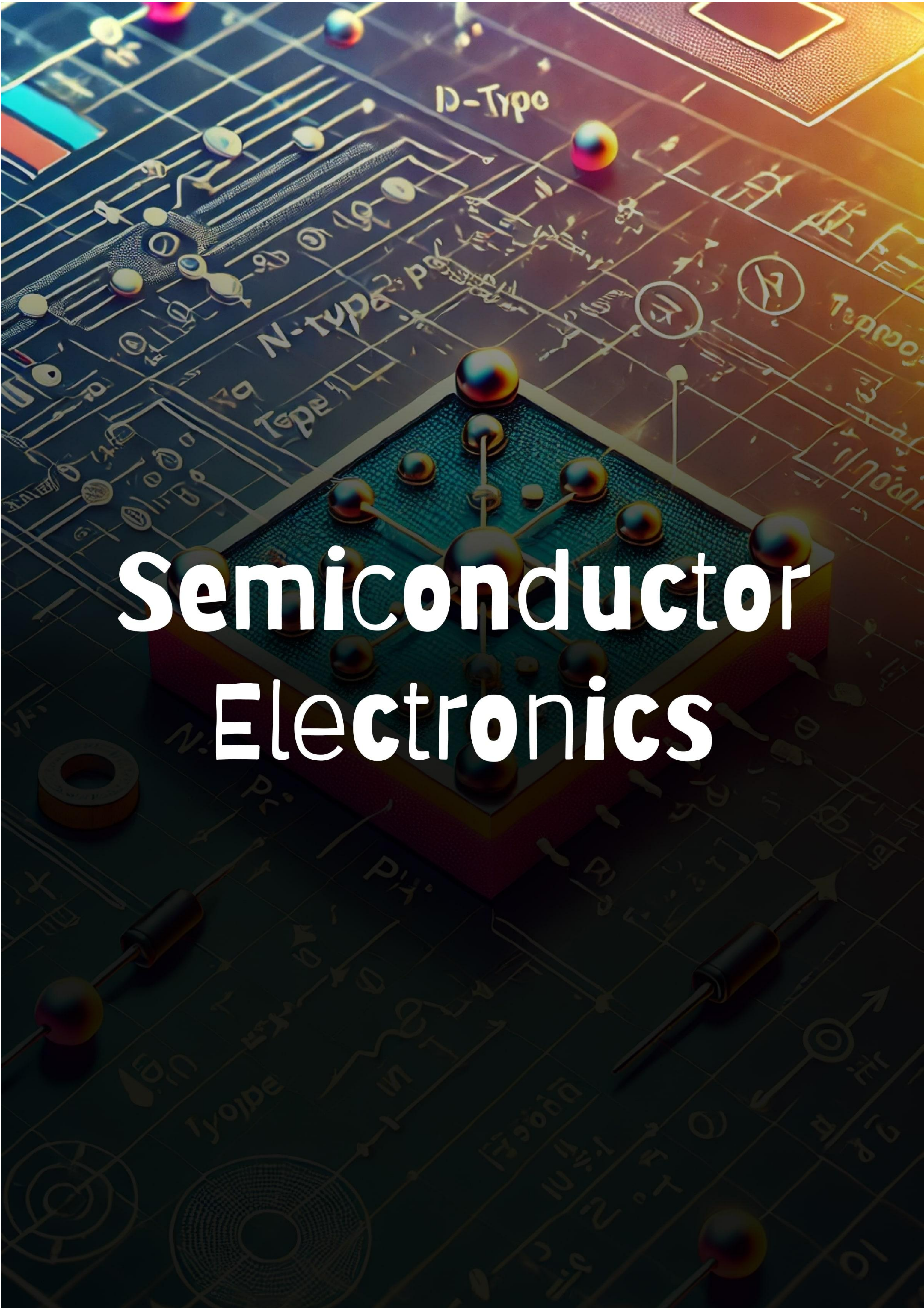

Semiconductor Electronics

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CLASSIFICATION OF METALS, INSULATORS & SEMICONDUCTORS

(A) ON BASIS OF CONDUCTIVITY / RESISTIVITY

Metals → $\rho = 10^{-2}$ to $10^{-8}\ \Omega m$

Semiconductors → $\rho = 10^{-3}$ to $10^{6}\ \Omega m$

Insulators → $\rho = 10^{11}$ to $10^{19}\ \Omega m$

★Types of semiconductors:

1.) Elemental Eg - Si, Ge

2.) Compound Eg - CdSe, InP, CdS, GaAs — Inorganic

Aithracine, doped pthalocyamines — organic

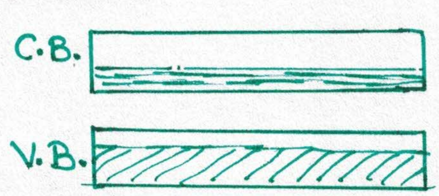
Polypyrrole, polyanniline — polymers

(B) ON BASIS OF ENERGY BANDS

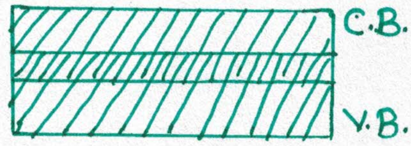
- **Conduction Band:** The min. energy level required by an e^- to move freely in a crystal marks the beginning of the CB.
- **Valence Band:** The energy band formed by overlapping of valence orbital e^-s forms the valence bond.

BAND STRUCTURE IN CONDUCTORS

(1) Partially filled Conduction Band:



(2) Overlapping C.B. & V.B.

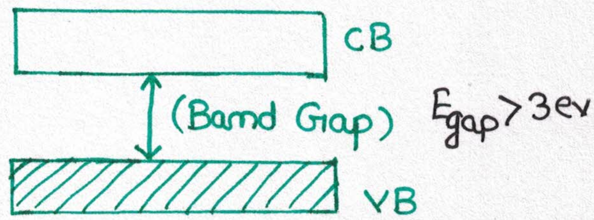


(i) BAND STRUCTURE OF INSULATORS

Empty C.B.

Bandgap → Gap between bottom of C.B. & top of V.B.

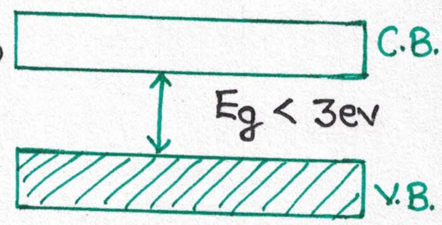
→ Due to large bandgap e^-'s can't jump onto C.B. at room temperature.



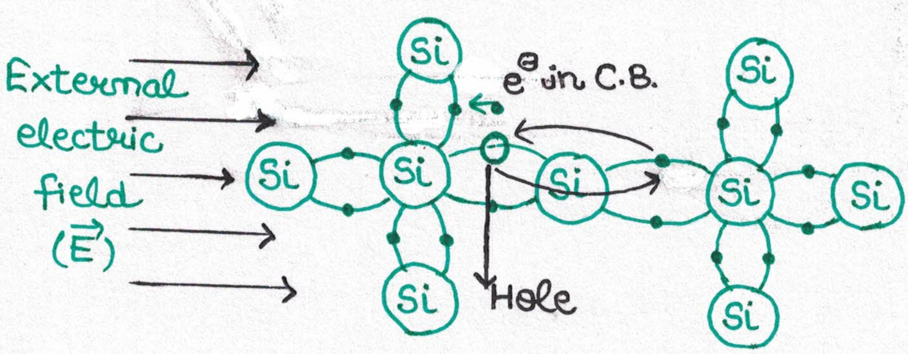
BAND STRUCTURE OF SEMI-CONDUCTORS

but as temperature will be rising, V.B. will lose $e^{\ominus}$'s.

Situation at absolute zero temp. →



INTRINSIC SEMI-CONDUCTORS



At very low temp., the valence $e^{\ominus}$'s are stably located in the bonds of a Si crystal.

However, as temp ↑ due to thermal excitation, some of the e^-'s may get dislodged from a bond and get into the conduction band, leaving a vacancy in the V.B. (hole)

When electric field is applied to such a crystal (say left to right), a current is produced in the crystal due to two phenomena:

(1) Motion of dislodged e^-'s from Right to left in the C.B. (electron current)

(2) Jumping of e^-'s in V.B. to fill the vacancies to their left (or shifting the vacancy to the right) called hole current.

For calculating purpose of current, an e^- moving to the left is equivalent to a position moving to the right. Thus, conceptually we think of holes as +ve charge carriers drifting in the direction of $\vec{E}$.

The net current $(I = I_e + I_h)$

EXTRINSIC SEMICONDUCTORS

(A) n-TYPE SEMICONDUCTOR

When an intrinsic semiconductor is doped with penta-valent impurity (eg- P, As, Sb), then 4 of the e^-'s of the impurity readily form covalent bonds with the adjacent Si atoms, still with one e^- to pair which readily goes into the C.B.

Thus in such semi-conductors, there are significantly more no. of free e^-'s, as compared to no. of holes.

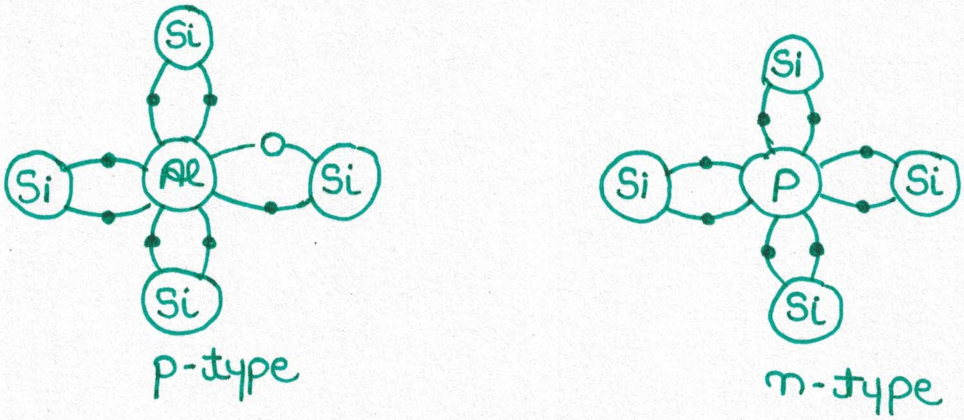
Practically, in a doped semiconductor, the charge carriers produced by doping are much more in no. than due to e^- hole pair generation, due to which, their conduction behaviour is not very sensitive to temp. changes.

(B) p-TYPE SEMICONDUCTOR

When an intrinsic semiconductor is doped with a trivalent impurity (eg- Al, Ga, In) then $e^{\ominus}$ are redily engaged in bond with 3 adjacent Si atoms whereas there is a vacancy for an e^- to form a bond with the fourth Si atom.

Upon application of $\vec{E}$, this vacancy may be filled due to migration of e^- from elsewhere in the crystal. Thus, this is just like a hole.

In such semiconductors, no. of holes >> no. of free e^-'s.

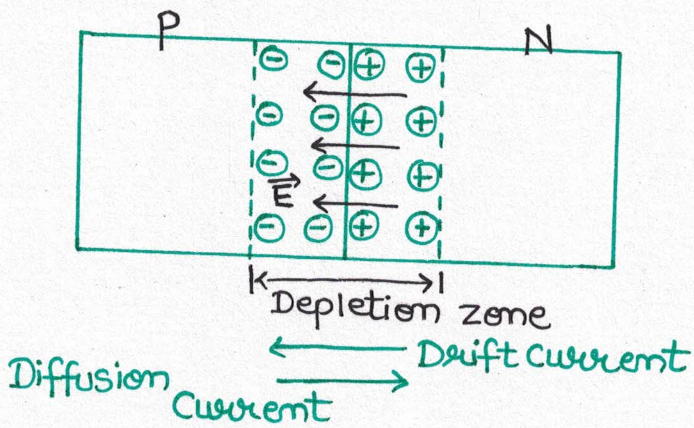


NOTE: In a semiconductor, the product of no. of holes & no. of e^-'s remains practically constant irrespective of doping concentration.

$$(n_e)(n_h) = (n_i)^2$$

n_i = no. of conduction electrons in intrinsic semiconductor conduction.

P-N JUNCTION



At a P-N junction, there are two phenomena governing the motion of the charge carriers across the junction:

1. DIFFUSION CURRENT

The N-type crystal has higher concentration of e^-'s as compared to the p-type.

Thus due to concentration gradient, e^-'s tend to diffuse from N to P side.
Similarly, holes tend to diffuse from P to N side.
Due to storming of holes on p-side by the e^- from N-side, the e^- hole pairs get cancelled leading to a very low charge carrier concentration near the junction. This region is called depletion zone.

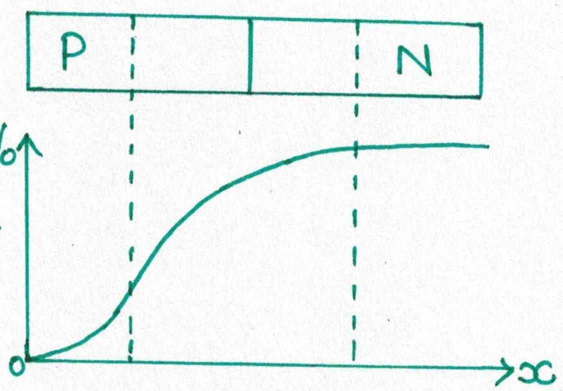
2. DRIFT CURRENT

Due to diffusion, P-side crystal gets a net -ve charge & the N-side gets a net +ve charge ~~and the N-side gets a net +ve~~ leading to a net electric field from N to P side.
Thus whenever an e^- hole pair gets generated in the depletion zone, the e^- gets pulled towards N-side & hole gets pulled towards P-side. This leads to a current from N to P-side known as drift-current.

Drift current is equal & opposite to the Diffusion current in equilibrium.

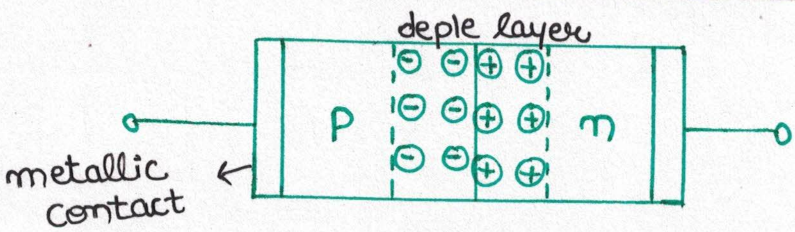
BARRIER POTENTIAL

Due to generation of electric field in the depletion region, a p/d is created across the depletion zone. This p/d is called barrier-potential.

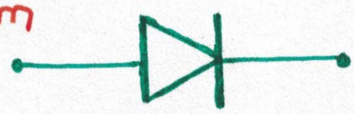


V_0 = Barrier Potential

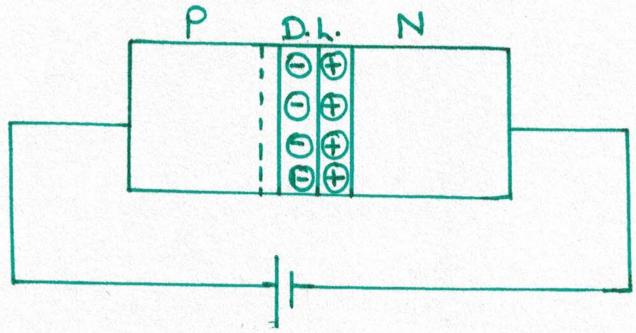
SEMI-CONDUCTOR DIODE



Representation



PN-JUNCTION DIODE UNDER FORWARD BIAS



- When +ve terminal of battery is connected to P-side, and -ve terminal of battery is connected to N-side, we say that diode is Forward biased.
- The applied p/d mostly drops across the D.Z. because of high resistance of this zone.
- The sign of biasing p/d is opposite to that of barrier potential.
- Thus, if V_0 = barrier potential
  & V = applied p/d
  then, p/d across barrier becomes $V_0 - V$.
  Thus making it easier for the holes to jump to N-side and e^-'s to jump to P-side.
  As V↑ ; diffusion i keeps on ↑ due to ↓ in barrier potential.
  Magnitude of this current is of the order of (mA).
  This current is also called minority carrier injection because carriers are diffusing towards their minority side.