# DIRECT AND INDIRECT BAND GAP SC's

- **Introduction:**

⇨ According to the band theory of solids, the energy spectrum of electrons consists of a large number of energy bands and are separated by a forbidden gap.

⇨ The band gap represents the minimum energy difference between the top of VB and bottom of the CB.

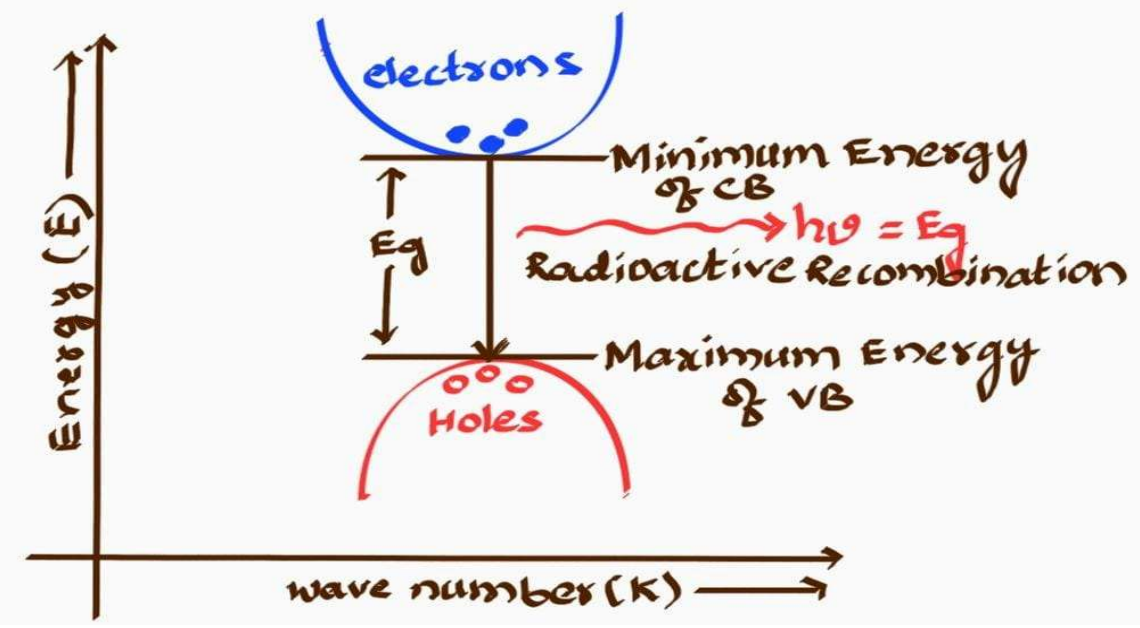
⇨ Based on the structure of energy band composition and type of energy emission, SC are classified into 2 types:

1. Direct band gap SC
2. Indirect band gap SC

⇨ E-k curve relation between energy(E) and wave numbers (K) for 1-D lattice depends on the orientation of the electron wave vector to the crystallographic axis.

## 1. Direct Band Gap SC:

- A semiconductor (SC) in which the maximum energy of the Valence Band (VB) and the minimum energy of the Conduction Band (CB) exist at the same value of wave number (K) is called a Direct Band Gap Semiconductor (DBG SC).

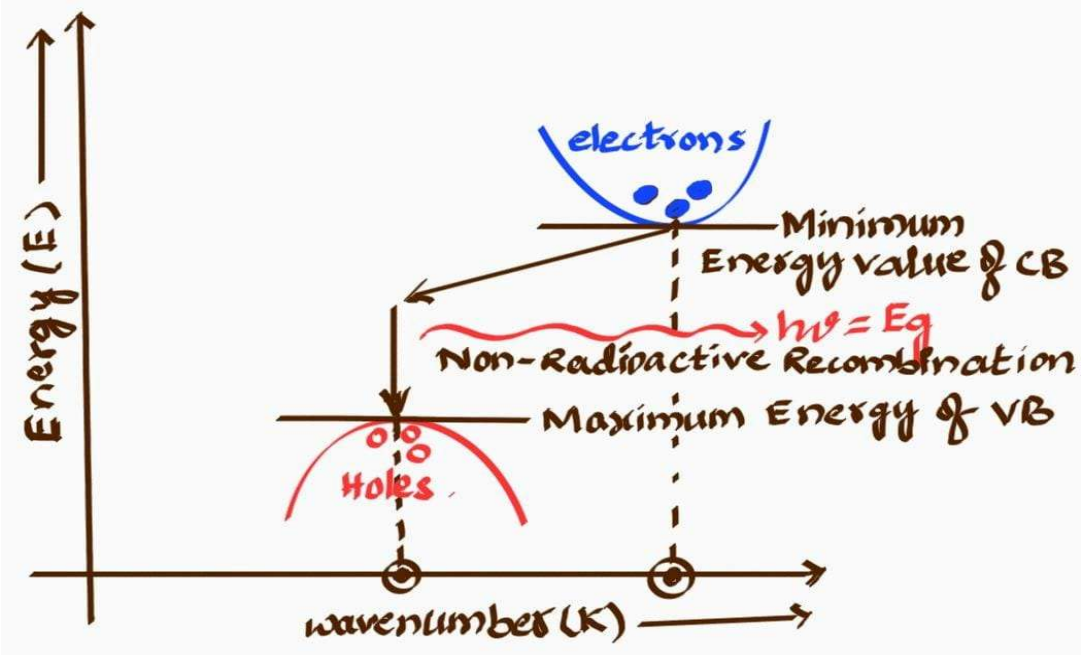



- In this type, a photon of light is released during the recombination of holes and electrons. This process is known as radiative recombination or spontaneous emission.
- It is more effective because the direction of motion of electrons remains unchanged.
- In this type of semiconductor, the lifetime of charge carriers is very short.

- Electron-hole pairs can be easily generated because it requires less momentum.
- Recombination probability is very high.
- These are used to fabricate LEDs and laser diodes.
- These are mostly compound semiconductors.
- **Examples**: InP, GaAs.

## 2. Indirect Band Gap SC:

- A semiconductor (SC) in which the maximum energy of the Valence Band (VB) and the minimum energy of the Conduction Band (CB) exist at different values of wave number (K) is known as an Indirect Band Gap Semiconductor (IBG SC).




- In this type, heat energy is produced during the combination of holes and electrons. This process is known as non-radiative recombination.
- It is less efficient because the direction of motion of the electron changes.
- In this type, the lifetime of charge carriers is long.
- The incident process is slower because it requires an electron, hole, and phonon for interaction.
- Recombination occurs through some defect states.
- Due to the longer lifetime of charge carriers, these are used to amplify signals, as in the case of diodes and transistors.
- These are mostly elemental semiconductors.
- **Examples:** Si (0.7 eV), Ge (1.12 eV), ...

## DIFFERENCES BETWEEN DIRECT AND INDIRECT BAND GAP SEMICONDUCTORS

| ○ Feature | • Direct Band Gap Semiconductor (DBG SC) | • Indirect Band Gap Semiconductor (IBG SC) |
|---|---|---|
| • **Energy Band Alignment** | • Maximum VB energy and minimum CB energy at the **same** wave number (K). | • Maximum VB energy and minimum CB energy at **different** wavenumber (K). |
| • **Recombination Product** | • Photon of light is released. | • Heat energy is produced. |
| • **Recombination Process Name** | • Radiative recombination / spontaneous emission. | • Non-radiative recombination. |
| • **Efficiency** | • More effective/efficient. | • Less efficient. |
| • **Electron Motion Direction** | • Direction of electron motion remains unchanged during recombination. | • Direction of electron motion changes during recombination. |
| • **Charge Carrier Lifetime** | • Very short. | • Long. |
| • **Recombination Speed** | • Faster (implied by "more effective"). | • Slower, as it requires electron, hole, and phonon interaction. |
| • **Recombination Mechanism** | • Direct recombination. | • Occurs through some defect states. |
| • **Electron-Hole Pair Gen.** | • Electron-hole pairs are easily generated (requires less momentum). | • (Not explicitly stated for IBG SC, but generally harder due to phonon involvement). |
| • **Common Material Types** | • Mostly compound semiconductors. | • Mostly elemental semiconductors. |
| • **Typical Examples** | • InP, GaAs. | • Si , Ge . |
| • **Applications** | • Used to fabricate LEDs and laser diodes. | • Used to amplify signals (diodes, transistors). |