Optoelectronics Devices & Circuits (MEC-166)

UNIT-II

By

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SYLLABUS

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M. Tech. (Digital Systems) Syllabus

MEC-166	**Optoelectronics Devices & Circuits**	
Topics Covered		
UNIT-I		
Elements and compound Semiconductor, Electronic Properties of semiconductor, Carrier effective masses and band structure, effect of temperature and pressure on bandgap, Carrier scattering phenomena, conductance processes in semiconductor, bulk and surface recombination phenomena.		9
UNIT-II		
Optical Properties of semiconductor, EHP formation and recombination, absorption in semiconductor, Effect of electric field on absorption, absorption in quantum wells, radiation in semiconductor, Deep level transitions, Augur recombination's.		9
UNIT-III		
Junction theory, Schottky barrier and ohmic contacts, semiconductor heterojunctions, LEDs, Photo Detectors, Solar cells.		9
UNIT-IV		
Optoelectronics modulation and switching devices: Analog and Digital modulation, Franz-Keldysh and stark effects modulators, Electro-optic modulators. Optoelectronics Integrated Circuits (OEICs): Need for hybrid and monolithic integration, OEIC transmitters and receivers.		9
Textbooks		
1.	Semiconductor optoelectronic Devices By Pallab Bhattachrya, Prentice Hall Publications.	
2.	Physics of Semiconductor Devices, By S.M. Sze, Wiley Publication.	

Key Points

- Optical Processes In Semiconductors
- Electron-Hole Pair formation and recombination
  - Radiative and Nonradiative Recombination
  - Band to band Recombination
- Absorption in semiconductors
- Effect of electric field on absorption: Franz-Keldysh and stark Effects
- Deep level transition
- Auger Recombination
- Bulk and surface recombination phenomena

EHP Generation and Recombination

- Carrier generation and carrier recombination are processes by which mobile charge carriers (electrons and holes) are created and eliminated.
- Carrier generation and recombination processes are fundamental to the operation of many optoelectronic semiconductor device, such as photodiode, light emitting diodes and laser diodes.

- The electron hole pair (EHP) is the fundamental unit of generation and recombination, corresponding to an electron transition between the valance band and the conduction band. Where generation of electron is transition from the valance band to conduction band while recombination is reverse transition.

- **Carrier generation** describes processes by which electrons gain energy and move from the valence band to the conduction band, producing two mobile carriers;
- **Recombination** describes processes by which a conduction band electron loses energy and re-occupies the energy state of an electron hole in the valence band.

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.

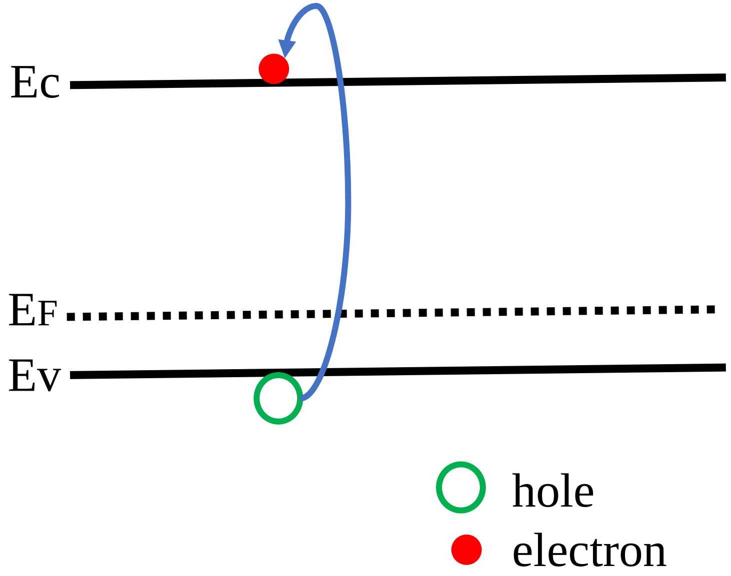
Electron-Hole Pair Generation

➢ 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 → from Fermi level and electron ,hole distribution.
- Now n and p → 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.

2. Optical Generation

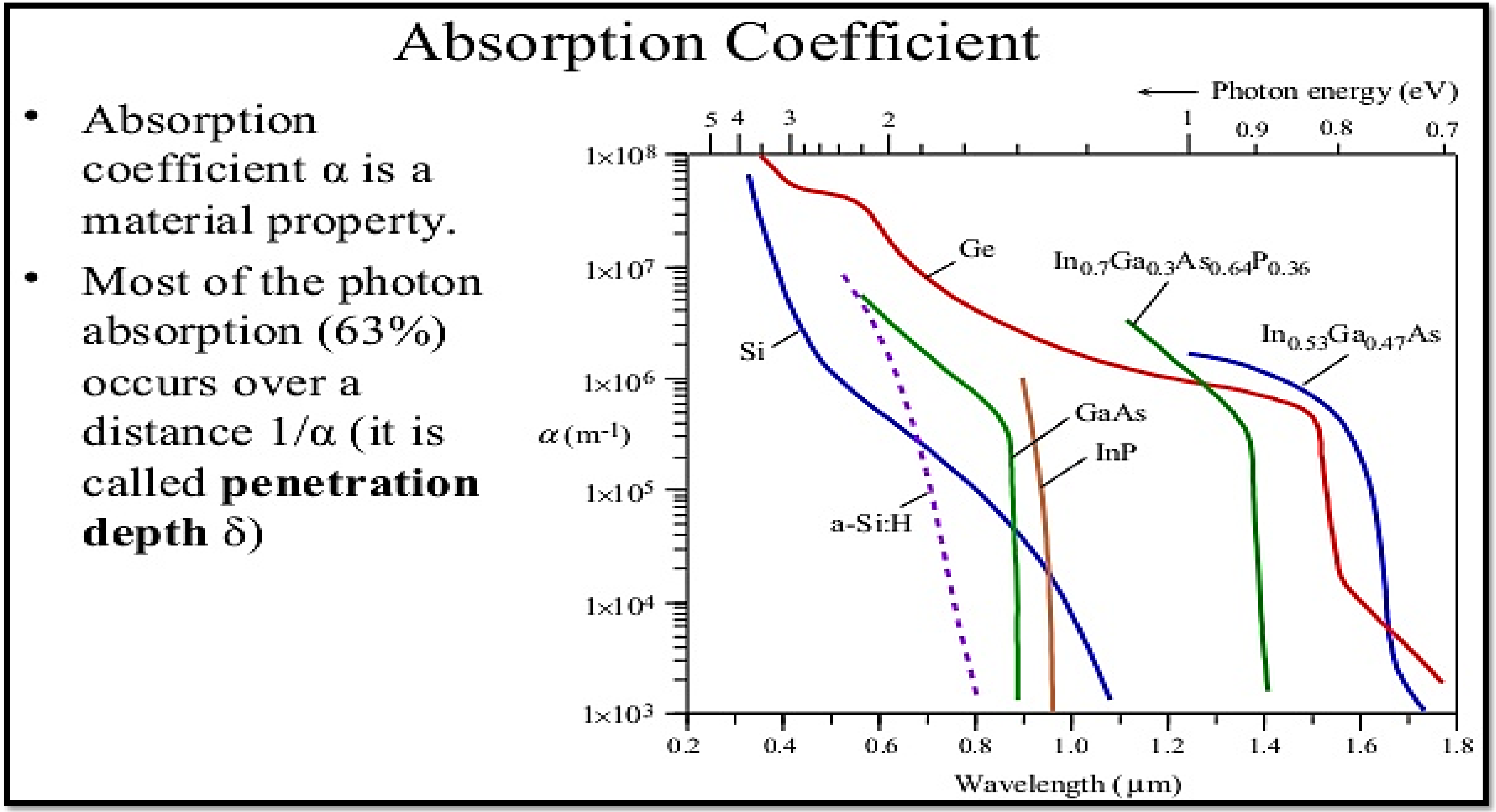
- If a light or photon of energy greater than the bandgap of a semiconductor falls on a semiconductor , it departs its energy to the electron in V.B. and the electron rises to the C.B. leaving a hole in the V.B.

- 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)



3. Electrical Generation

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

- This is possible because on applying electrical bias 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