18PYB103J-Physics- Semiconductor Physics

Unit -3

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Topic covered

- Concept of optical transitions in bulk semiconductors
- optical absorption process
- Concept of recombination process
- Optical recombination process
- Explanation for spontaneous emission
- Explanation for stimulated emission
- Joint density of states in semiconductor
- Density of states for photons
- Fermi's golden rule
- Concept of optical loss & gain
- Basic concepts of Photovoltaics
- Photovoltaic effect
- Applications of Photovoltaic effect
- Determination of efficiency of a PV cell
- Theory of Drude model
- Determination of conductivity

Concept of optical transitions in bulk semiconductors

Band to band (interband) transitions –

- As indicated in Figure , these transitions are typically between the valence and conduction bands.
- The fundamental absorption, where the absorption of a photon generates the transition of an electron from the valence to the conduction band. The frequency of the photon must be such that
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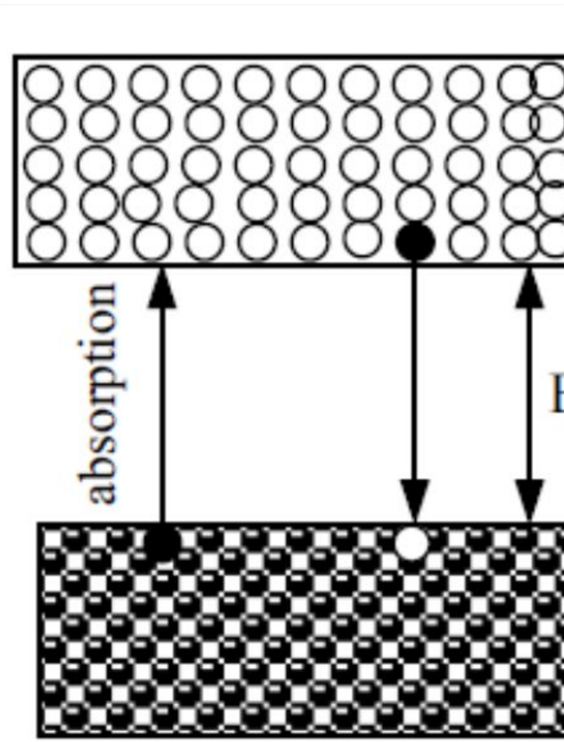
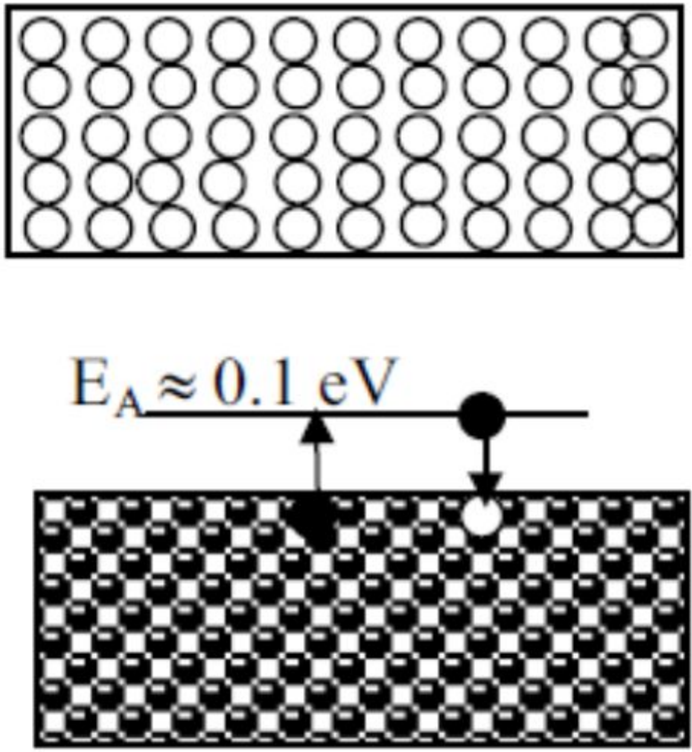
- Thus an electro $\nu > \nu_G = E_G/h$. enerated, in a process used in radiation captors;



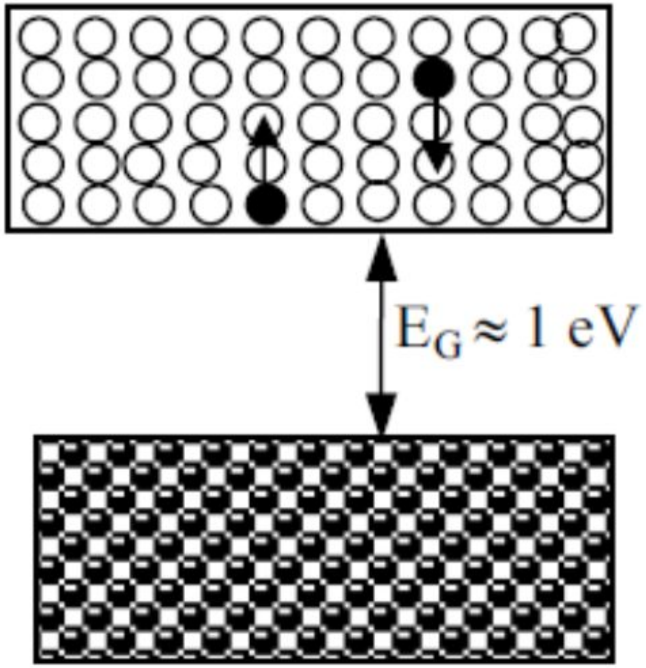
Transitions from the bands to impurities

- These can result from photons that, for example, in a p-type semiconductor pass a valence band electron to the level of an acceptor where the electron is trapped. A hole thus is formed in the valence band.



Transitions due to free carriers (intraband)

- A photon can transmit its energy to an electron which is thus pushed up to an empty and higher level in the band (shown for the conduction band in Figure).
- This process is followed by a thermalization of the electron which relaxes back to a lower point in the conduction band while losing its surplus energy thermally to the lattice, and hence lattice vibrations.

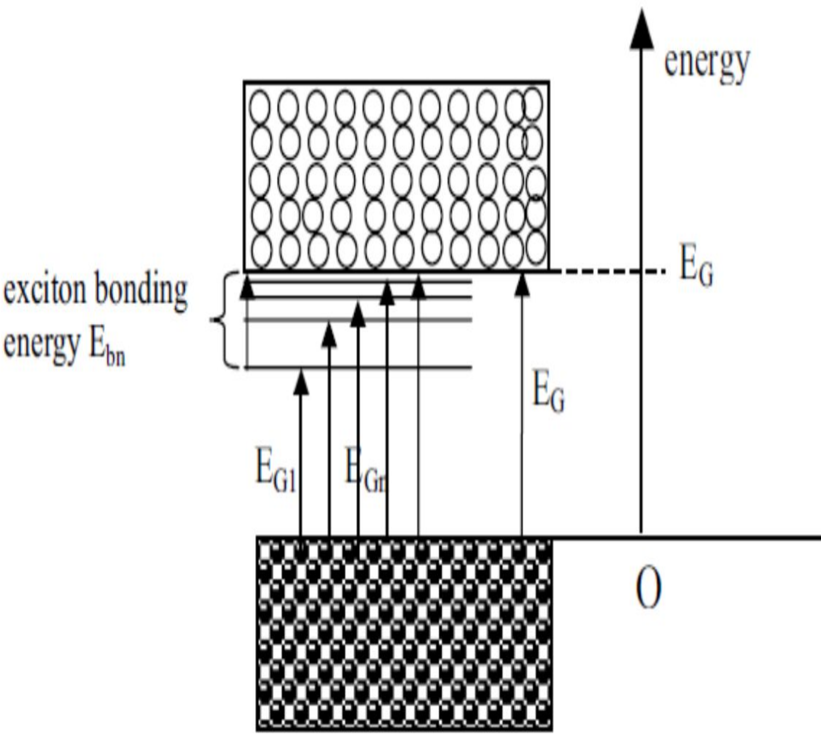


Phonon transitions -

- Low energy photons (of long wavelengths) can give up their energy to the lattice by directly exciting vibrations of the atoms, from which are generated phonons.

Excitonic transitions -

- The absorption of a photon can generate an electron and a hole separated by a finite distance so that they can be bound to one another by a coulombic interaction energy.
- This pairing can be compared to a hydrogen atom, as here the role of the nucleus is played out by the hole (termed a Wannier exciton).



Exciton energy level (E_{Gn}) and bonding ene

optical absorption process

- The fundamental absorption, where the absorption of a photon generates the transition of an electron from the valence to the conduction band. The frequency of the photo $\nu > \nu_G = E_G/h.$ that

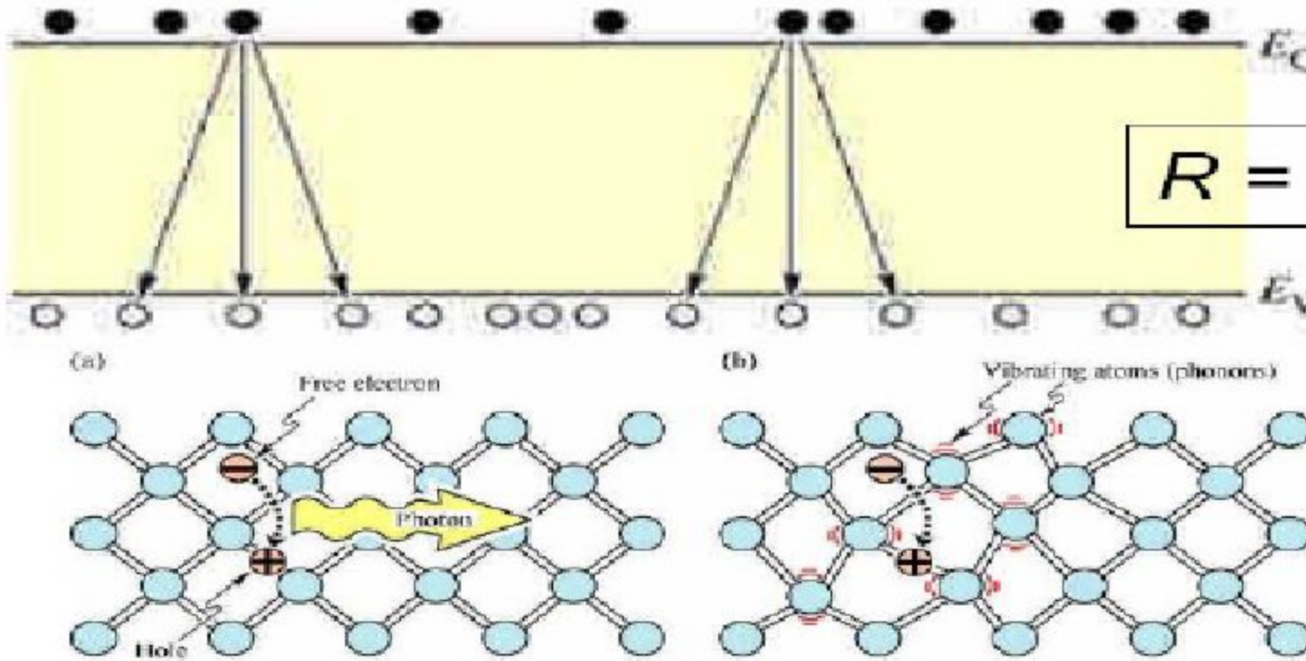
- Thus an electron hole pair is generated, in a process used in radiation captors;
- spontaneous emission, which is the inverse of that the above, where an electron spontaneously transits from the conduction band to the balance band and gives rise to a photon; and a stimulated emission, which is due to a photon that irradiates the semi-conductor and induces the transition of an electron from the conduction to the valence band and the simultaneous emission of a photon of the same energy as the exciting photon. This process is central to semiconductor based lasers.

Recombination process

- The operation of all optoelectronic devices is based on creation or annihilation of electron hole pairs.
- Pair formation essentially involves raising an electron in energy from the valence band to conduction band leaving h
  behind in valence band.
- simplest way to achieve this phenomenon is to irradiate the semiconductor
- photons with sufficient energy are absorbed, import their energy to the valence band electrons and raise them to the
  conduction band. This process is called absorption.
- Recombination; reverse process of electron hole pair annihilation, where energy is released is called recombination.
- recombination maybe radiative or nonradiative.
- nonradiative transition is the process where the excess Energy due to recombination distributed as photons which en
  usually equal to band gap.
- Luminescence; luminescence process is in which electron hole pair are create and recombined radiatively.
- photoluminescence; involves the radiative recombination of electron hole pair was created by injection of photons.

  Cathodoluminescence is the process of radiative recombination of electron hole pairs created by electron bombardment.
- electroluminescence is the process of radiative recombination following injection with In the junction or similar dev
- when excess Carriers are are created by one of the technique, non equilibrium condition are generated and the conce
  Fermi level is no longer valid.

Radiative and Non-radiative Recombin



$R = B\, n$

Fig. 2.5. (a) Radiative recombination of an electron-hole pair accompanied by the emission of a photon with energy $h\nu = E_g$. (b) In non-radiative recombination events, the energy released during the electron-hole recombination is converted to phonons (adopted from Shockley, 1950).

- Recombination rate is proportional to the product of the of electrons and holes, i.e. $R = B\, n\, p$, where B = bimole recombination coefficient, n = electron concentration, p concentration
- Non-radiative recombination creates heat instead of lig

Feasible Recombination Processes

$e^{-} + h^{+}$ => LIGHT ($h\nu$) Radiative recombination, Recomb.

$e^{-} + h^{+}$ => HEAT (kT) Non-radiative recombination, Non-

Non-radiative recombination via impurities