ANALOG & DIGITAL ELECTRONICS

Course No: PH-218

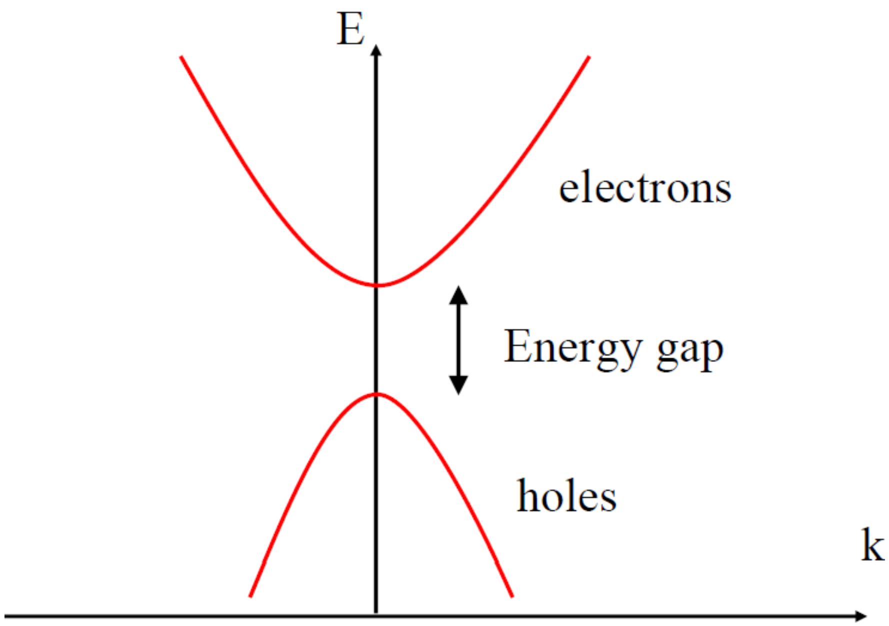
Tutorial -1

Course Instructor:

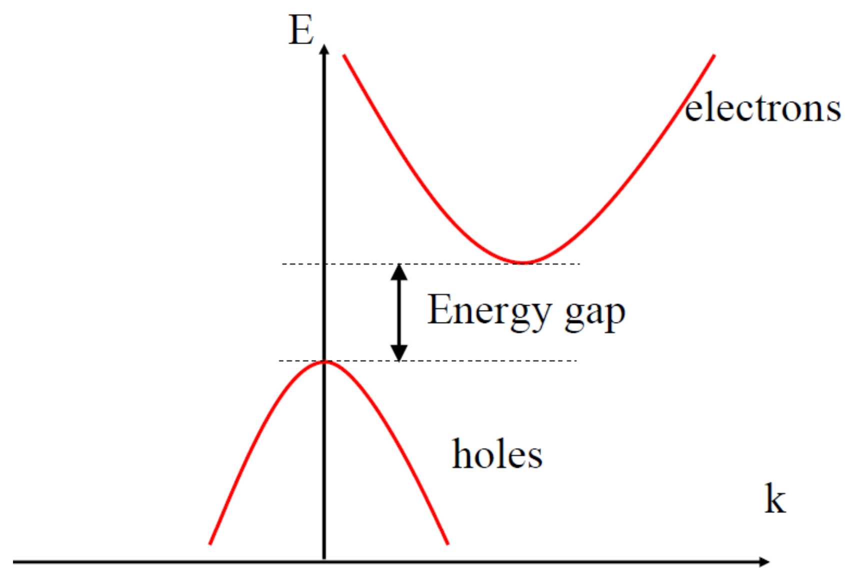
❖ **Dr. A.P. Vajpeyi**

Department of Physics,
Indian Institute of Technology Guwahati, India

Direct and Indirect bandgap semiconductors:



Direct bandgap semiconductors



Indirect bandgap semiconductors

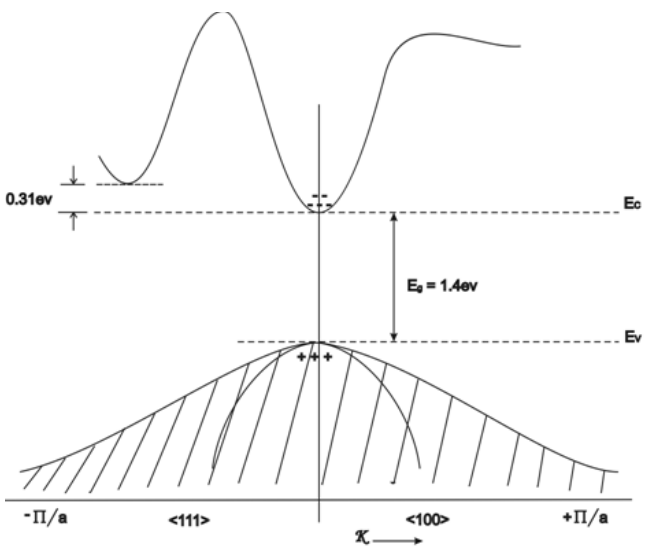
- Those materials for which maximum of valence band and minimum of conduction band lie for same value of k, called direct bandgap materials (i.e. satisfies the condition of energy and momentum conservation). For example: GaAs, InP, CdS..etc

- Those materials for which maximum of valence band and minimum of conduction band do not occur at same value of k, called indirect bandgap materials. For example: Si and Ge

➢ Indirect bandgap materials are not suitable for optical devices (LEDs and Laser diodes)

Indirect bandgap semiconductors:

Direct bandgap semiconductors:



(C) GaAs,InSb,CdS

Figure 1.59. E-k diagram of GaAs

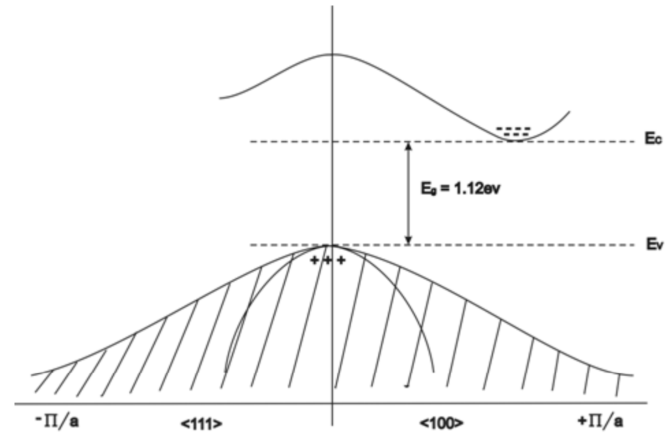


Figure1.58 (b) Silicon

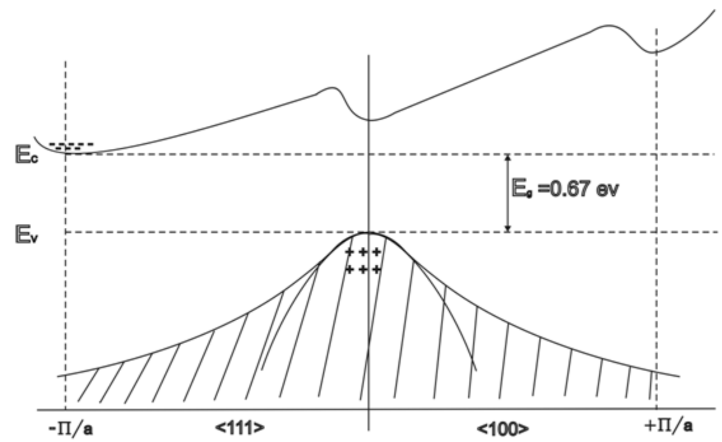


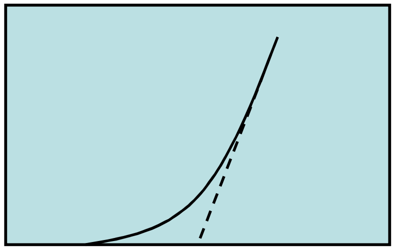
Figure 1.58. (A) Germanium

A common and simple method for determining whether a band gap is direct or indirect uses absorption spectroscopy. By plotting certain powers of the absorption coefficient against photon energy, one can normally tell both what value the band gap has, and whether or not it is direct.

Direct bandgap semiconductors

$$\alpha \approx A^* \sqrt{h\nu - E_g}$$

$$A^* = \frac{q^2 x_{vc}^2 (2m_r)^{3/2}}{\lambda_0 \epsilon_0 \hbar^3 n}$$



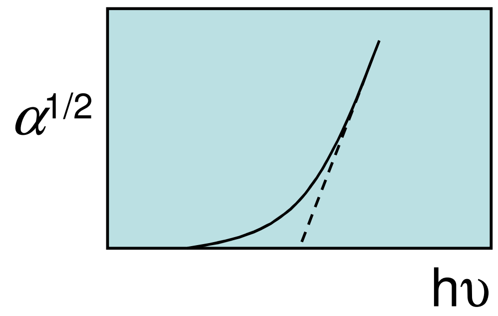
$$m_r = \frac{m_h^* m_e^*}{m_h^* + m_e^*}$$

n is the (real) index of refraction

x_{vc} is a "matrix element", with units of length and typical value the same order of magnitude as the lattice constant.

if a plot of $h\nu$ versus α^2 forms a straight line, it can normally be inferred that there is a direct band gap, measurable by extrapolating the straight line to the $\alpha = 0$ axis.

Indirect bandgap semiconductors



$$\alpha \propto \frac{(h\nu - E_g + E_p)^2}{\exp(\frac{E_p}{kT}) - 1} + \frac{(h\nu - E_g - E_p)^2}{1 - \exp(-\frac{E_p}{kT})}$$

E_p is the energy of the phonon that assists in the transition

if a plot of $h\nu$ versus $\alpha^{1/2}$ forms a straight line, it can normally be inferred that there is a indirect band gap, measurable by extrapolating the straight line to the $\alpha = 0$ axis (assuming Ep=0).

Why Nanomaterials ?

- 1D confinement: quantum wells; structures consisting of a thin well materials sandwiched between two layers of a barrier materials.

- 2D confinement: quantum wires; structures consisting of a thin and narrow well materials surrounded by barrier materials.

- 3D confinement: quantum dots; nano-size particles in a barrier materials.

- The quantum confinement => allowed electron and hole states are quantized in the well region => energy required to generate *e*-*h* pair or radiation emitted from the process of *e*-*h* pair recombination is modified

=> wavelength tuning of the radiation
(used in LED or laser applications)