Unit-3

Lecture -2

LED, Hetrojunction, Homojunctions, Materials

The Light Emitting Diode (LED)

- For fiber-optics, the LED should have a high radiance (light intensity), fast response time and a high quantum efficiency
- Double or single hetero-structure devices
- Surface emitting (diffused radiation) Vs Edge emitting (more directional) LED's
- Emitted wavelength depends on bandgap energy

$$E_g = h\nu = hc / \lambda$$

Heterojunction

- Heterojunction is the advanced junction design to reduce diffraction loss in the optical cavity.
- This is accomplished by modification of the laser material to control the index of refraction of the cavity and the width of the junction.

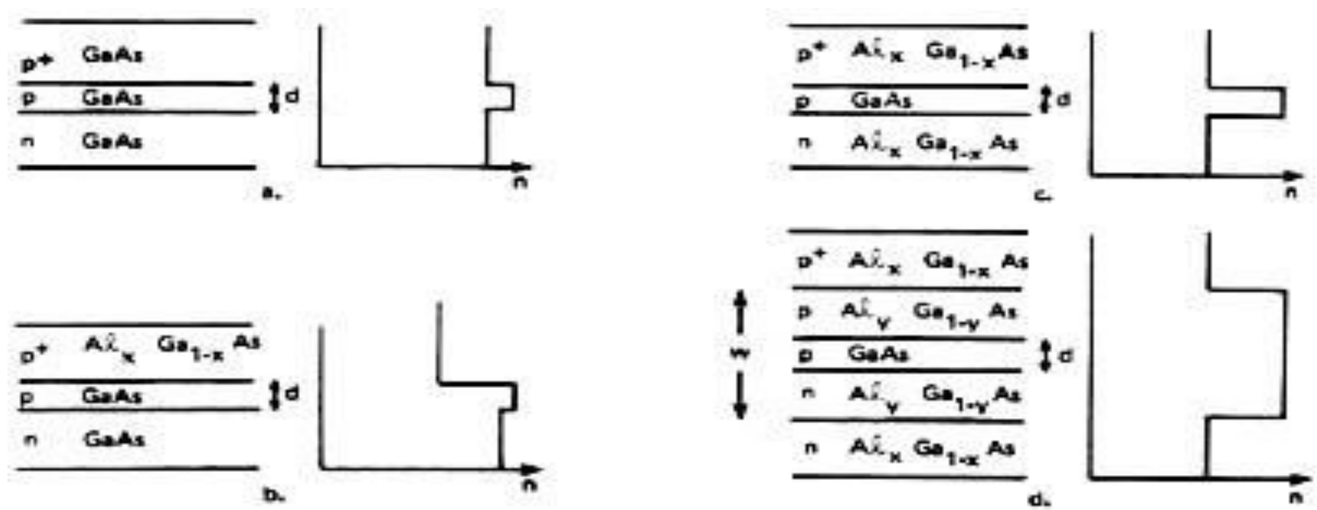
- The p-n junction of the basic GaAs LED/laser described before is called a homojunction because only one type of semiconductor material is used in the junction with different dopants to produce the junction itself.

- The index of refraction of the material depends upon the impurity used and the doping level.

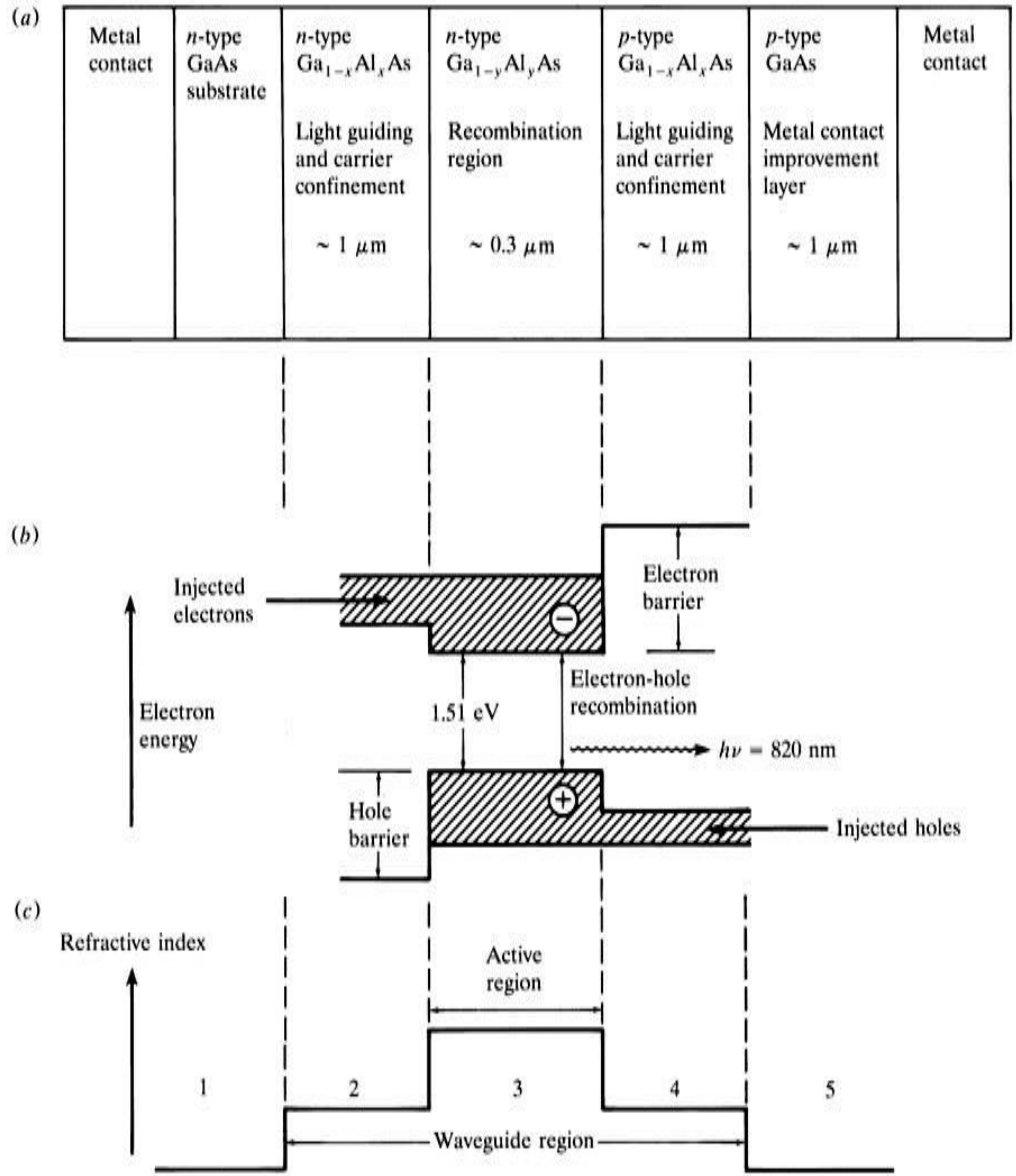
- ***The Heterojunction*** region is actually lightly doped with p-type material and has the highest index of refraction.
- The n-type material and the more heavily doped p-type material both have lower indices of refraction.
- This produces a light pipe effect that helps to confine the laser light to the active junction region.
- In the homojunction, however, this index difference is low and much light is lost.

Gallium Arsenide-Aluminum Gallium Arsenide Heterojunction

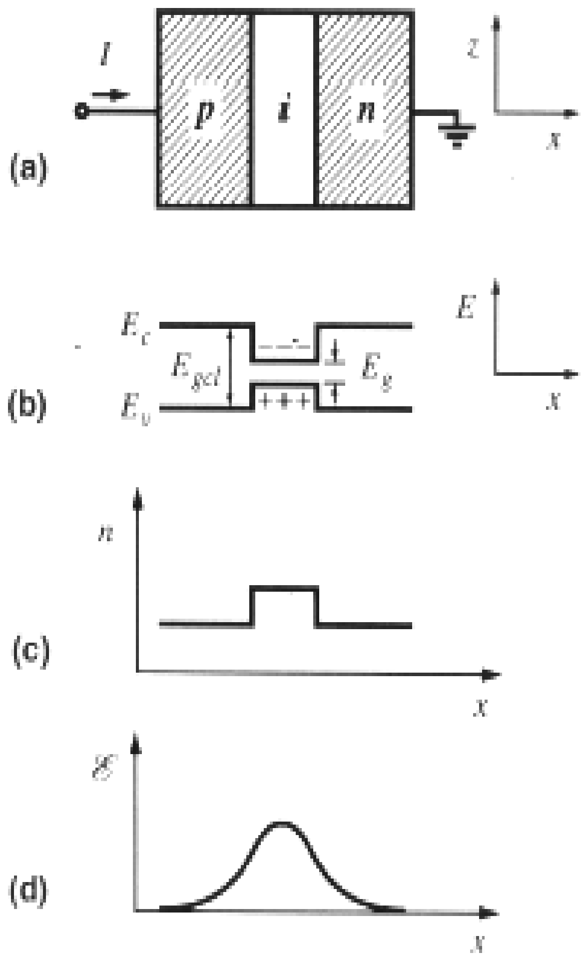
- **Structure and index of refraction n for various types of junctions in gallium arsenide with a junction width d.**
- **(*a*) is for a homojunction.**
- **(*b*) is for a gallium arsenide-aluminum gallium arsenide single heterojunction.**
- **(*c*) is for a gallium arsenide-aluminum gallium arsenide double heterojunction with improved optical confinement.**
- **(*d*) is for a double heterojunction with a large optical cavity of width w.**



Double-heterostructure configuration



Structure of a Generic Light Emitter: Double-Heterostructure Device



Double Heterostructure provides **transverse confinement** of both Carriers and Photons

(transverse direction → direction normal to the plane of the *pn* junction, x axis)

a) Schematic of a structure

b) Energy diagram of the conduction and valence bands vs. transverse distance

c) Refractive index profile

d) Electric field profile for a mode traveling in the z-direction

OPERATING WAVELENGTH

Fiber optic communication systems operate in the

- 850-nm,
- 1300-nm, and
- 1550-nm wavelength windows.
- Semiconductor sources are designed to operate at wavelengths that minimize optical fiber absorption and maximize system bandwidth

LED Wavelength

$$\lambda(\mu m) = \frac{1.2399}{E(\mathrm{eV})}$$

λ = hc/E(eV)

λ = wavelength in microns
H = Planks constant
C = speed of light
E = Photon energy in eV

Bandgap Energy and Possible Wavelength Ranges in Various Materials

Material	Formula	Wavelength Range λ (μm)	Bandgap Energy W_g (eV)
Indium Phosphide	InP	0.92	1.35
Indium Arsenide	InAs	3.6	0.34
Gallium Phosphide	GaP	0.55	2.24
Gallium Arsenide	GaAs	0.87	1.42
Aluminium Arsenide	AlAs	0.59	2.09
Gallium Indium Phosphide	GaInP	0.64-0.68	1.82-1.94
Aluminium Gallium Arsenide	AlGaAs	0.8-0.9	1.4-1.55
Indium Gallium Arsenide	InGaAs	1.0-1.3	0.95-1.24
Indium Gallium Arsenide Phosphide	InGaAsP	0.9-1.7	0.73-1.35