SRM
Institute of Science and Technology

# DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
# SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

## Module-IV Lecture-13

Significance of band gap in semiconductors & Concept of absorption and emission

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Opto electronic devices are based on the interaction of light with matter, typically semiconductors.

In these devices, light or electromagnetic (EM) radiation is absorbed by the semiconductor and converted into electrical signals (electron-hole pairs) or electrical signals are converted to EM radiation (typically in the IR-Vis UV range).

To understand the working of these devices it is essentially to look at light - semiconductor interaction.

Consider light of wavelength, $\lambda$, incident on a semiconductor with band gap Eg. The energy of the radiation E is given by hc $\lambda$ .
Based on the relation between E and Eg there can be two conditions.

1. E < Eg - semiconductor is transparent, though there could be scattering at the


## Absorption in semiconductors:

Within these energy level systems we can have a variety of mechanisms by which electrons (and holes) absorb optical energy. Most of these processes can occur in quantum wells, wires, and dots, as well as in bulk material.

**Band-to-band:** an electron in the valence band absorbs a photon with enough energy to be excited to the conduction band, leaving a hole behind.

**Band-to-exciton:** an electron in the valence band absorbs almost enough energy to be excited to the conduction band.

The electron and hole it leaves behind remain electrically "bound" together, much like the electron and proton of a hydrogen atom.


- Band-to-impurity or impurity to band: an electron absorbs a photon that excites it from the valence band to an empty impurity atom, or from an occupied impurity atom to the conduction band.

- Free carrier: an electron in the conduction band, or hole in the valence band, absorbs a photon an is excited to a higher energy level within the same set of bands (i.e, conduction or valence).

- In quantum structures there can be photon absorption due to carriers being excited between the quantum levels within the same band (termed "intra-band"), as well as between the various quantum levels in one band and those in another "(inter-band"):

Intra-band: these transitions can occur only between even and odd index levels and are only operative for light polarized parallel to the direction of quantization.

That is, in a quantum well the light must be polarized normal to the well itself, and in the direction of the composition variation.

Inter-band: inter-band transitions can occur between conduction and valence bands, or between different valence bands (light-hole, heavy-hole, and spin-off).

There are transitions can be active for either polarization of the light, depending on the symmetries of the respective bands.

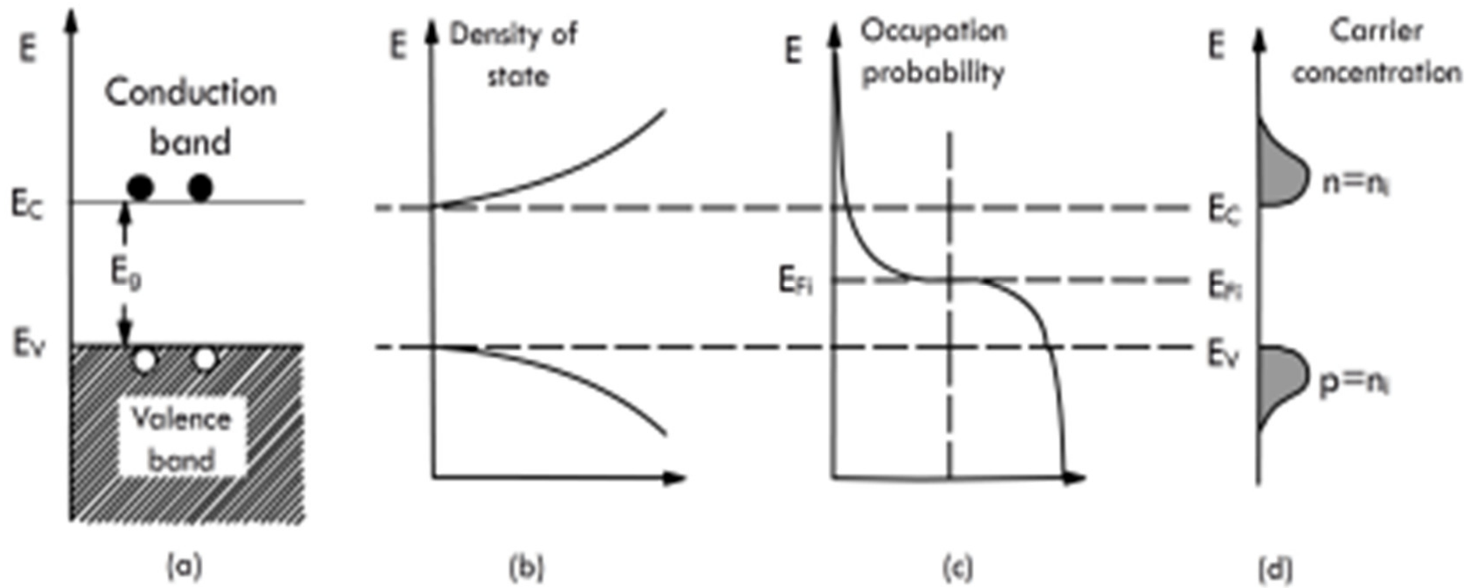


**Figure 1:** (a) Energy band diagram for a semiconductor showing the valence and conduction band edges.
(b) The density of states monotonically increases from the band edges
(c) Occupation probability of electrons and holes in the CB and VB, calculated with respect to the intrinsic Fermi function
(d) Product of (b) and (c) gives the concentration of electrons in CB and holes in the VB.