Optoelectronics Devices & Circuits (MEC-166)

UNIT-I

By

Dr. POOJA LOHIA

Department of Electronics & Communication

Madan Mohan Malaviya University of Technology, Gorakhpur

SYLLABUS

Madan Mohan Malaviya University of Technology, Gorakhpur-273 010, India

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

- Introduction to Optoelectronics Devices
- Energy bands in solids, E-k diagram
- Elemental and Compound Semiconductor
- Semiconductor optoelectronic materials
- Carrier effective mass
- Effect of Temperature and Pressure on bandgap
- Carrier scattering
- Effect of scattering om mobility of carriers
- Conductance process in semiconductor
- Bulk and surface recombination phenomena

Introduction : Bulk and Surface Recombination Phenomena

- In a semiconductor carriers are generated by intrinsic photo excitation or by injection across a forward bias p-n junction.
- Since the density of majority carriers are not usually affected, these are termed **minority-carrier generation process.**
- The *excess* minority carrier, after living a mean life, generally recombines with a majority carrier and the pair is dissipated.
- In a n-type semiconductor, net rate of recombination of holes is

(25)

where is the **hole life time** and are the **non equilibrium** and **equilibrium hole concentrations.**

Introduction : Bulk and Surface Recombination Phenomena

- The recombination can be radiative or nonradiative.

- In this section we will study non radiative recombination, in which phonon is usually emitted.

Recombination-Generation via Defects or Levels in the Band gap

- In band to band downward transition their is a small probability of emission of phonons, in which recombination becomes non radiative.
- Such nonradiative recombination take place more likely via levels with in the band gap of the semiconductor as shown in figure given below-

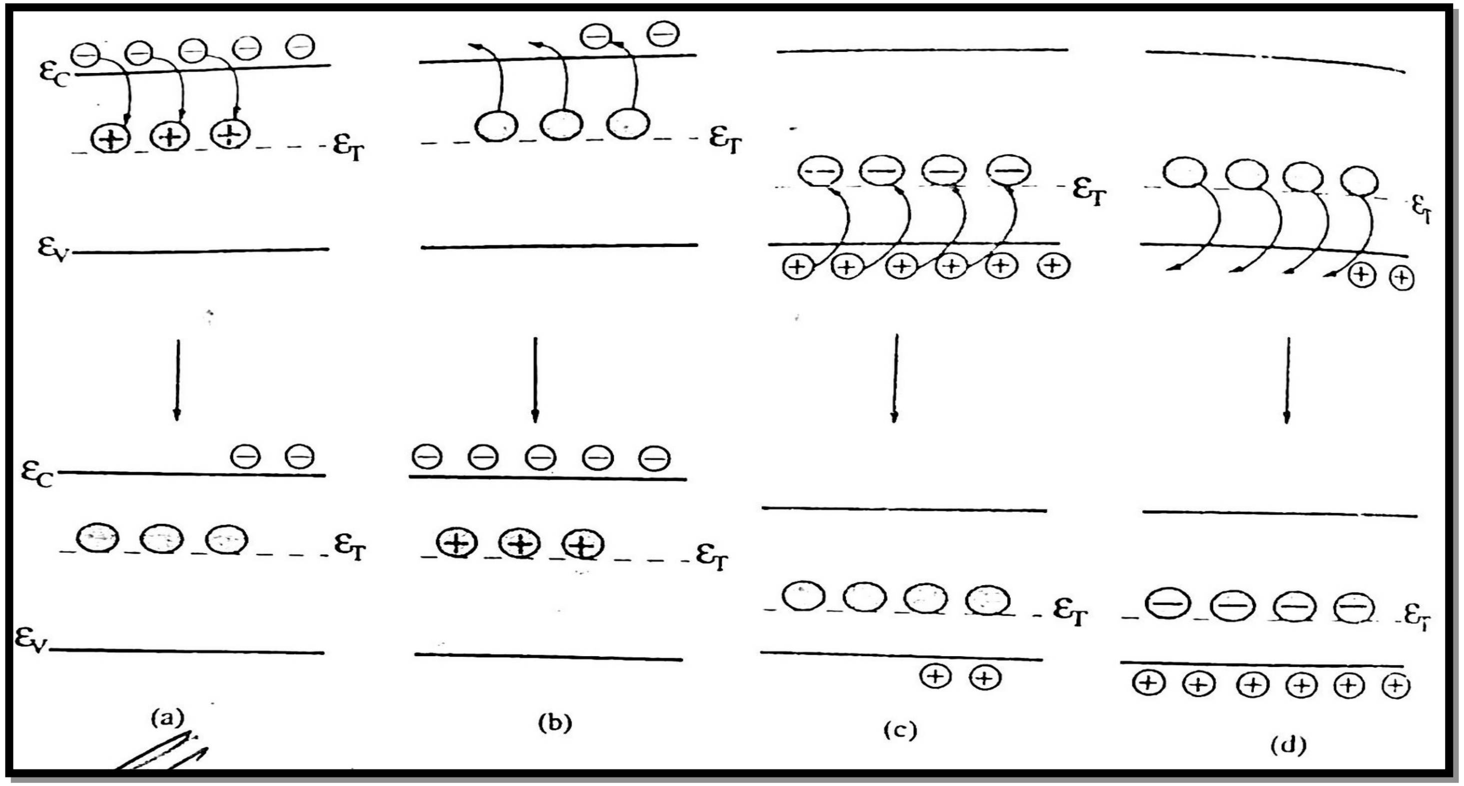

Illustration of (a) electron capture, (b) electron emission, (c) hole capture, and (d) hole emission. The deep levels in (a) and (b) are electron traps and those in (c) and (d) are hole traps

Recombination-Generation via Defects or Levels in the Band gap

- Deep levels initially act as carrier recombination or trapping centers and adversely affect device performance.

- Deep levels can be produced by a variety of defects that include substitution and interstitial impurity atom, lattice vacancies or complex defects formed by a combination of two types of defects.

- The probability of the involvement of a phonon is very high in such transitions, which make them non radiative.

Surface recombination in Semiconductors

- All the bulk properties of a semiconductor comes to an abrupt halt at a surface.
- The surface usually consists of dangling bonds or bonds that are satisfied by atoms other than the host atoms in the bulk.
- A common element is oxygen, and therefore a native oxygen is quickly formed on a semiconductor surface.
- The dangling bonds and bonding with foreign atoms give rise to a high density of defects at the surface of a semiconductor.
- As a result there is a distribution of defect states in the bandgap at the surface as shown in figure.
- The fermi level is pinned by overall charge state at the surface rather than by charge neutrality in the bulk.

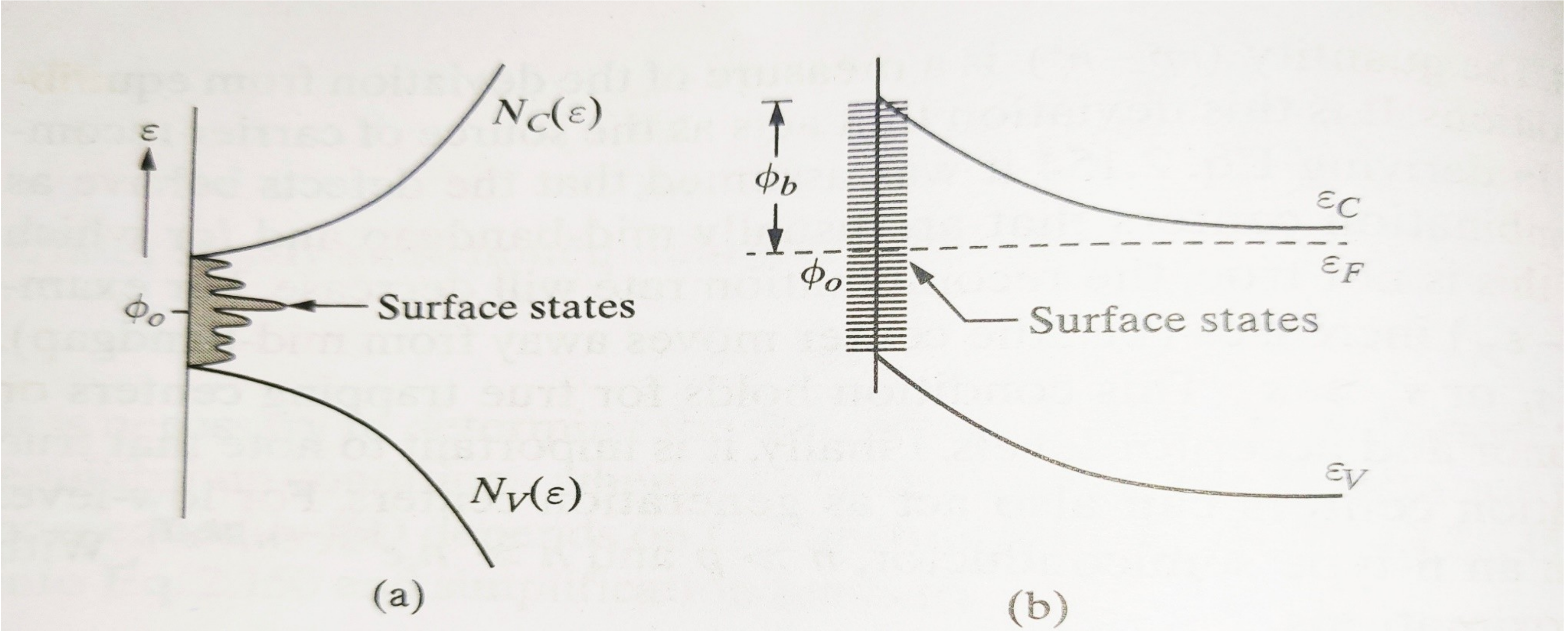

Fig1.7: (a) Distribution of surface states in the bandgap of a semiconductor (b)band-bending caused by fermi level pining at the surface.

- is called the neutral level.
- In (b) the acceptor-like surface states are occupied with electrons above and the surface has a net negative charge, which balances the positive charge in depletion layer of the n-type semiconductor.

- Due to large density of such surface sates there is an enhanced recombination at he surface of the semiconductor.
- The resulting distribution of excess minority carrier in the semiconductor is shown in fig 1.8.
- The surface state density is usually characterised by delta function as shown in fig 1.8.

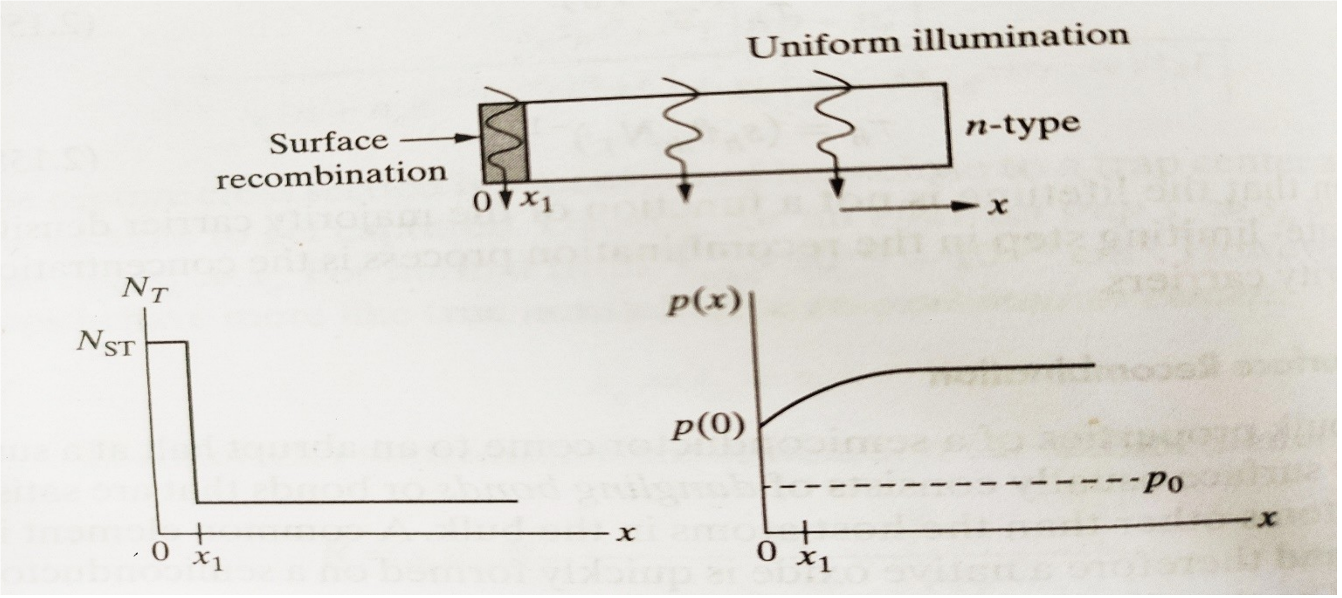

Fig 1.8 : Enhanced surface recombination and resulting distribution of excess minority carriers in the presence of surface states

Surface Recombination

- When **light falls** on such a surface, most of it can **recombine at the surface** even before reaching the bulk .

- This is extremely detrimental to the operation of most optoelectronic devices, and **special treatment of the semiconductor surface** is usually necessary.

- Due to the density of recombination centers at the surface, the resulting distribution of excess minority carriers in the semiconductor is as shown in previous figure.

- It is assumed that the surface sate density extends to a thickness into the material then Surface recombination rate is given by:

[]

Surface recombination Rate

- Where it is assumed that the material is n-type and hole are minority carriers.
- Under steady state conditions must be equal to the flux of minority carrier into the surface region. Thus,

at x=0

= []

Where

- This is the surface recombination velocity.
- It is a measure of surface recombination rate or the density of defects responsible for it.

Minimization of Surface Recombination

- Surface recombination can be minimized either:

➢ By passivating the surface with dielectric such as silicon dioxide or silicon nitrate. Or

➢ By having a lattice matched heterojunction at the free surface.

- In both the cases the wider bandgap material on top of the free surface not only minimizes surface recombination, but also serves as a window layer.
- So that in a device such as detector or solar cell light can be absorbed in active region of interest.


THANK YOU