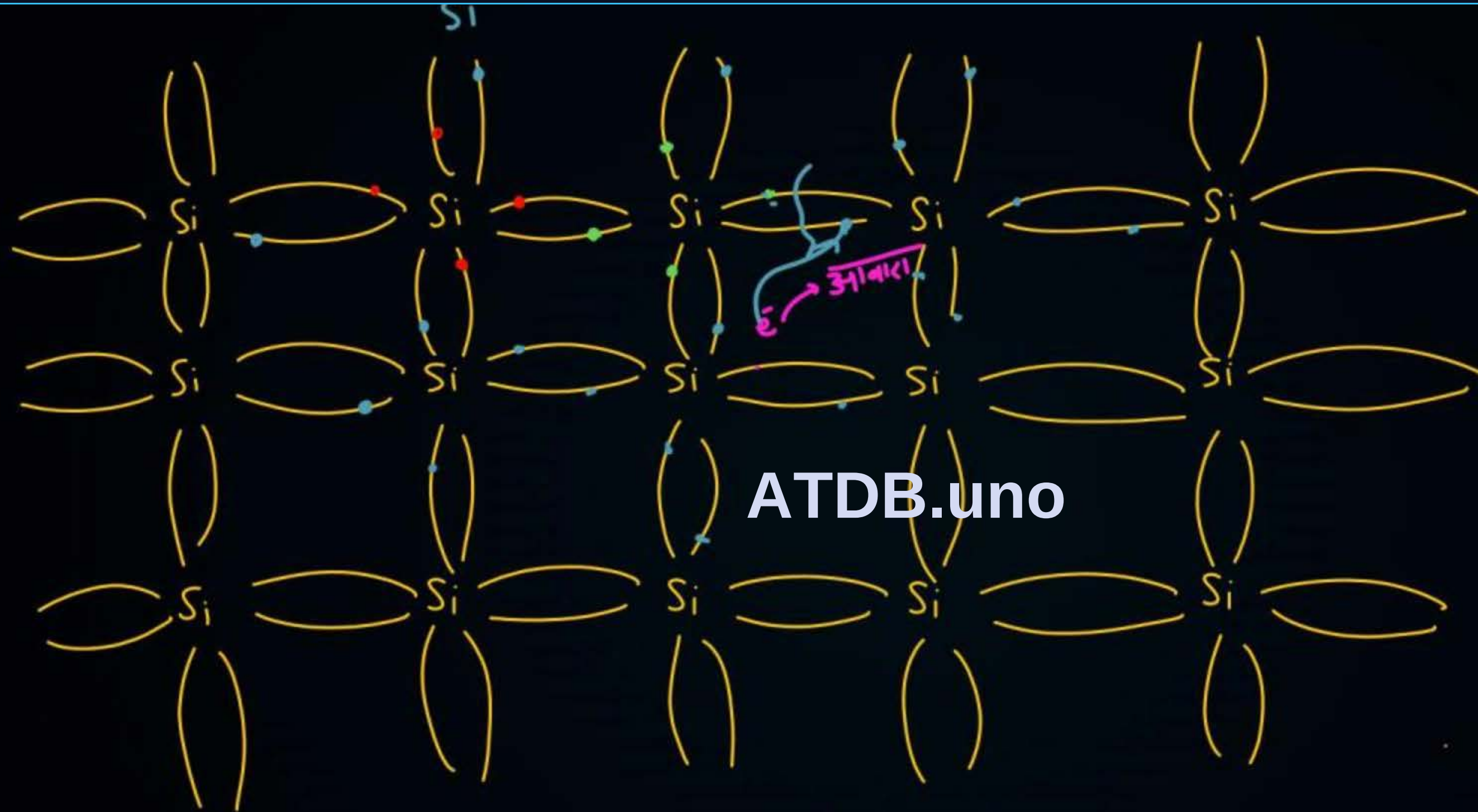
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Type of Semi Conductor .

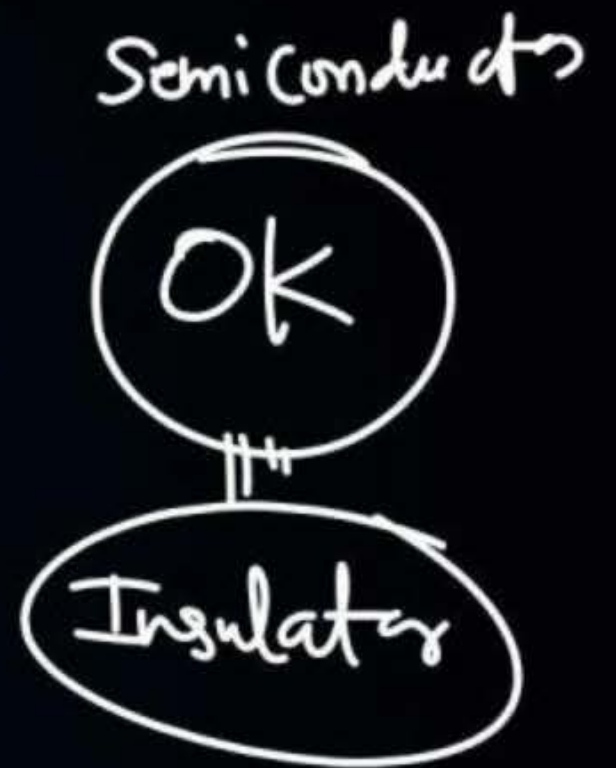
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Classification of conductors, insulators and semiconductor : -

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

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

Na → 1s², 2s², 2p⁶, 3s¹

Valence band

completely filled

half filled incomplete

↑↓	↑↓	↑↓	↑↓	↑↓	↑↓
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Valence band

Fermi Energy

partially filled

completely filled 2p

completely filled 2s

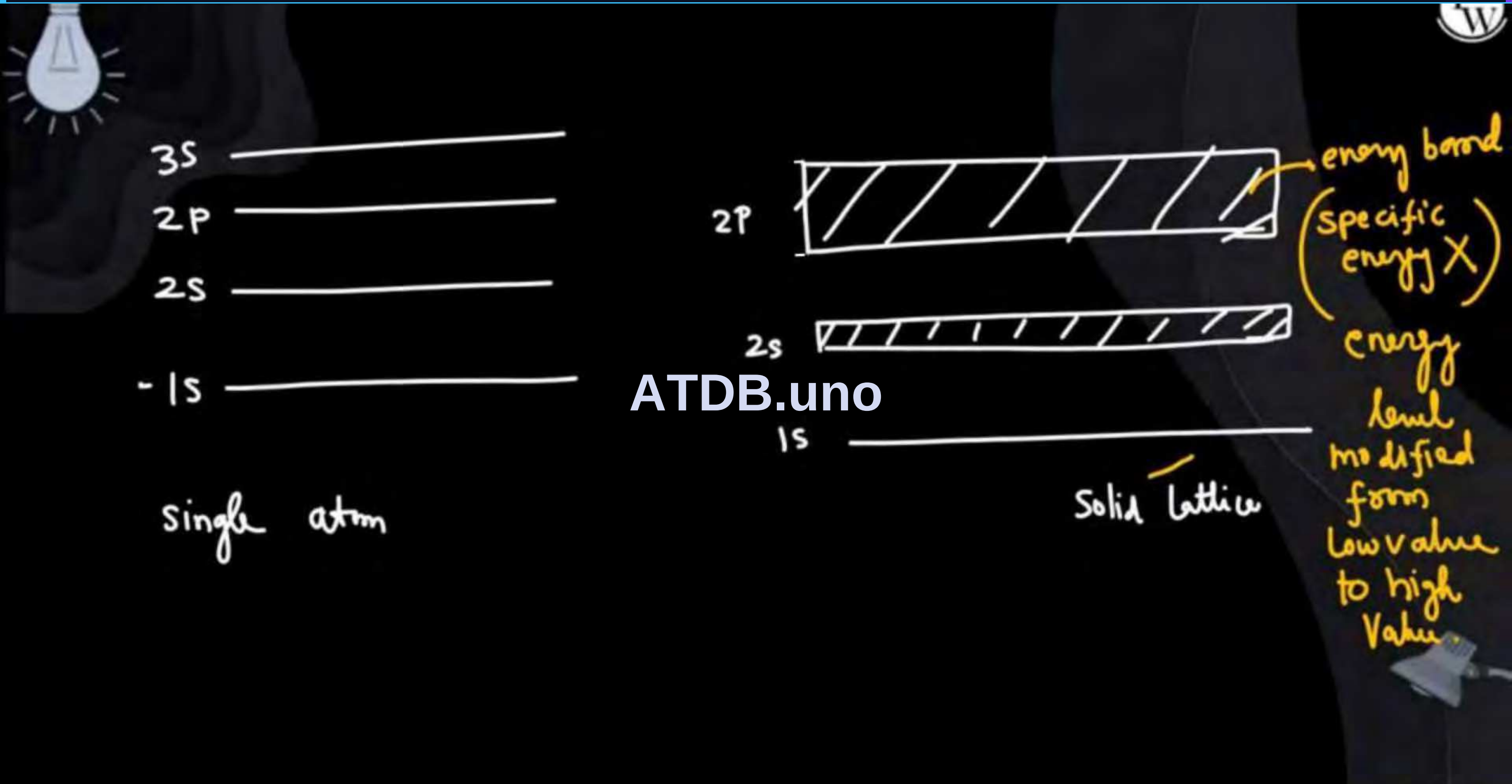
1s



- In an isolated atom there are well defined energy levels of e^- .
- But in case of solid state, when atoms are very close to each other, their energy values slightly change.
hence in large no. of atoms in a sample we will have a continuous range of energy levels for particular energy states.
- Range of energy possessed by e^- in a solid is known as energy band.



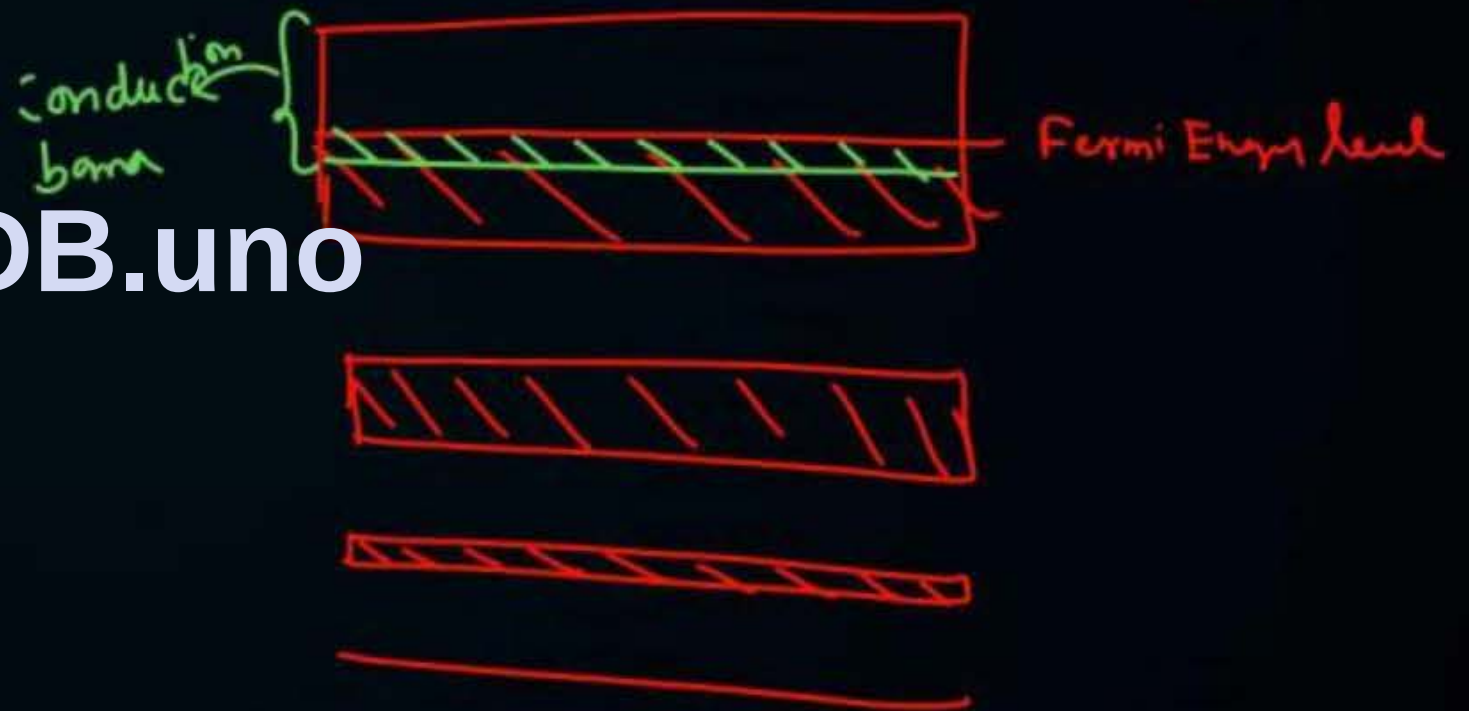
- * As we move to higher orbital or away from nucleus modification in energy band thickness increases due to more affected from surrounding atom





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

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Valence Band $\rightarrow$ which are **completely filled** with e^- at 0K

||
(ETR)

$\rightarrow$ never empty

$\rightarrow e^-$ are not capable of gaining energy from ex. E.F.
they do not contribute to electric current.

$\rightarrow$ bounded e^-

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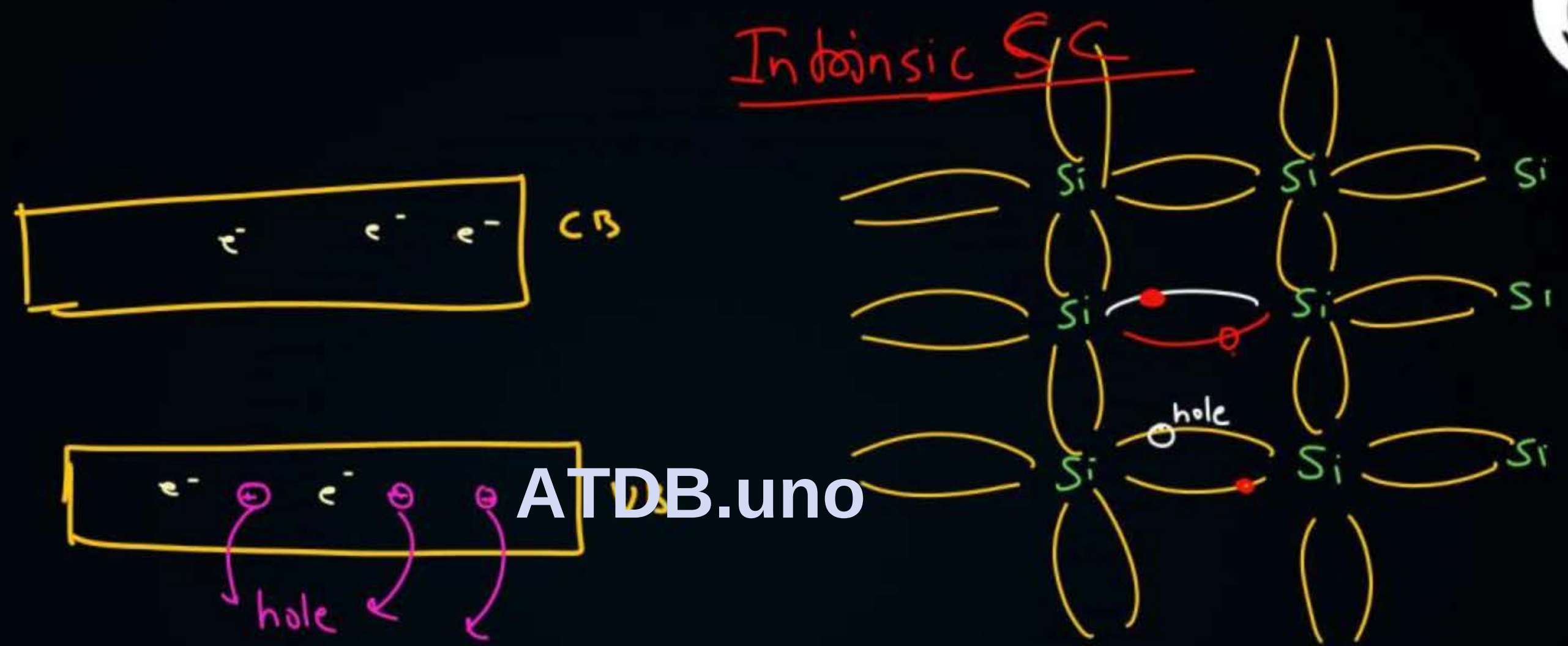
Conduction Band $\rightarrow$ Band which are partially filled or completely

(KOTA/PATNA)

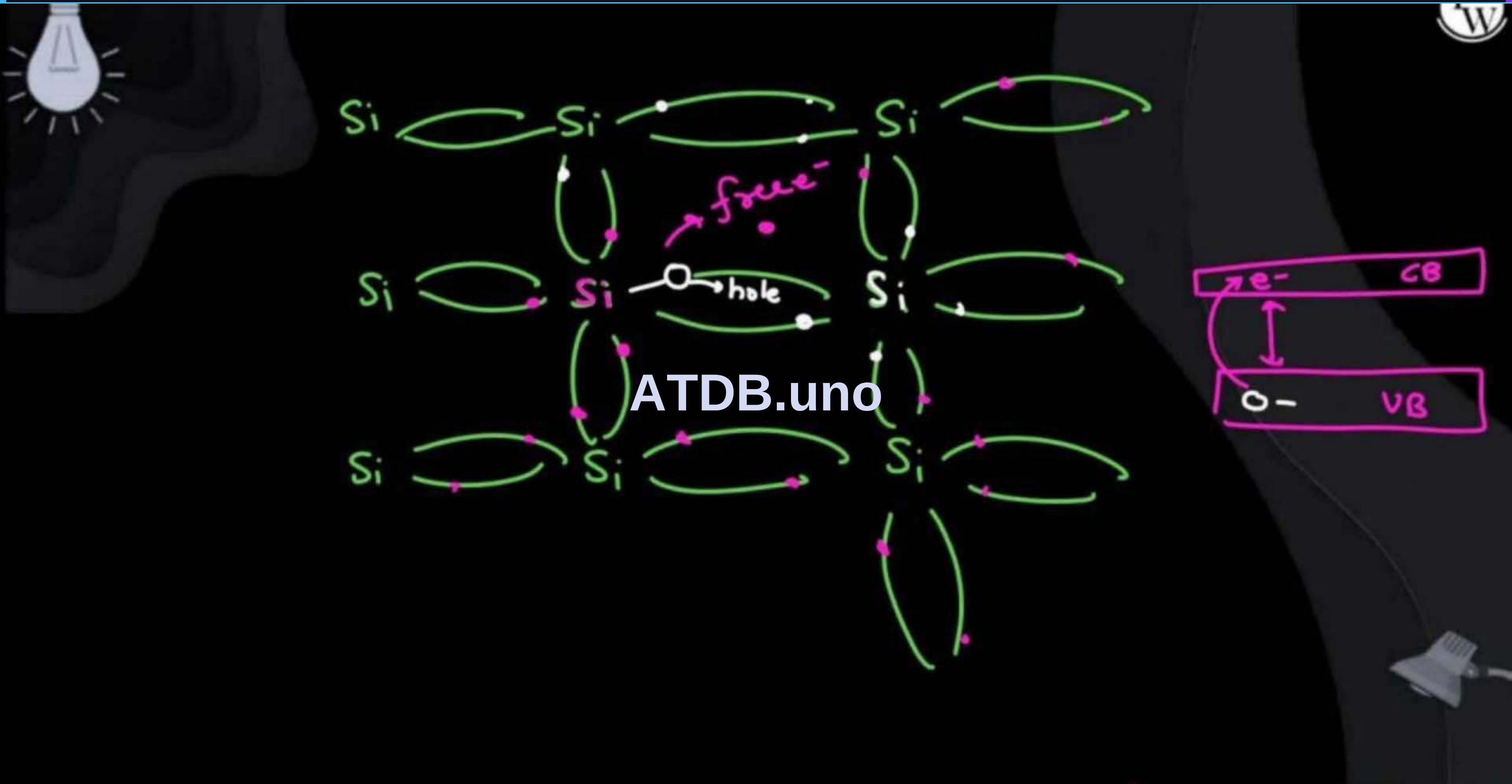
$\rightarrow e^-$ gain energy from ex. E.F. **आवर्त**
- they contribute to electric current.

vacant
 $\uparrow$

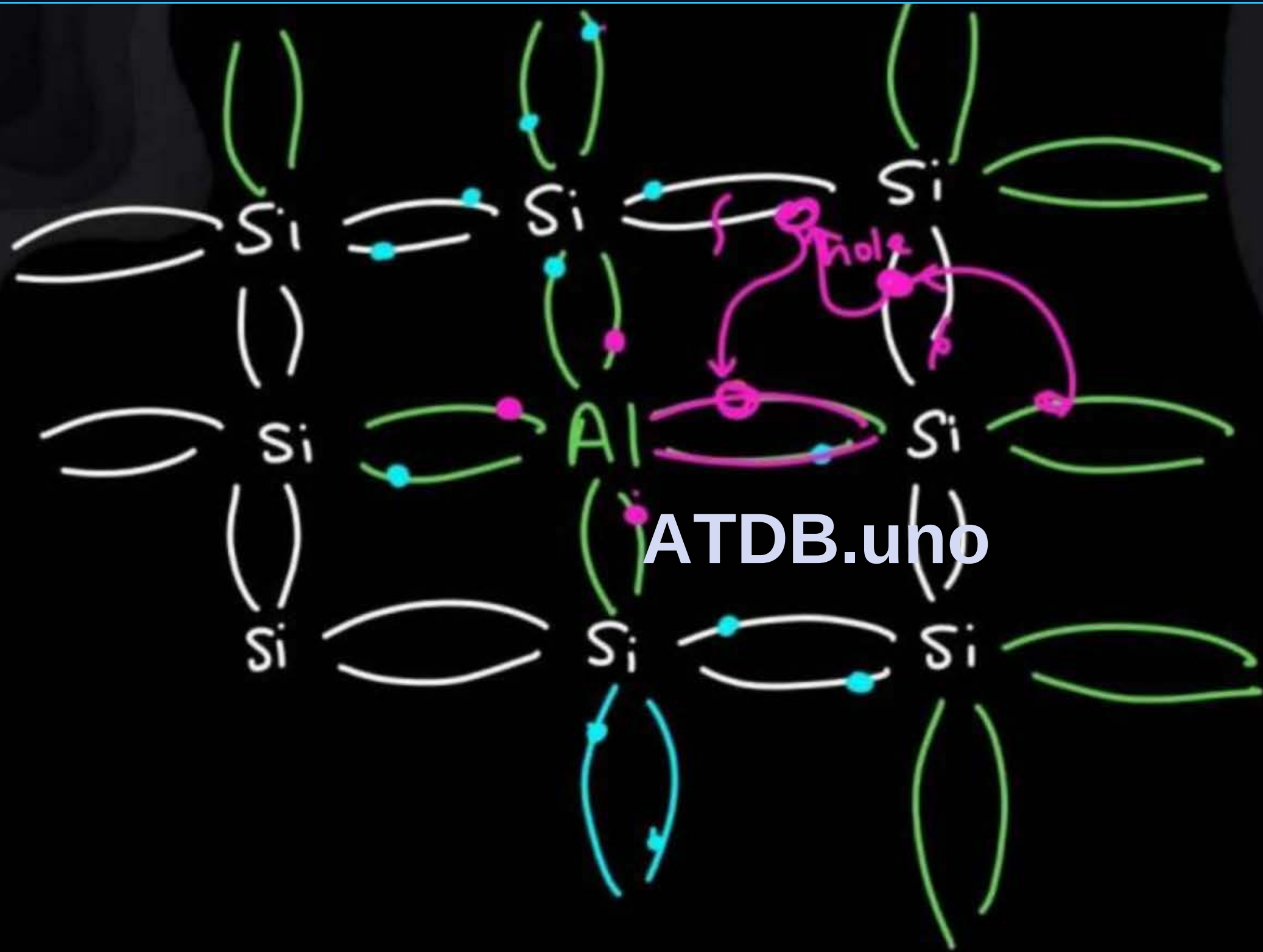




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Classification of conductors, insulators & semiconductor



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

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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) (ΔE_g)



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

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	$10^{-2} - 10^{-8} \Omega m$	$10^{-5} - 10^6 \Omega m$	$10^{11} - 10^{19} \Omega m$
Conductivity	$10^2 - 10^8 \text{ mho/m}$	$10^5 - 10^{-6} \text{ mho/m}$	$10^{-11} - 10^{-19} \text{ mho/m}$
Temp. Coefficient of resistance (α)	Positive $T \uparrow R \uparrow$ $R = R_0(1 + \alpha \Delta T)$ $\alpha > 0$	Negative, $\alpha < 0$	Negative

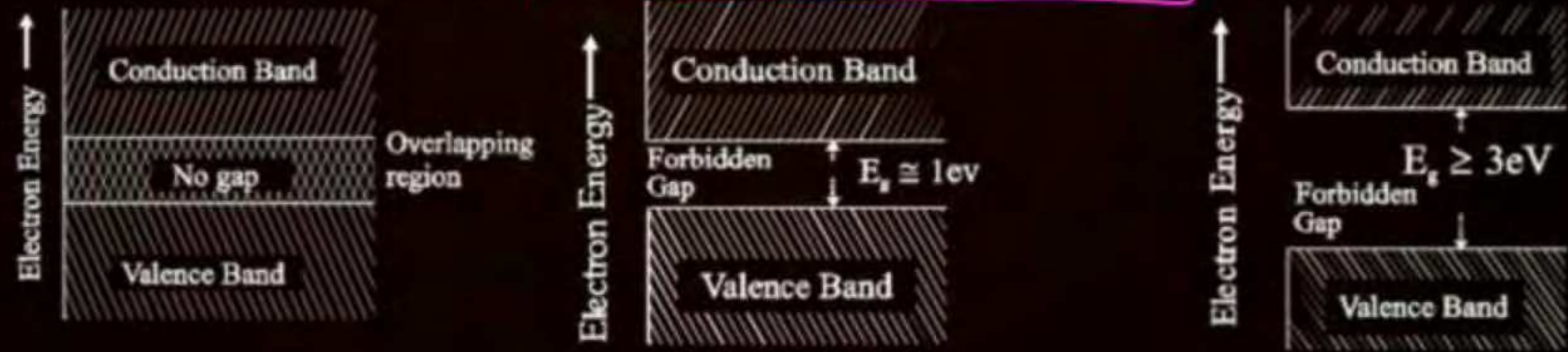
Current

Due to free electrons

Due to electrons and holes

No current

Energy band diagram



Forbidden energy gap Example:

$\div 0 \text{ eV}$ Pt, Al, Cu, Ag	$\div 1 \text{ eV}$ Ge, Si, GaAs, GaF ₂	$\geq 3 \text{ eV}$ Wood, plastic, Diamond, Mica
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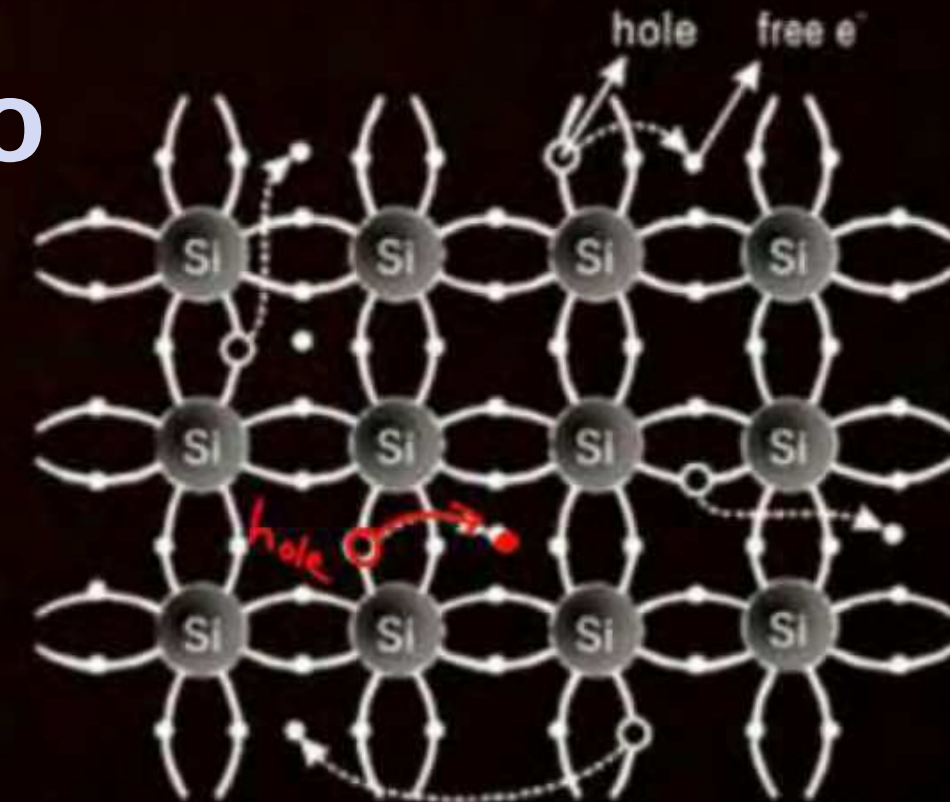
Concept of "holes" in semiconductors



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^- creates in valence band,

which has same charge ^{+e} as electron but positive. This positively charged vacancy 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



OK $\equiv$ (Semiconductor $\equiv$ Insulator)

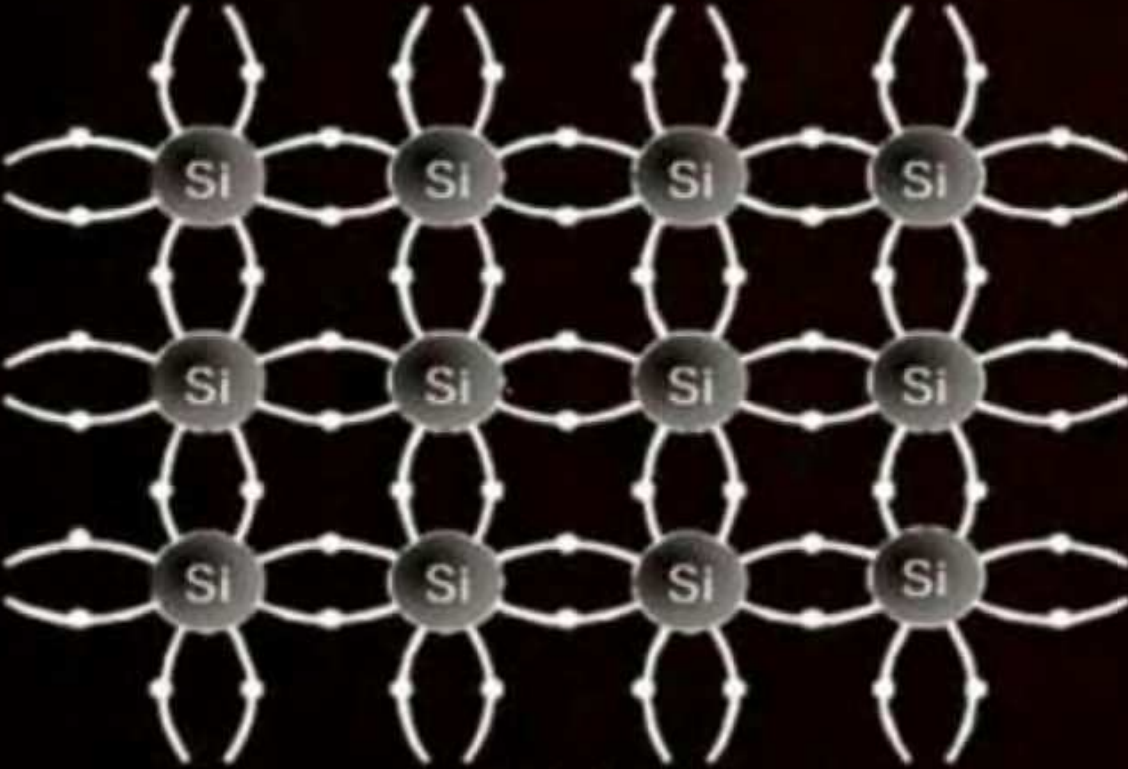
At absolute zero kelvin temperature

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

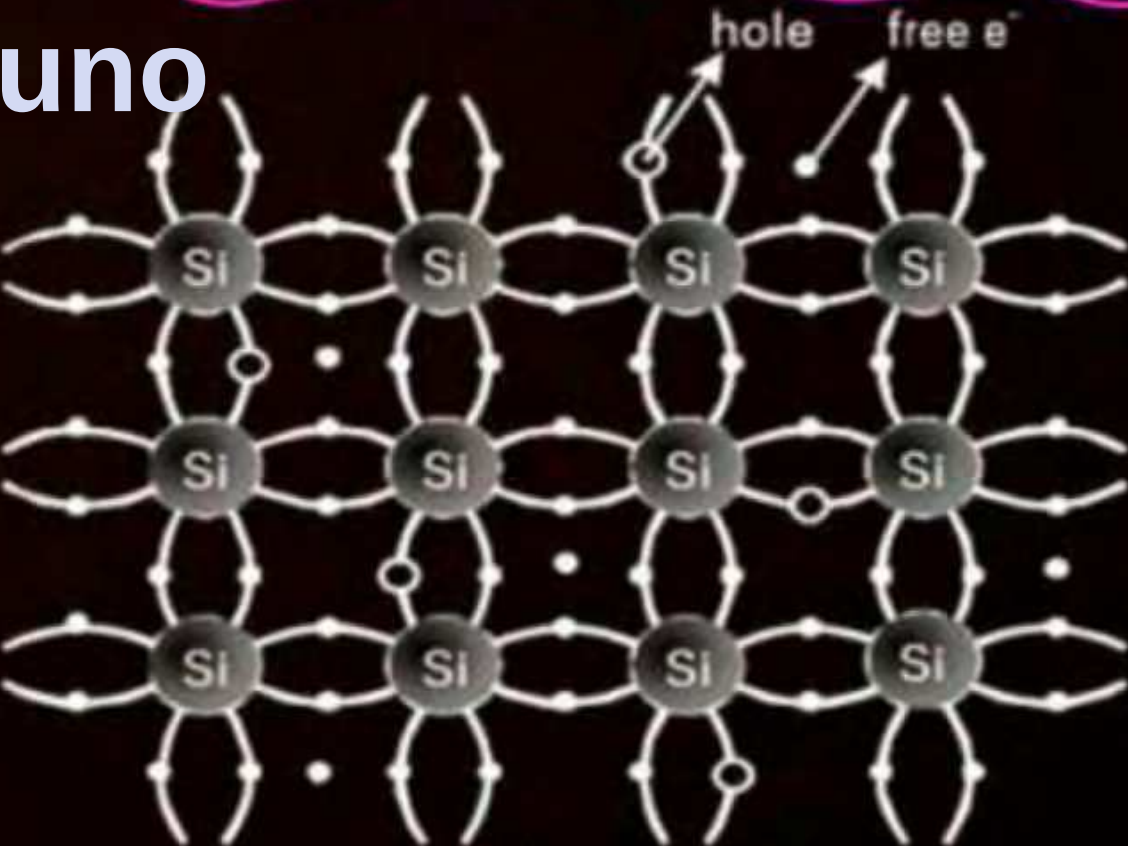
Above absolute temperature

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

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at 0 K
Valence band fully filled
Conduction band fully empty



at high temperature
Valence band partially empty
Conduction band partially filled

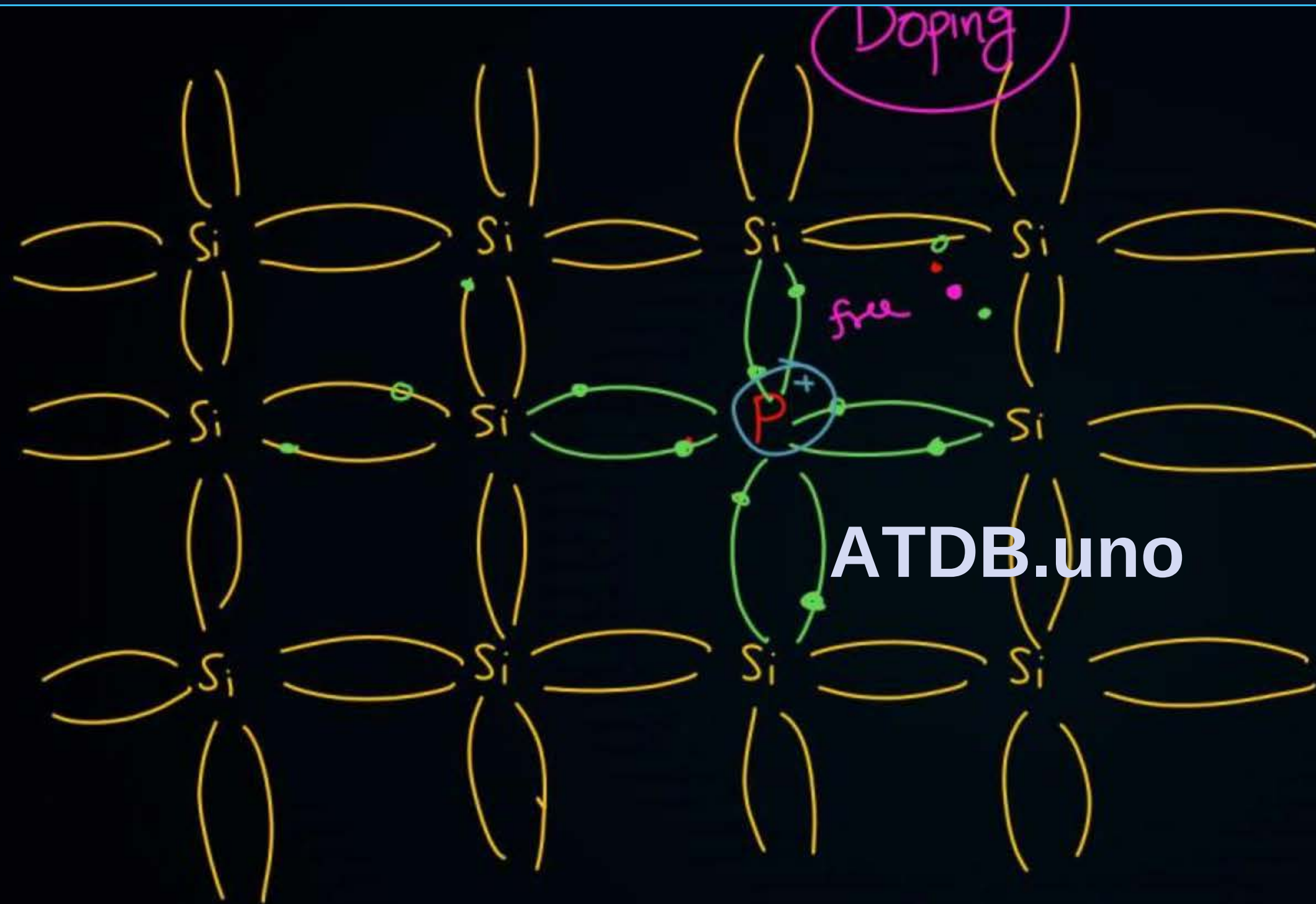


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Pure Semi Conductor

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

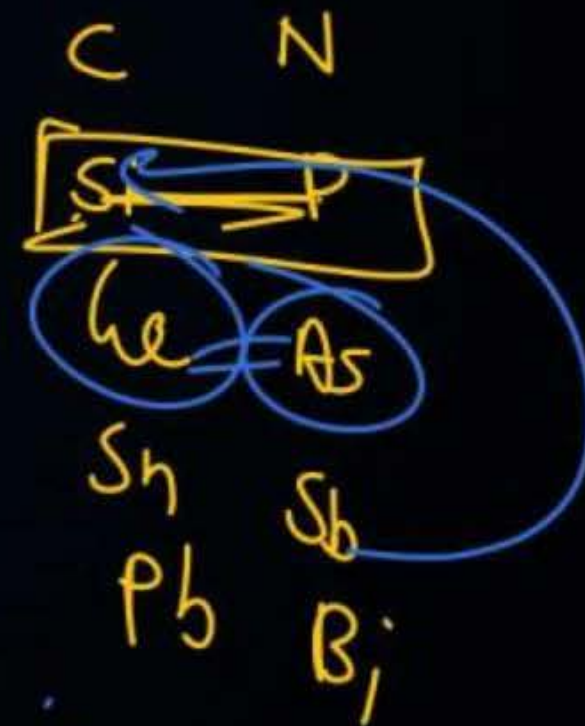
$$n_e = n_h$$



n type Semi Conductor

$(n_e \gg n_{holes})$

⊗ e^- are





Intrinsic Semiconductor $\longrightarrow$ Pure
Extrinsic Semiconductor $\longrightarrow$ Doping. $\left(\begin{matrix} \text{Si} + \text{P} \\ 10^5 : 1 \end{matrix} \right)$, impurity.

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Effect of impurity in semiconductor



↗ Intrinsic 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 $1 : 10^8$



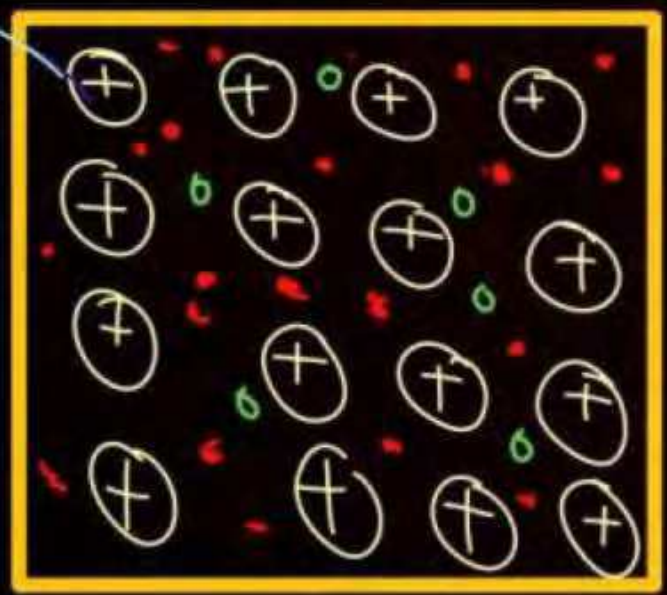
N – type semiconductor



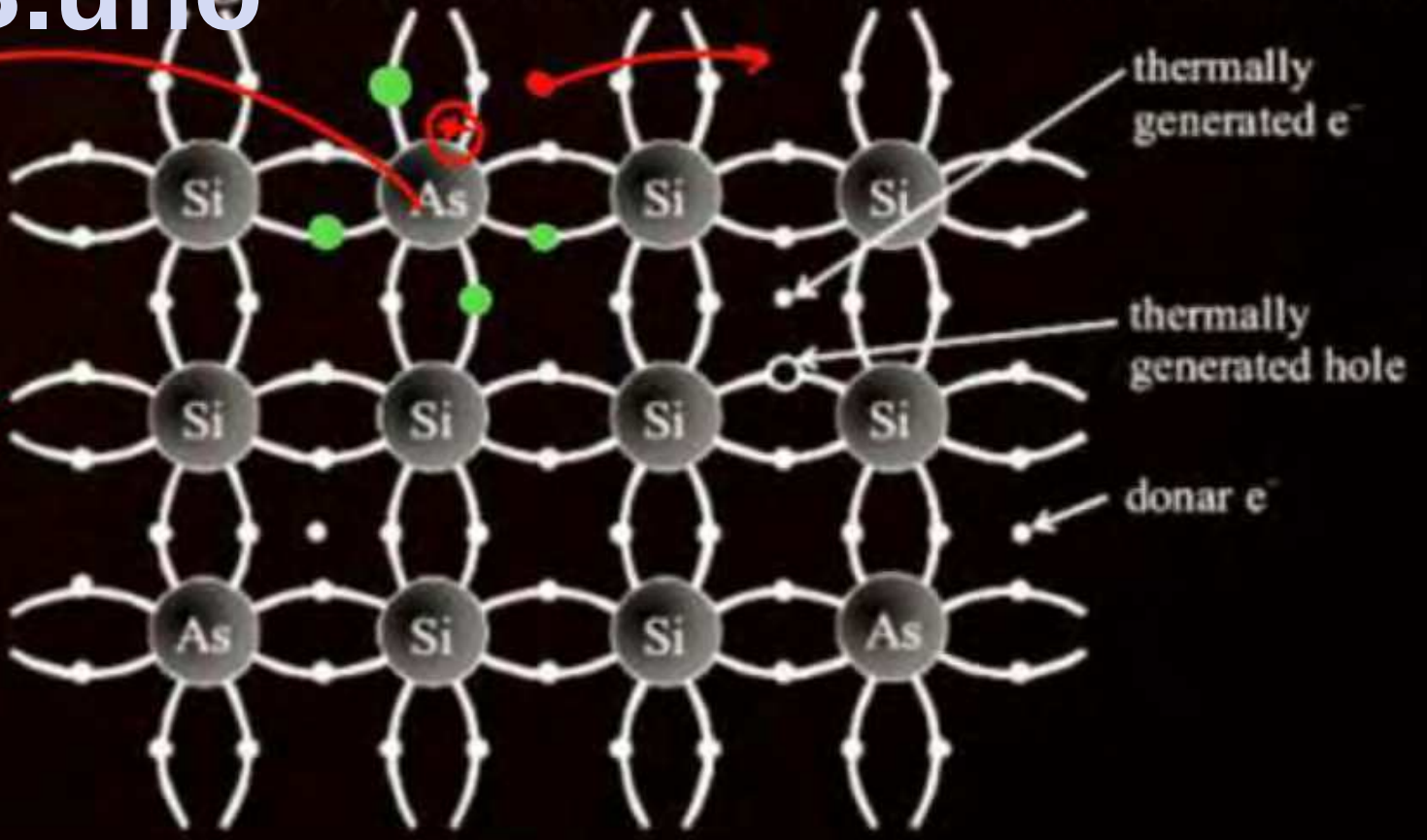
When a pure semiconductor (Si or Ge) is doped by pentavalent impurity (P, As, Sb, Bi) then four electrons out of the five valence electrons of impurity take part, in covalent bonding, with four silicon atoms surrounding it and the fifth electron is set free. These impurity atoms which donate free e⁻ 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.

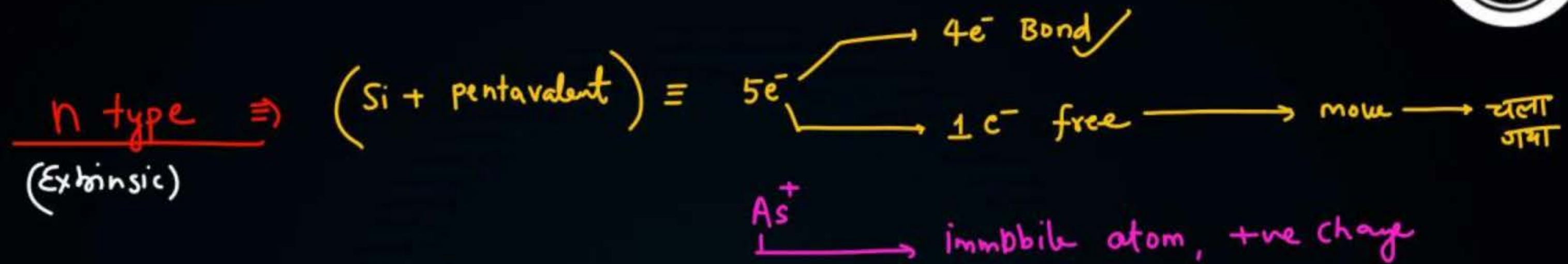
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As⁺
ε (Bounded)
ε



As ≡ Bounded
+ve charge



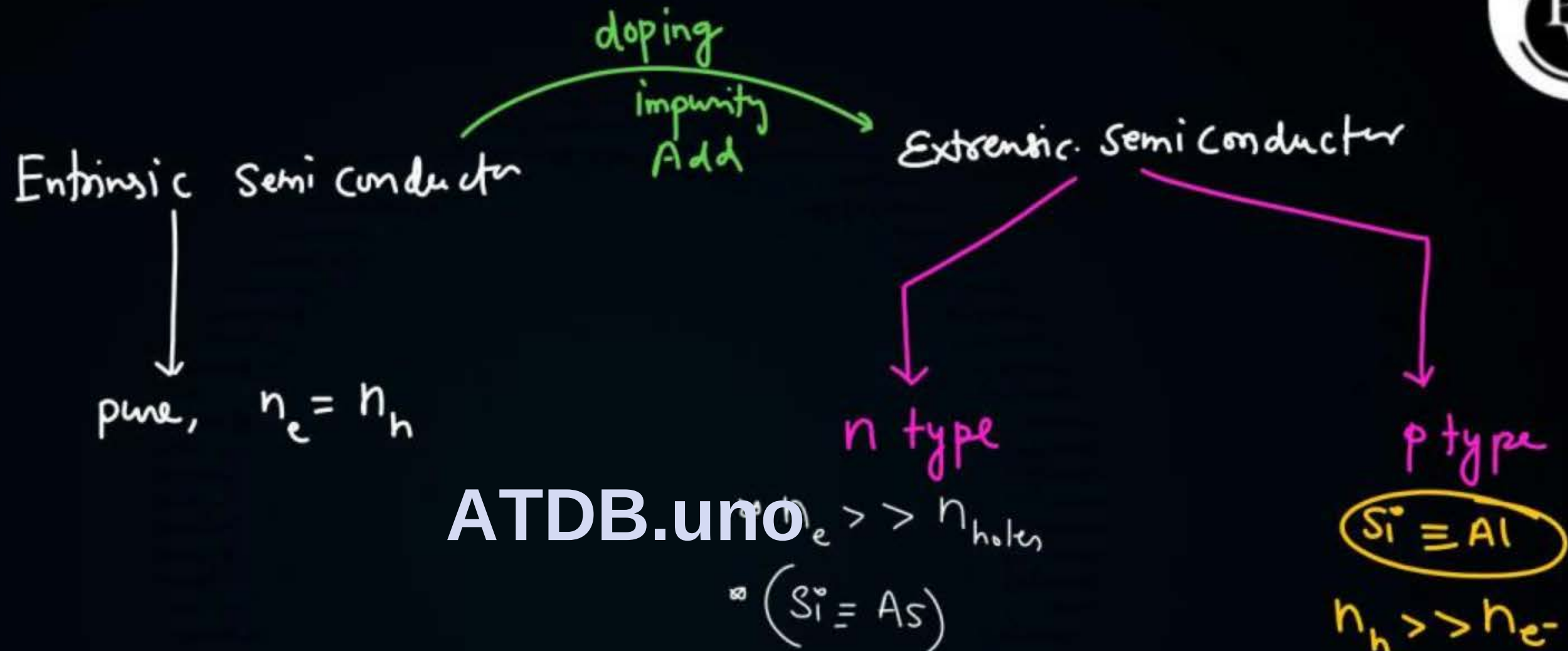


* e^- are majority carriers.

* holes $\therefore$ minority carrier $n_e > n_{holes}$

* Overall material is neutral.

> n-type $\equiv$ SC $\equiv$ Charge $\equiv$ neutral.



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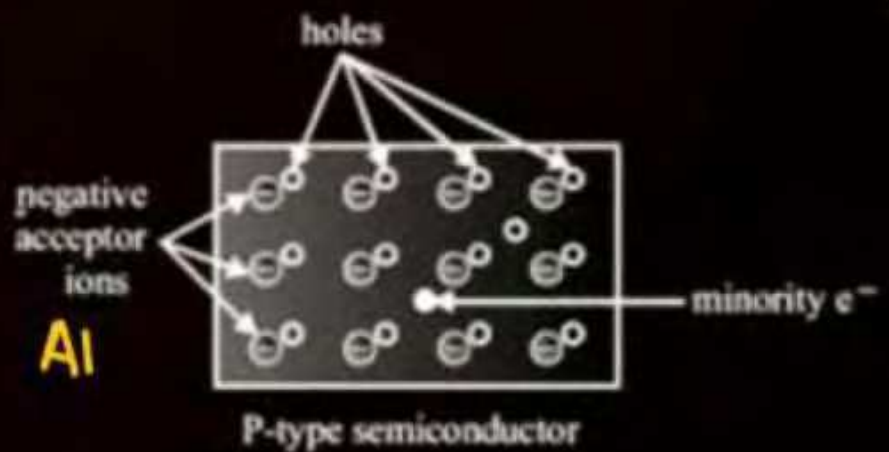
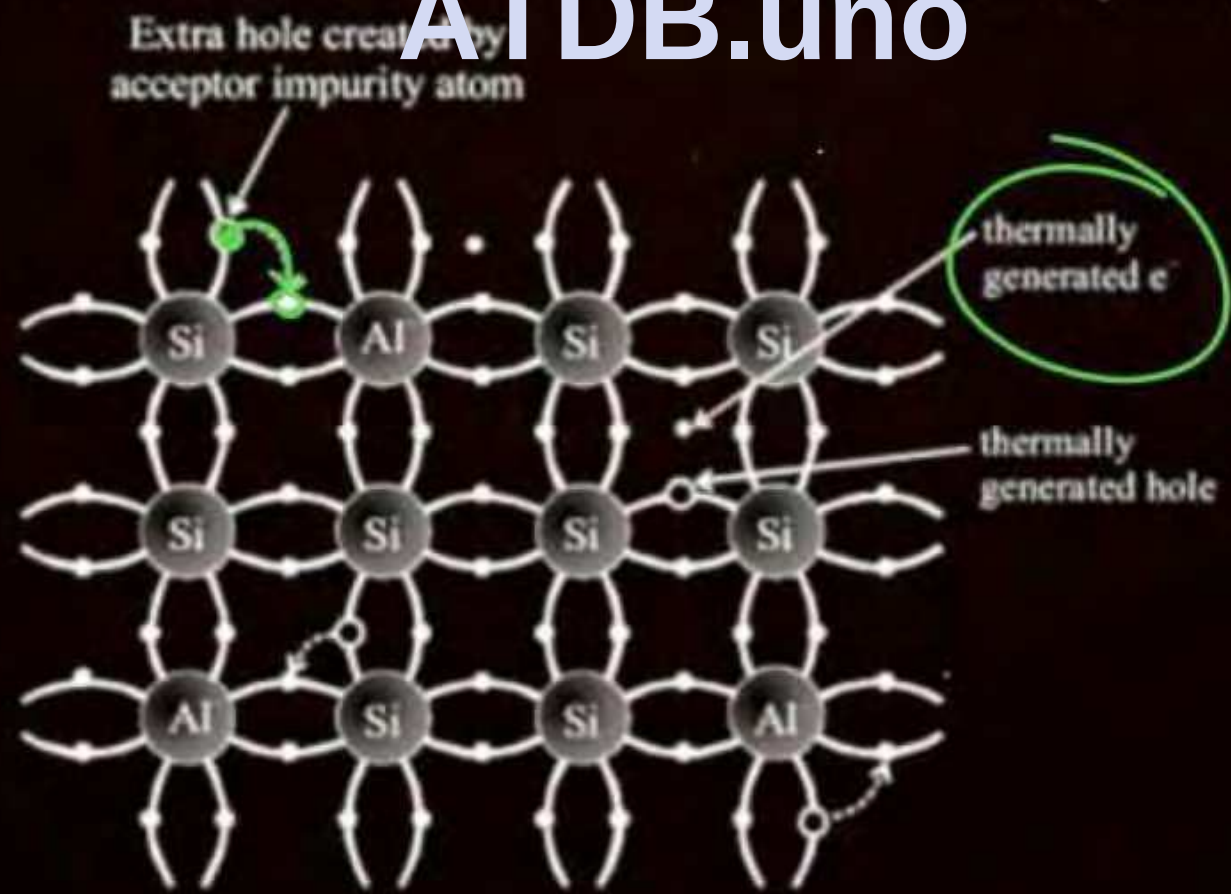
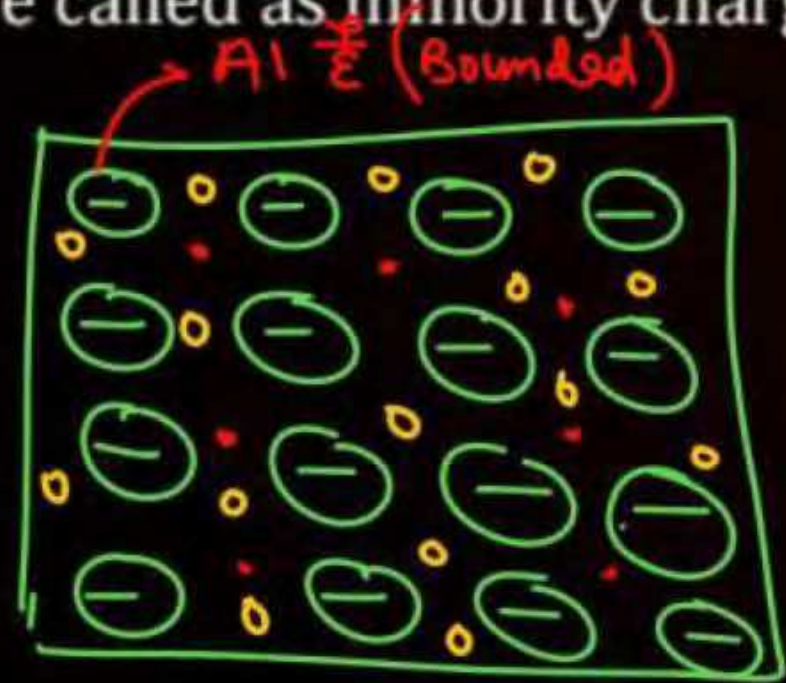


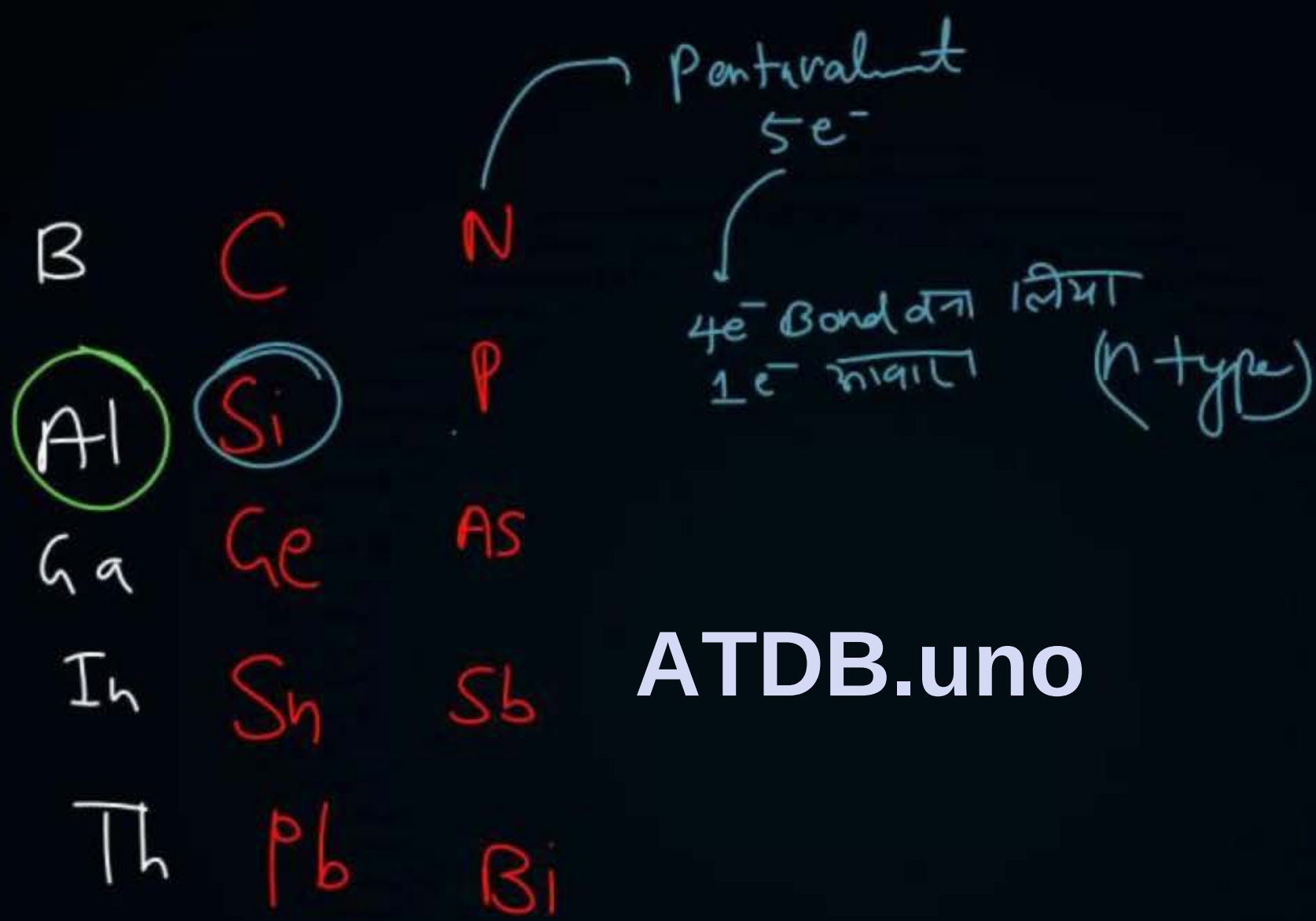
P – type semiconductor



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.

Al



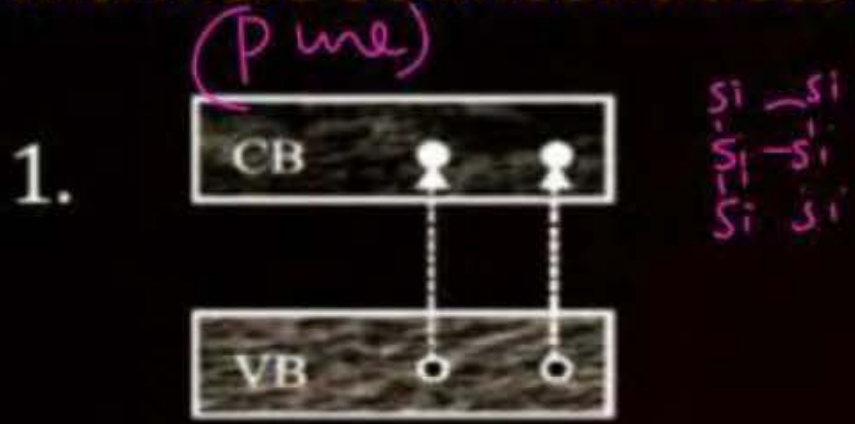


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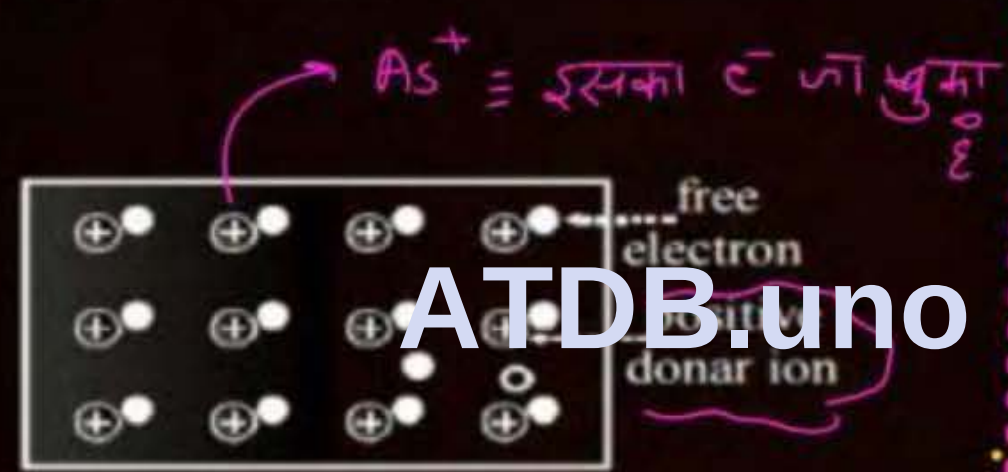
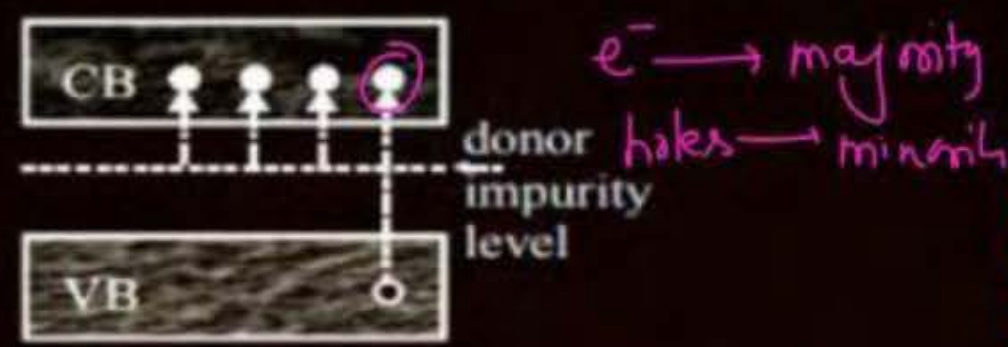
Intrinsic Semiconductor

N-type (Pentavalent impurity)

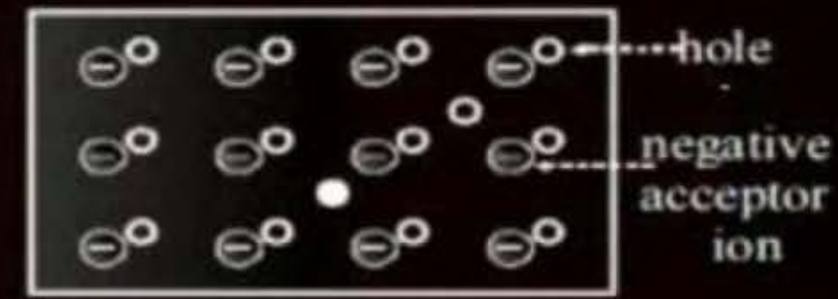
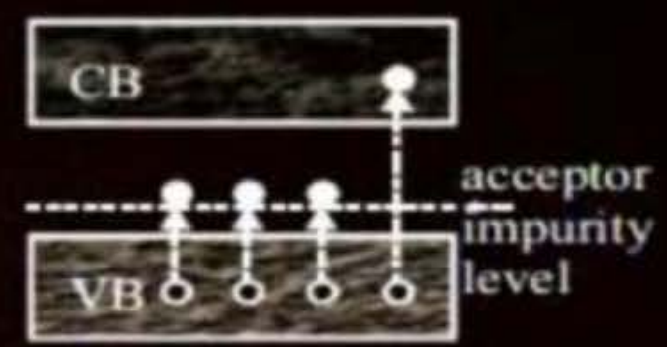
P-type(Trivalent impurity)



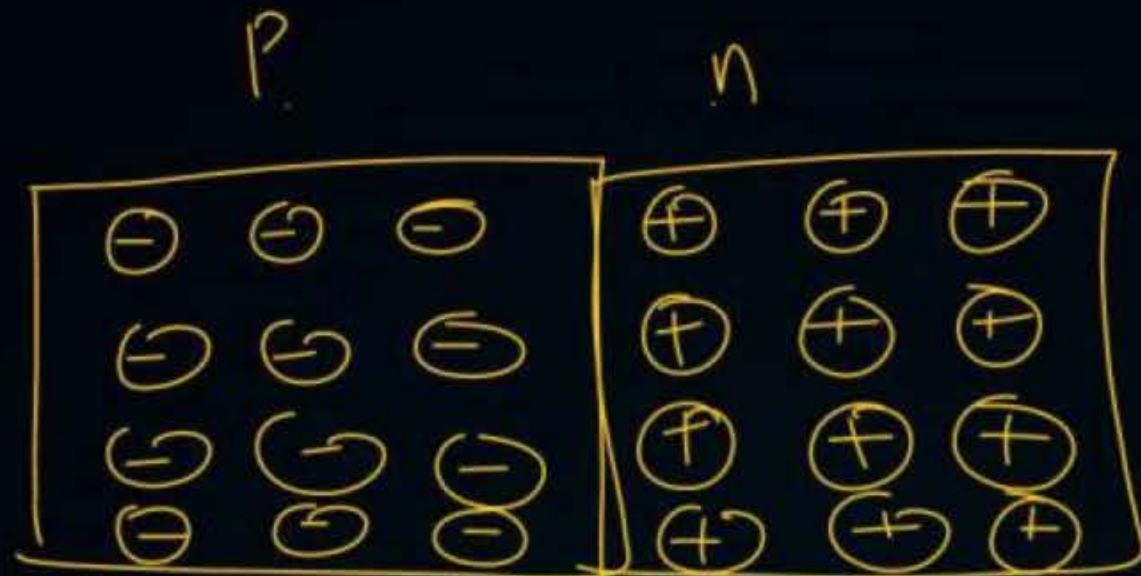
3. Current due to electron and hole
4. $n_e = n_h = n_i$
5. $I = I_e + I_h$
6. Entirely neutral
7. Quantity of electrons and holes are equal



- ✳ Mainly due to electrons (दोनों में)
- $n_h \ll n_e$ ($N_D \simeq n_e$) $i_h \ll i_e$
- $I \simeq I_e$
- Entirely neutral
- Majority – Electrons
- Minority – Holes



- Mainly due to holes ✓
- $n_h \gg n_e$ ($N_A \simeq n_h$) $n_{holes} \gg n_e$
- $I \simeq I_h$
- Entirely neutral
- Majority – Holes
- Minority – Electrons



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P n junction diode



THANK
YOU

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