Optoelectronics Devices & Circuits (MEC-166)

UNIT-I

By

Dr. POOJA LOHIA

Department of Electronics & Communication

Madan Mohan Malaviya University of Technology, Gorakhpur

SYLLABUS

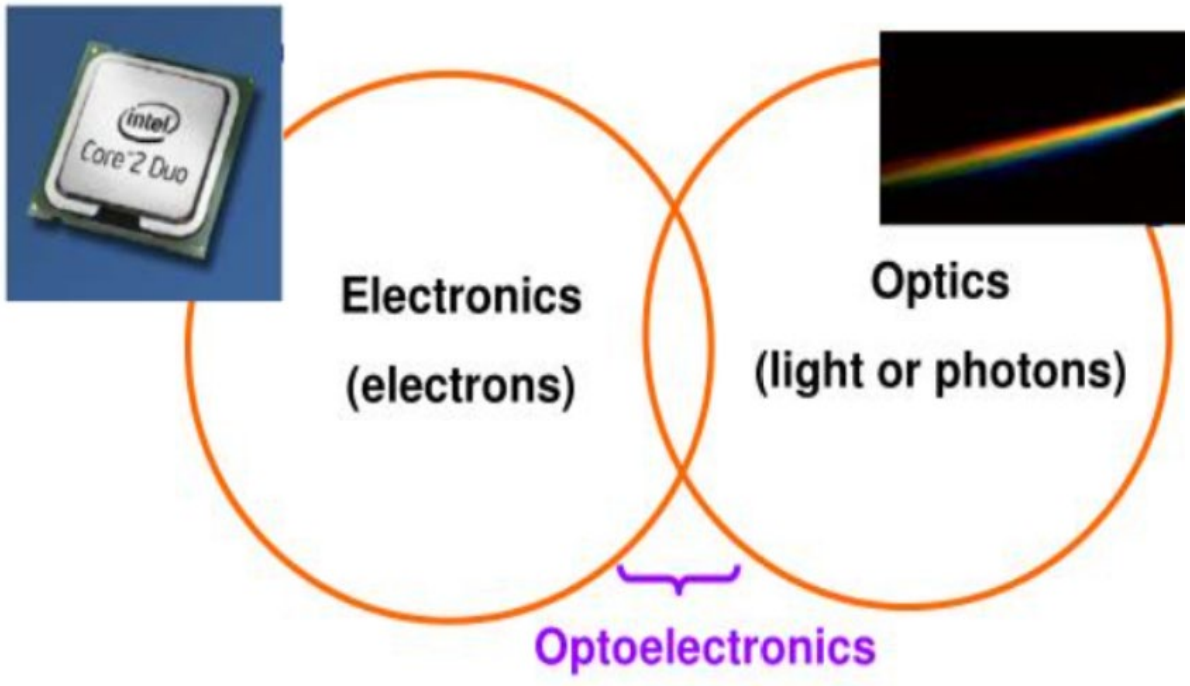
Madan Mohan Malaviya University of Technology, Gorakhpur-273 010, India

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



- **Optoelectronics** is the study and application of electronic devices that interact with light.
- Optoelectronic = Opto + Electronic
- Optoelectronics is an emerging technology for electronic devices that source, detect and control light.

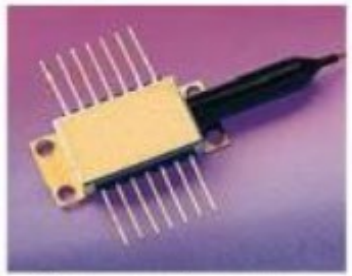
Optoelectronics Devices

- Devices in which such interaction take place ; accompanied by **energy conversion** process(electrical to optical vise-versa) known as **Optoelectronic devices.**

- It is a multidisciplinary domain with fusion of engineering and science. The area of study mainly deals with optics i.e. processing of Light through semiconductor materials.

Examples of Optoelectronic Devices

Telecommunication laser



Newport.com

Blue laser

TDK

Optical fiber

Corning

LED traffic lights

Rsc.org

Photodiodes

Hamamatsu

Solar cells

Wikipedia

- Light Emitting Diodes(LEDs)
- Laser Diode (LDs)
- Photodiode (PDs)
- Solar cells
- Optical fiber

Photonics in Our Daily Lives

Home

- Energy-saving fluorescent lamps
- Infrared remote controls
- TV flat panel / large screen
- Optical fibers for cable TV
- Compact disc players
- IR motion sensors for home security
- Video disk players
- Alarm clock radio with LED display
- IR noncontact “ear” thermometers
- Infrared remote headphones

Office

- Optical scanners
- Fax machines
- Optical fiber telephone cables
- Optical data storage
- Laser printers
- Photocopiers
- Overhead slide projectors
- Video teleconferences
- Laser pointers
- Computer active matrix displays
- Computer displays
- Infrared remote connections
- Special optical computers

Car

- Infrared security systems
- Optical monitors for antilock brakes
- Optical fiber dashboard displays
- LED traffic signals
- Laser traffic radar
- Solar-powered emergency services

Manufacturing

- Laser welding and cutting
- Optical stereo-lithography
- Machine vision
- Image recognition for quality control
- Nondestructive testing
- Precision measurement
- Optical inspection of labeling and packaging
- Laser fabric cutting machines

STORE

- Supermarket bar-code scanners
- Credit card holograms

Medical

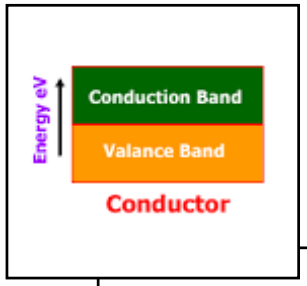
- Laser surgery
- Medical diagnosis tools
- Microscopes

Other

- Laser light shows
- Digital cameras
- Night vision goggles
- Missile guidance
- Laser weapons
- Surveillance cameras
- Surveying—alignment and range finders
- Computer-generated optical elements

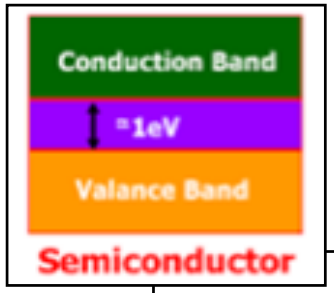
Art gallery holography exhibits

Types of Material



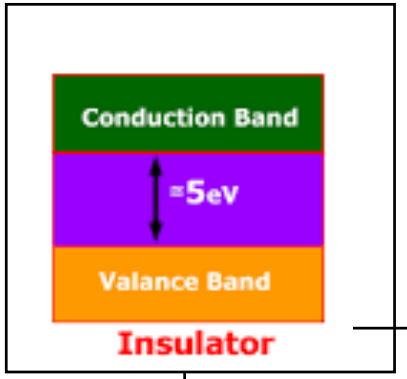
Conductor

- One valance electron
- V.B & C.B. overlapped $E_g \approx 0$ eV)
- Small resistivity
- Good conduction of electrical current
- Eg : Copper, Alluminium etc.



Semiconductor

- Four valance electron
- V.B & C.B. is separated by $E_g \approx$ 1.1 eV)
- High resistivity
- Moderate conduction of electrical current
- Eg : Silicon, Germanium etc.



Insulator

- Eight valance electron
- V.B & C.B. separated by $E_g \approx$ 6-10 eV)
- Very high resitivity
- No any conduction of electrical current
- Eg : Mica, Paper etc.

Semiconductors

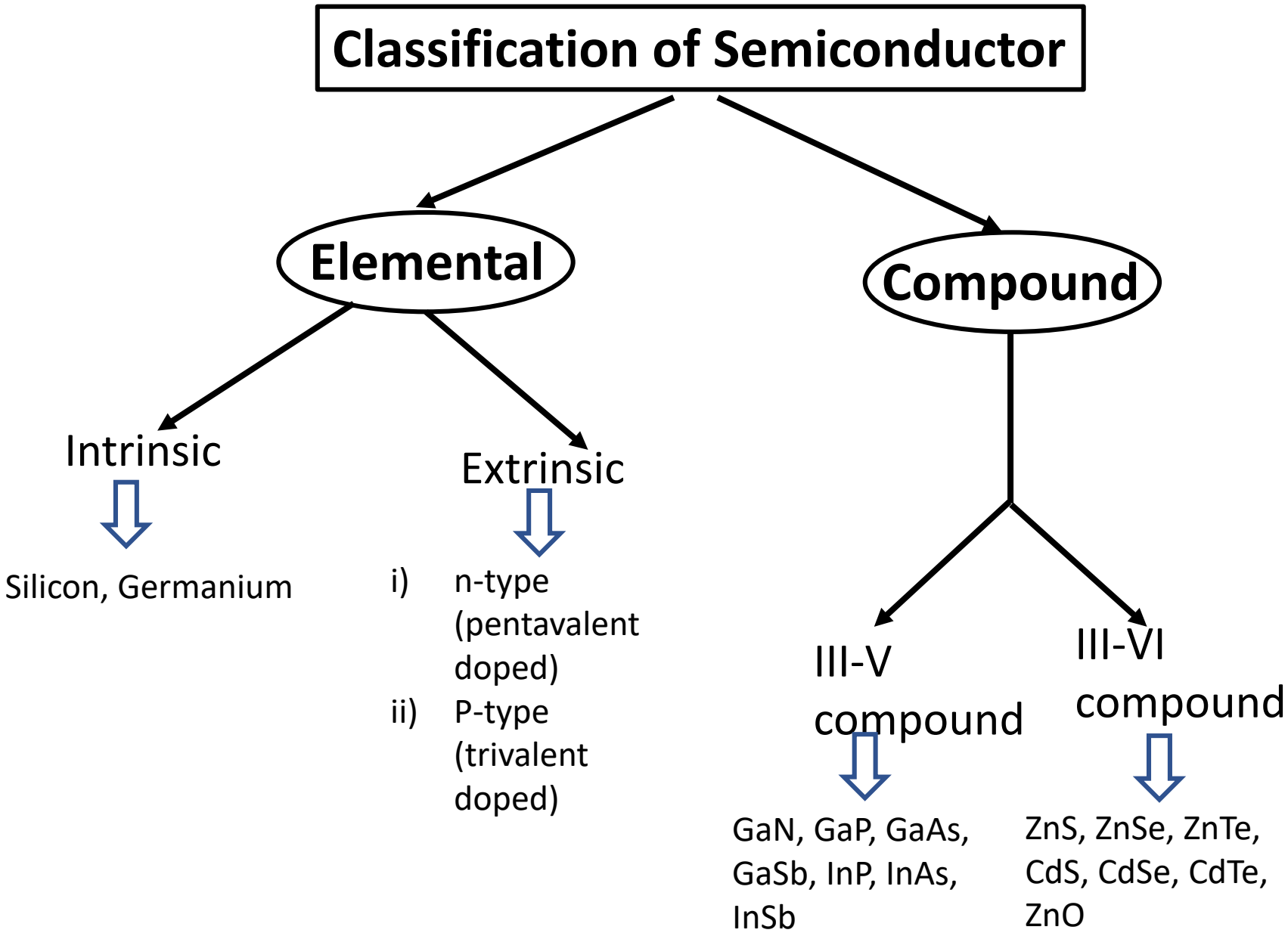
Advantages

- Tunable conductivity
- Miniaturization of electrical components
- Low power consumption
- Longer life
- Used in 3D printing machines
- Tunable bandgap
- Sensing ability

Applications

- Electrical switch
- Amplifier
- Logic device (CMOS logic)
- Memory devices
- LEDs
- Laser diode
- Solar Cell
- Photodetector
- Op-Amp
- ICs
- Diodes
- Capacitor
- Transistors
- Resistor

Classification of Semiconductor



Material for Optoelectronic Devices

- Semiconductor particularly Si is widely used for development of microelectronic devices, but it has some drawbacks : the fundamental **bandgap is indirect** this implies they **emit very poorly,** and **absorption coefficient** is low.

- **Compound semiconductors** are used for optoelectronic applications.
- They offers **desired properties** & could be synthesized without much difficulty.
- III-V compound :GaN, GaP, GaAs, GaSb, InP, InAs, InSb
- III-VI compound :ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, ZnO

Properties of Compound semiconductor

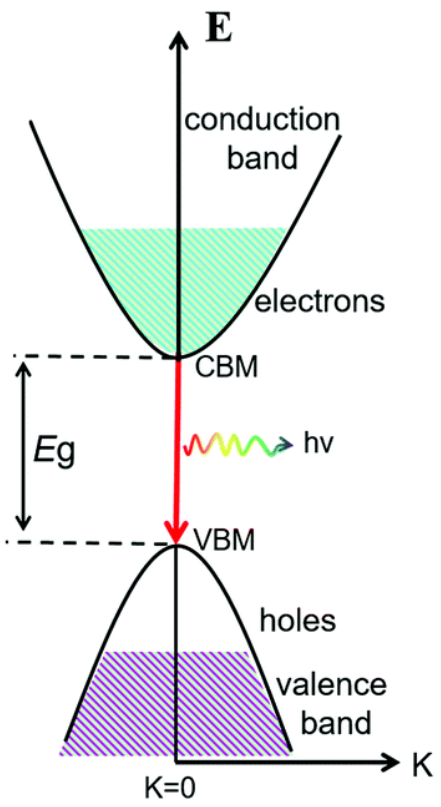
- Compound semiconductors have **high electron mobilities** & **velocities** property desired for **high speed devices**.
- They are **direct band semiconductor**.
- They have **high radiative efficiency** and **high absorption coefficient** that makes them important for optoelectronic materials.

- Binary compound
- Ternary Compound
- Quaternary Compound

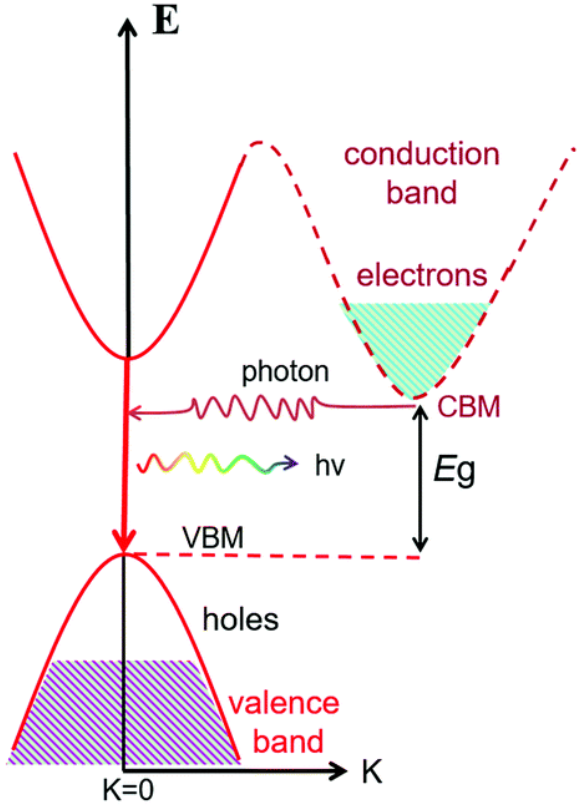
Optical Properties of Semiconductor

- In direct bandgap semiconductor, Conduction band minima and valence band maxima occurs at same value of momentum. An electron from CB directly return to VB without changing its momentum. And releases energy in the form of light (photon 'hv'). Ex: GaAs, Gap, GaAsP.

- CB minima and VB maxima occurs at different value of momentum. When electron from CB returns VB after changing its momentum is called indirect band gap sc. Energy changes its momentum by releasing phonon which is a heat particle. Ex: Si, Ge.



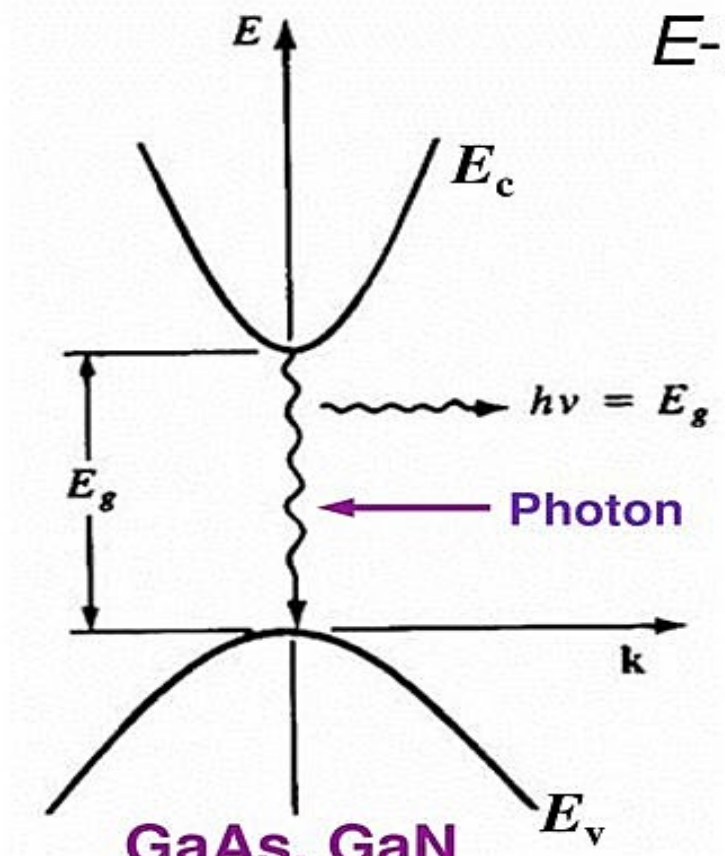
direct band gap structure



indirect band gap structure

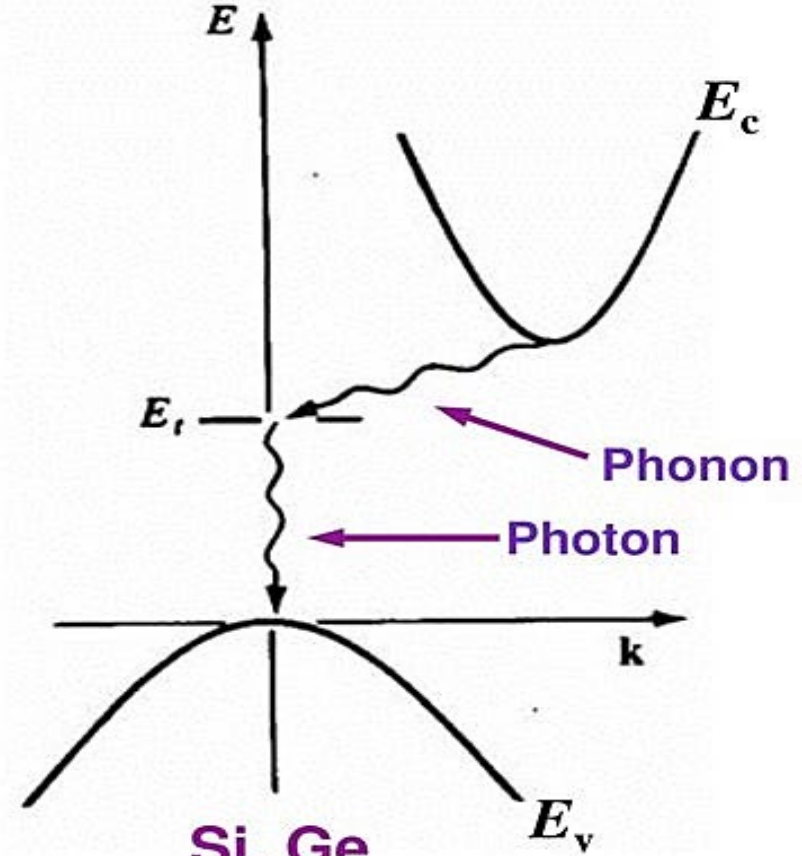
Direct and Indirect Bandgap Semiconductors

E-**k** Diagrams



GaAs, GaN
(direct semiconductors)

- Little change in momentum is required for recombination
- Momentum is conserved by photon (light) emission



Si, Ge
(indirect semiconductors)

- Large change in momentum is required for recombination
- Momentum is conserved by mainly phonon (vibration) emission + photon emission


THANK YOU