SEMI-CONDUCTING MATERIALS

Semiconductors are materials which have a conductivity between conductors (generally metals) and non-conductors or insulators.

Due to their role in the fabrication of electronic devices, semiconductors are an important part of our lives.

1874 — AC-DC converter (rectifier)

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1948 — Bardeen & Brattain (1947) } Transistor
Shockley (1948

↓

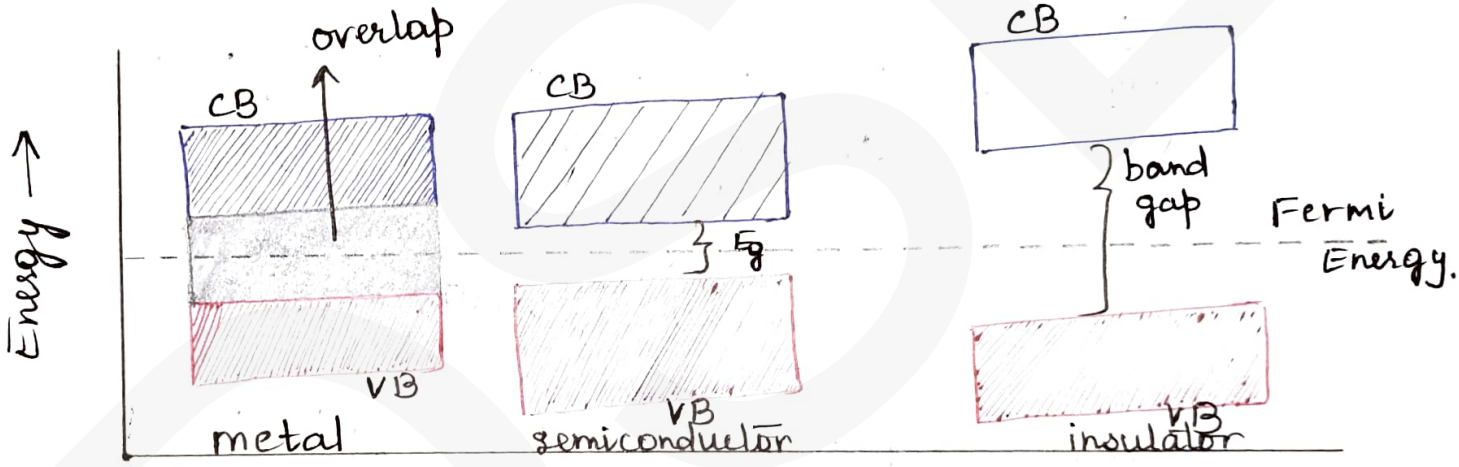
Transistor calculator

1959 — Bipolar integrated circuit (IC).

Definition

Semiconductors has electrical resistance which is lesser than an insulator but greater than that of a conductor. The resistivity range is 10^{-4} to 0.5 Ωm.

A semiconductor has nearly an empty conduction band and an almost filled valence band with a very small energy gap ($\simeq$ 1 eV)



General properties of semiconductor

1) They mostly have a crystalline structure and bonding between the atoms is formed by covalent bond.

2) They mostly have an empty conduction (CB) band at O.K and almost filled valence band (VB). The energy gap between VB & CB is very small.

3. They exhibit a negative temperature coefficient of resistance, i.e., increase in temperature leads to decrease in resistance.

4. Semiconductors in their neutral state behaves like poor conductors. By doping semiconductors (impurity addition), its electrical conductivity increases.

CLASSIFICATION OF SEMI CONDUCTOR

Based on composition

- Elemental (Si, Ge) : single IV group element
  Indirect band gap.
- compound (GaAs, ZnO) : combination of III & V
  (e.g. II & VI) group element.
  Direct band gap.

Based on purity

- Intrinsic : No doping, tetravalent, covalent bonding
  IV group elements
- Extrinsic : Doped
  - p type : ~~pentavalent~~ trivalent group V element doped
  - n type : ~~trivalent~~ pentavalent

Based on band gap.

- Direct (compound): Energy max of VB & Energy min of CB have same momentum
- Indirect (elemental): Energy max of VB & Energy min of CB doesn't have same momentum.

Difference between elemental and compound semiconductors

(* This along with next section : direct and indirect band gap material forms the answer for "differentiate direct and indirect band gap material")

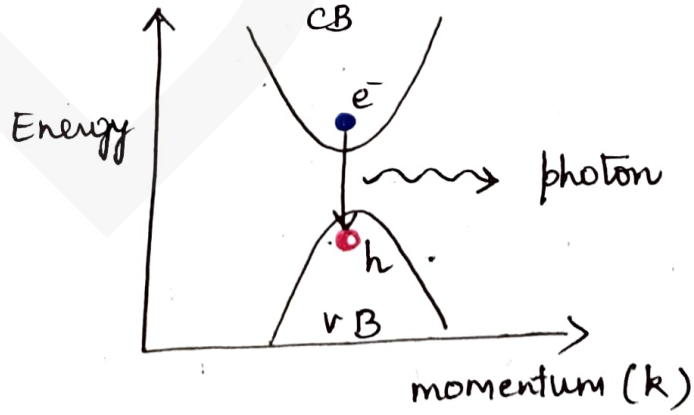
	Elemental	Compound
1.	They are made up of a single element. eg: Ge, Si	They are made up of compounds eg: GaA, GaP, CdS, MgO.
2.	They are known as indirect band gap semiconductor	They are also known as direct band gap semiconductor.
3.	e^--h recombination takes place through traps	e^--h recombination takes place directly.
4.	Life time of charge carriers is more due to indirect recombination	Life time of the carriers is less due to direct recombination.
5.	Heat energy is produced during recombination	No ~~heat~~ excess heat is generated.

6.	Light photons are not directly emitted, instead phonon emission followed by photon takes place.	Recombination is radiative & photon is emitted directly.
7.	They carry more current	They carry less current.
8.	They are used for making diodes & transistors.	They are used for making LED's and Laser (opto electronic devices.

What are direct, indirect band gap materials?

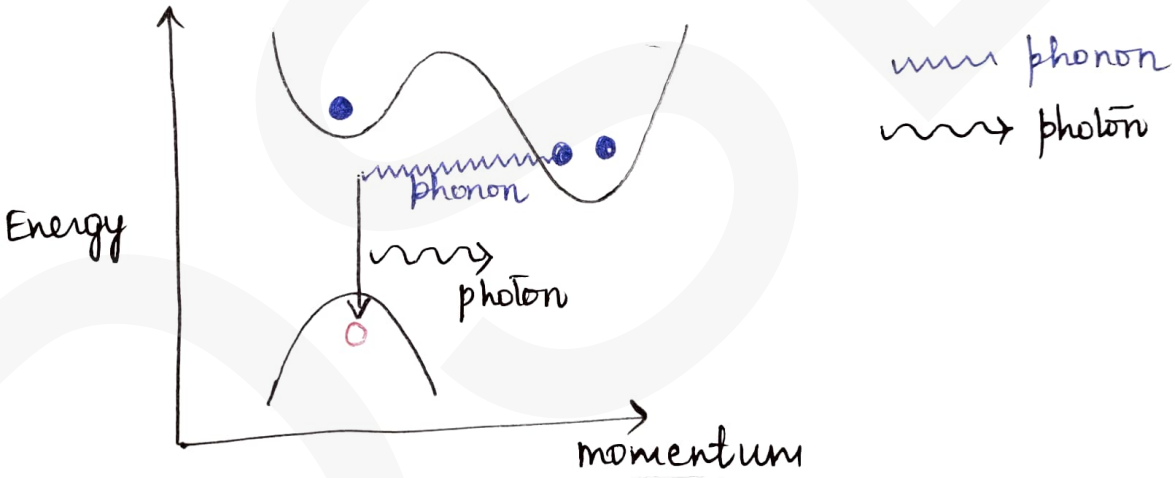
Band gap: It represents the minimum energy difference between the top of the valence band and the bottom of the conduction band.

In direct band gap semi conductor, the maximum of the valence band & minimum of the conduction band occur at the same value of the momentum.



During the recombination of $\bar{e}$ from CB to with a hole in VB, the momentum of $\bar{e}$ remains same (as it is in same line with hole's momentum). The energy equal to band gap energy is released as light photon

In the case of indirect band gap semiconductor the maximum of valence band doesn't coincide with minimum of conduction band ie they have different momentum value.



During the recombination process, when an $\bar{e}$ & h recombine, momentum should be conserved. In order to do so $\bar{e}$ in an indirect band gap material loses momentum in the form of phonon & recombine with a hole in valence band emitting a photon.

Similarly phonon absorption can also take place when an $\bar{e}$ from VB moves to CB.

Hence there is always involvement of phonon in indirect band gap materials

[Note : phonon : are quantisation of lattice vibration as we have quatisation of light as photon.]

INTRINSIC SEMICONDUCTORS

* A semiconductor in its pure form ie free from any additive impurities is known as intrinsic semi-conductor.
* Its electrical conductivity is changed only by thermal excitation.
* They have four valence e^{-s} (tetravalent)
* They ~~share~~ form covalent bonds by sharing four e^{-s} with each other so as to form a stable structure.