(MPM-202) Optoelectronics and Optical Communication System

UNIT-I (Optical Process in Semiconductors)

Lecture-6

by

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SYLLABUS

MPC-202 OPTOELECTRONICS AND OPTICAL COMMUNICATION SYSTEM Credits 4 (3-1-0)

UNIT I: Optical process in semiconductors

Optoelectronic properties of semiconductor: effect of temperature and pressure on bandgap, carrier scattering phenomena, conductance processes in semiconductor, bulk and surface recombination phenomena, optical properties of semiconductor, EHP formation and recombination, absorption in semiconductors, effect of electric field on absorption.

UNIT II: Optical sources and detectors

An overview of optical sources (Semiconductor Laser and LEDs), Optical Detectors: Type of photo detectors, characteristics of photo detectors, noise in photo detectors, photo transistors and photo conductors.

UNIT III: Optical fiber

Structure of optical wave guide, light propagation in optical fiber, ray and wave theory, modes of optical fiber, step and graded index fibers, transmission characteristics of optical fibers, signal degradation in optical fibers; attenuation, dispersion and pulse broadening in different types of optical fibres.

UNIT IV: Fiber components and optoelectronic modulation

Fiber components: Fibre alignments and joint loss, fiber splices, fiber connectors, optical fiber communication, components of an optical fiber communication system, modulation formats, digital and analog optical communication systems, analysis and performance of optical receivers, optoelectronic modulation.

Electron-Hole Pair Formation and Recombination

- The operation of almost all optoelectronic devices is based on the creation and annihilation of electron-hole pairs.

- Photons with sufficient energy are absorbed, and these impart their energy to the valance band electrons and raise them to the conduction band leaving a hole in valance band. This process is, therefore, also called ***absorption***.

- The reverse process that of electron and hole **recombination,** is associated with the pair giving up its excess energy.

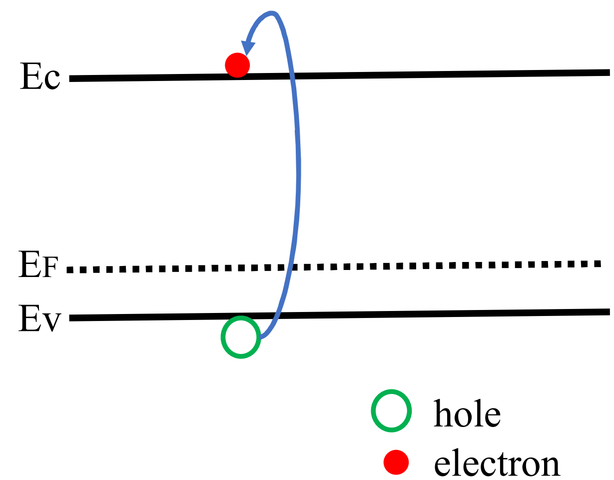
Electron-Hole Pair Generation

➢ There are three mainly generation processes-

- Thermal Generation
- Optical Generation
- Electrical Generation

1. Thermal Generation

- Assume a slightly p-type semiconductor as shown in figure.
- Due to thermal fluctuations electrons from V.B. go to the conduction band this is thermal generation Process.



Electron-Hole Pair Generation

- Let G be the generation rate and R be the recombination rate then

The extra number of electrons generated = The extra number of holes generated

i.e. $\Delta n = \Delta p$ in thermal generation of carriers.

- In equilibrium, G = R that gives steady state condition which define equilibrium carrier concentration of electron and hole (n and p).

- Earlier n and p $\longrightarrow$ from Fermi level and electron ,hole distribution.
- Now n and p $\longrightarrow$ from balance of generation and recombination process.

Electron-Hole Pair Generation

- **G** in thermal generation completely depends on temperature and is constant at a given temperature while recombination rate **R** depends on rate constant **'B'** and equilibrium charge concentration of electrons and holes in C.B. and V.B. respectively.

$$\text{Since } G = R \Rightarrow G = Bnp$$

This is general equation in equilibrium condition when generation is only due to thermal fluctuation.

Electron-Hole Pair Generation

2. Optical Generation

- If a light or photon of energy greater than the bandgap of a semiconductor falls on a semiconductor , it departs its energy to the electron in V.B. and the electron rises to the C.B. leaving a hole in the V.B.

- Similar to thermal generation $\Delta n = \Delta p$

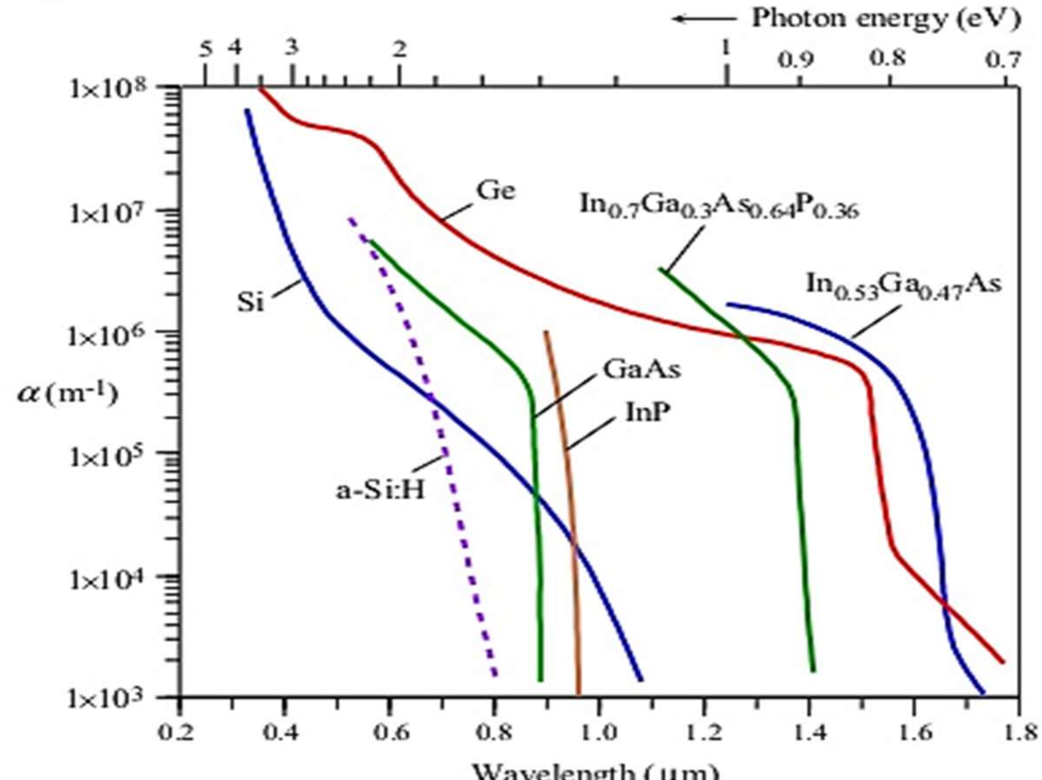
- One photon, with energy higher than the bandgap, absorbed generates one electron and one hole.

Electron-Hole Pair Generation

- Optical generation depends on the material's absorption coefficient (α)

Absorption Coefficient

- Absorption coefficient α is a material property.
- Most of the photon absorption (63%) occurs over a distance $1/\alpha$ (it is called **penetration depth** δ)



Electron-Hole Pair Generation

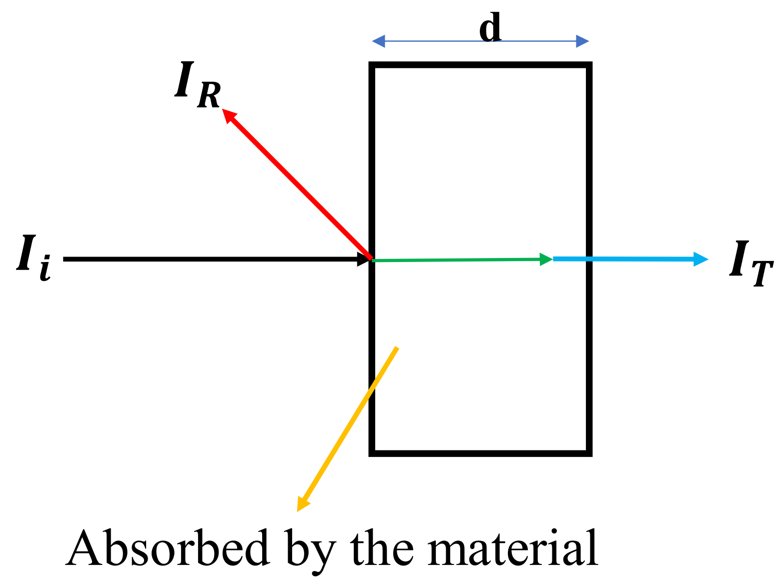
- Optical generation rate $'G_{ph}'$ is defined as the number of electron hole pairs generated per unit volume per second.

- Total incoming intensity

$$I_i = I_R + I_T + I_A$$

$$1 = \frac{I_R}{I_i} + \frac{I_T}{I_i} + \frac{I_A}{I_i}$$

$$\boxed{R + T + A = 1}$$



Electron-Hole Pair Generation

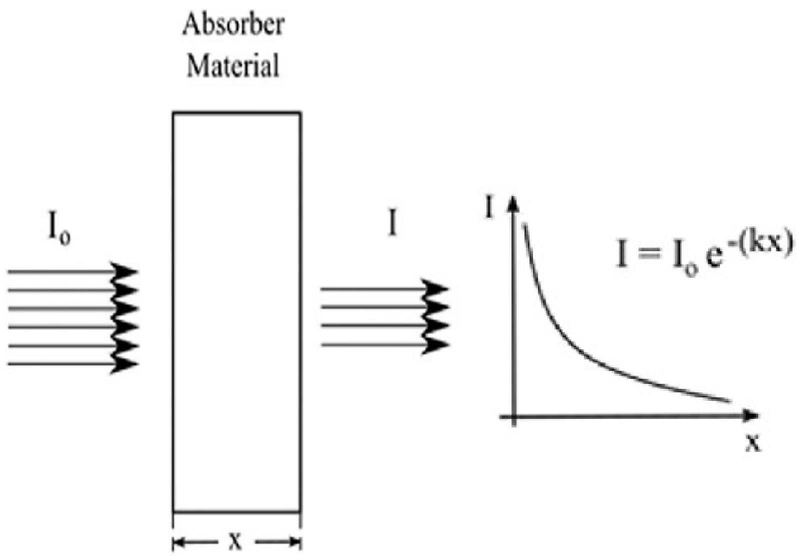
- Let $\boldsymbol{I_0}$ be the part of light incident going to interface

$$\boldsymbol{I_i(1-R)=I_0}$$

- And $I = I_0\exp(-\alpha d)$ is coming out of the semiconductor.

- So first we have to figure out how many photons have absorbed inside the material.

- Consider a slice of 'dx'



Electron-Hole Pair Generation

- Number of photons absorbed in the slice dx per unit volume

$$= \frac{\boldsymbol{I(x+dx)-I(x)}}{\boldsymbol{dx}} = \frac{\boldsymbol{dI}}{\boldsymbol{dx}}$$

- Number of e-h pair generated $= -\frac{\boldsymbol{dI}}{\boldsymbol{dx}}$

$$= \alpha I_0 \exp(-\alpha x)$$

- Generally, source of light is not monochromatic and it has wide wavelength

$$\boxed{\boldsymbol{G_{ph}(x,\lambda) = \alpha(\lambda) I_0 \exp(-\alpha(\lambda)\mathbf{x})}}$$

Electron-Hole Pair Generation

3. Electrical Generation

- By applying electrical bias one can create carriers in excess of equilibrium concentration.

- This is possible because on applying electrical bais to different junctions one is able to inject carriers.

- $\Delta n \neq \Delta p$ i.e. it is not necessary the number of excess hole and electron generated be equal in electrical generation.


THANK YOU