



BUDDHA SERIES

(Unit Wise Solved Questions & Answers)

Course–B.Tech (ECE)

Buddha Institute of Technology

(AKTUCODE-525)

Department: Electronics and Communication Engineering

Subject: Electronics Devices (BEC-301)

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UNIT 2

QUEST1: What is the difference between Direct and indirect band gap semiconductors. AKTU 2019-20

ANS: In a direct band-gap semiconductor, the top of the valence band (VB) and the bottom of the conduction band (CB) occur at the same value of momentum. In an indirect band-gap semiconductor, the maximum energy of the valence band (VB) occurs at a different value of momentum to the minimum in the conduction band (CB) energy.

Whether a semiconductor has a direct or an indirect band gap is important in determining physical properties such as photoconductivity and electroluminescence.

QUEST2: What do you mean by effective mass of a Carrier?

AKTU 2019-20, 21

ANS: The effective mass is a quantity that is used to simplify band structures by modeling the behavior of a free particle with that mass. For some purposes and some materials, the effective mass can be considered to be a simple constant of a material.

Effective mass for density of states calculations

The effective mass for density of states calculations equals the mass which provides the density of states using the expression for one isotropic maximum or minimum or:

$$g_c(E) = \frac{8\pi\sqrt{2}}{h^3} m_e^{*3/2} \sqrt{E - E_C}, \text{ for } E \geq E_C$$

for the density of states in the conduction band and:

$$g_v(E) = \frac{8\pi\sqrt{2}}{h^3} m_h^{*3/2} \sqrt{E_V - E}, \text{ for } E \leq E_V$$

for the density of states in the valence band.

for instance for a single band minimum described by a longitudinal mass and two transverse masses the effective mass for density of states calculations is the geometric mean of the three masses. Including the fact that there are several equivalent minima at the same energy one obtains the effective mass for density of states calculations from:

$$m_{e,dos}^* = M_c^{2/3} (m_l m_t m_t)^{1/3}$$

where M_c is the number of equivalent band minima. For silicon one obtains:

$$m_{e,dos}^* = (m_l m_t m_t)^{1/3} = (6)^{2/3} (0.89 \times 0.19 \times 0.19)^{1/3} m_0 = 1.08 m_0.$$

Effective mass and energy bandgap of Ge, Si and GaAs

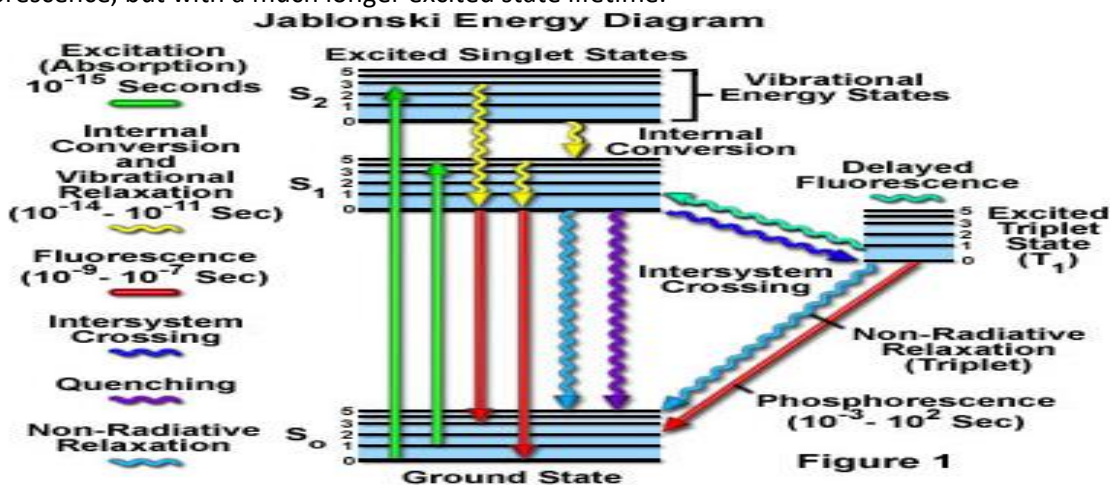
Name	Symbol	Germanium	Silicon	Gallium Arsenide
Smallest energy bandgap at 300 K	E_g (eV)	0.66	1.12	1.424
Effective mass for density of states calculations				
Electrons	$m_{e,dos}^*/m_0$	0.56	1.08	0.067
Holes	$m_{h,dos}^*/m_0$	0.29	0.57/0.81 ¹	0.47
Effective mass for conductivity calculations				
Electrons	$m_{e,cond}^*/m_0$	0.12	0.26	0.067
Holes	$m_{h,cond}^*/m_0$	0.21	0.36/0.386 ¹	0.34

$m_0 = 9.11 \times 10^{-31}$ kg is the free electron rest mass.

QUEST3: What is fluorescence? AKTU 2019-20

ANS: Fluorescent is related to the word flourspar, or fluorite, which is a mineral that glows. Notice the -u- in these words. Fluorescent comes from the Latin fluer "to flow" — flourspar can be added to welding compounds, for instance, to make them flow more easily.

Fluorescence is a member of the ubiquitous **luminescence** family of processes in which susceptible molecules emit light from electronically excited states created by either a physical (for example, absorption of light), mechanical (friction), or chemical mechanism. Generation of luminescence through excitation of a molecule by ultraviolet or visible light photons is a phenomenon termed **photoluminescence**, which is formally divided into two categories, **fluorescence** and **phosphorescence**, depending upon the electronic configuration of the excited state and the emission pathway. Fluorescence is the property of some atoms and molecules to absorb light at a particular wavelength and to subsequently emit light of longer wavelength after a brief interval, termed the fluorescence lifetime. The process of phosphorescence occurs in a manner similar to fluorescence, but with a much longer excited state lifetime.



QUEST4: How does direct recombination lifetime differ from indirect recombination life time? AKTU 2019-20,21

ANS: It is worth noting that the mechanism by which charge carriers recombine is a factor that determines the lifetime of the charge carrier; just as for direct band gap absorption, direct radiative recombination has shorter carrier lifetimes than indirect radiative recombination.

QUEST5: Write difference between Drift and diffusion.

AKTU 2019-20

ANS: Drift current is indeed the flow of current in a diode caused by an electric field. Diffusion is the current caused by carrier diffusion as a result of a change in carrier concentration.

Drift current	Diffusion current
1. It is due to the movement of carriers in response to an implemented electric field.	1. The motion of charge carriers from higher concentration to lower concentration produces diffusion current.
2. Positive carriers or holes flow in the same direction as the electric field, while negative carriers or electrons flow in the reverse direction.	2. When a semiconductor is doped non-uniformly, there is a non-uniform concentration of carriers or a concentration gradient.
3. The net movement of charged particles creates a drift current in the identical direction as the implemented electric field.	3. Nature's way of achieving equilibrium, in this case, is through the diffusion of carriers, and this provides rise to a diffusion current. This process does not need an external electric field and depends primarily on the repulsive forces between carriers of the same charge highly concentrated in an area.
4. The drift velocity rises with an increasing electric field and provides the mobility of the transmitters.	4. The repulsive forces will drive carriers' diffusion, leading to a variation in concentrations and eventually a uniform arrangement.
5. The drift current obeys Ohm's law and is mainly affected by the external field and charge carrier concentration.	5. The primary carrier concentrations also define the diffusion current's direction—the current progress to the direction where there is initially a higher density of electrons or a feebler concentration of holes.

QUEST6: Define sheet resistance.

AKTU 2019-20

ANS: Sheet resistance (also known as surface resistance or surface resistivity) is a common electrical property used to characterize thin films of conducting and semiconducting materials. It is a measure of the lateral resistance through a thin square of material, i.e. the resistance between opposite sides of a square.

Sheet resistance is applicable to two-dimensional systems in which thin films are considered two-dimensional entities. When the term sheet resistance is used, it is implied that the current is along the plane of the sheet, not perpendicular to it.

In a regular three-dimensional conductor, the resistance can be written as

$$R = \rho \frac{L}{A} = \rho \frac{L}{Wt},$$

where

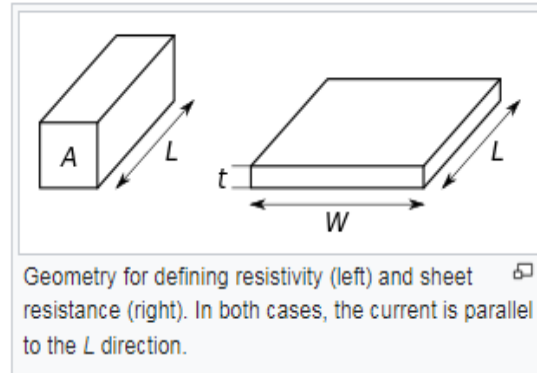
- ρ is material resistivity,
- L is the length,
- A is the cross-sectional area, which can be split into:
 - width W ,
 - thickness t .

Upon combining the resistivity with the thickness, the resistance can then be written as

$$R = \frac{\rho}{t} \frac{L}{W} = R_s \frac{L}{W},$$

where R_s is the sheet resistance. If the film thickness is known, the bulk resistivity ρ (in $\Omega \cdot \text{m}$) can be calculated by multiplying the sheet resistance by the film thickness in m:

$$\rho = R_s \cdot t.$$



QUEST7: Differentiate between direct and indirect band gap semiconductors. Also discuss the variation of energy band with alloy composition.

AKTU 2019-20, 21

ANS: The key difference between direct and indirect band gap is that in direct band gap, the crystal momentum of electrons and holes remains the same in the conduction band and the valence band and an electron can directly emit a photon, whereas indirect band gap has different k-vectors where a photon cannot be emitted. The way in which the bands change with composition x in the ternary compound $\text{Al}_x\text{Ga}_{1-x}\text{As}$. The binary compound GaAs is a direct material, with a band gap of 1.43 eV at room temperature.

QUEST8: Define mobility of a charge carrier.

AKTU 2019-20

ANS: Mobility of the charge carrier is defined as the drift velocity of the charge carrier per unit of the electric field. That is; Mobility= Drift velocity electric field. It is denoted by μ and is given as $\mu=vdE$.

The electron mobility is defined by the equation:

$$v_d = \mu_e E.$$

where:

- E is the magnitude of the electric field applied to a material,
- v_d is the magnitude of the electron drift velocity (in other words, the electron drift speed) caused by the electric field, and
- μ_e is the electron mobility.

The hole mobility is defined by a similar equation:

$$v_d = \mu_h E.$$

Both electron and hole mobilities are positive by definition.

Usually, the electron drift velocity in a material is directly proportional to the electric field, which means that the electron mobility is a constant (independent of the electric field). When this is not true (for example, in very large electric fields), mobility depends on the electric field.

The SI unit of velocity is m/s, and the SI unit of electric field is V/m. Therefore the SI unit of mobility is (m/s)/(V/m) = $m^2/(V \cdot s)$. However, mobility is much more commonly expressed in $cm^2/(V \cdot s) = 10^{-4} m^2/(V \cdot s)$.

Mobility is usually a strong function of material impurities and temperature, and is determined empirically.

Mobility values are typically presented in table or chart form. Mobility is also different for electrons and holes in a given material.

QUEST9: Define Semiconductor. Explain different kind of semiconductor devices with proper diagram. AKTU 2021-22

ANS: A semiconductor device is an electronic component that relies on the electronic properties of a semiconductor material (primarily silicon, germanium, and gallium arsenide, as well as organic semiconductors) for its function. Its conductivity lies between conductors and insulators.

QUEST10: How does the doping affect the performance of semiconductors with example?

ANS: In semiconductor production, doping is the intentional introduction of impurities into an intrinsic semiconductor for the purpose of modulating its electrical, optical and structural properties. The doped material is referred to as an extrinsic semiconductor.

Small numbers of dopant atoms can change the ability of a semiconductor to conduct electricity. When on the order of one dopant atom is added per 100 million atoms, the doping is said to be *low* or *light*. When many more dopant atoms are added, on the order of one per ten thousand atoms, the doping is referred to as *high* or *heavy*. This is often shown as *n+* for n-type doping or *p+* for p-type doping. (See the article on semiconductors for a more detailed description of the doping mechanism.) A semiconductor doped to such high levels that it acts more like a conductor than a semiconductor is referred to as a degenerate semiconductor. A semiconductor can be considered i-type semiconductor if it has been doped in equal quantities of p and n.

In the context of phosphors and scintillators, doping is better known as activation; this is not to be confused with dopant activation in semiconductors. Doping is also used to control the color in some pigments.

QUEST11: Explain the different kind of energy band in intrinsic and extrinsic semiconductor. AKTU 21-22

ANS: The first reference to an energy band diagram is an intrinsic semiconductor where the energy level lies exactly in the middle of the conduction band and valence bands. The energy level lies close to the conduction band in an extrinsic semiconductor. And the third type shows the energy level closer to the valence band. (i) The energy gap is of 1.1 eV for intrinsic semiconductor and less than 1.1 eV (due to donor energy state or acceptor energy state) for extrinsic semiconductor.

QUEST12: What is the Difference between Intrinsic and Extrinsic Semiconductors?

ANS: A semiconductor is an electrical material that exists between an insulator and a conductor. The most known semiconductors are Si and Ge. Semiconductors are classified into two types: intrinsic semiconductors and extrinsic semiconductors (p-type and n-type). The major difference between Intrinsic and Extrinsic Semiconductors is that in intrinsic semiconductors, a semiconductor is in its purest form whereas it does not happen in extrinsic semiconductors.

The intrinsic semiconductor is pure, whereas the extensive semiconductor contains impurities to make it conductive. At room temperature, intrinsic conductivity is zero, while extrinsic conductivity is quite low. This article presents an overview of intrinsic and extrinsic semiconductors using doping and energy band diagrams along with the difference between intrinsic and extrinsic semiconductors.

Intrinsic Semiconductors

Semiconductor in its purest form.

It has low conductivity.

The band gap between the conduction and valence bands is quite narrow.

Extrinsic Semiconductors

Semiconductor in its impure form.

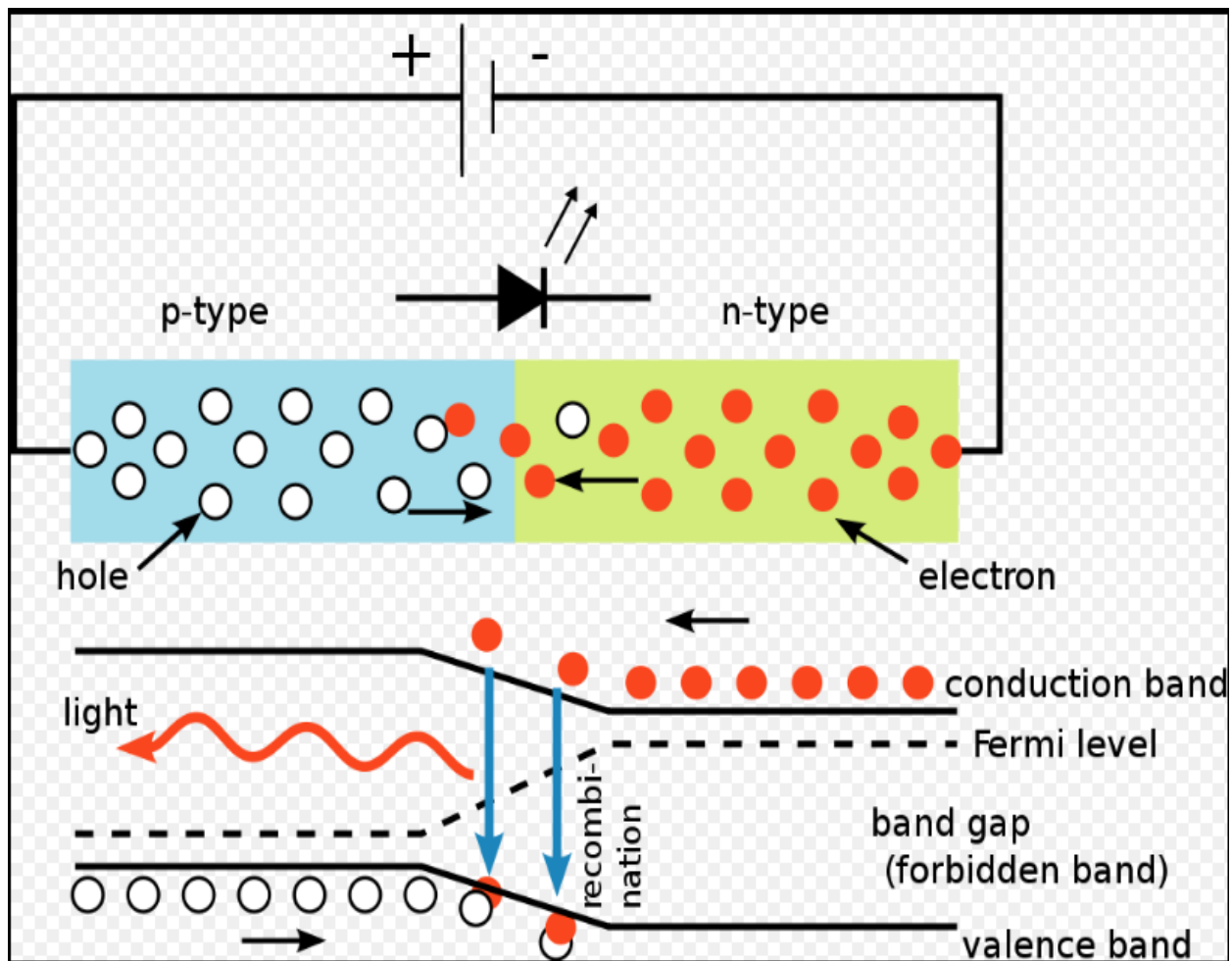
It has a higher conductivity than an intrinsic semiconductor.

The energy gap is greater than that of an intrinsic semiconductor.

QUEST13: What is the energy band diagram?

ANS: In solid-state physics of semiconductors, a band diagram is a diagram plotting various key electron energy levels (Fermi level and nearby energy band edges) as a function of some spatial dimension, which is often denoted x . These diagrams help to explain the operation of many kinds of semiconductor devices and to visualize how bands change with position (band bending). The bands may be colored to distinguish level filling.

A band diagram should not be confused with a band structure plot. In both a band diagram and a band structure plot, the vertical axis corresponds to the energy of an electron. The difference is that in a band structure plot the horizontal axis represents the wave vector of an electron in an infinitely large, homogeneous material (a crystal or vacuum), whereas in a band diagram the horizontal axis represents position in space, usually passing through multiple materials.



Because a band diagram shows the *changes* in the band structure from place to place, the resolution of a band diagram is limited by the Heisenberg uncertainty principle: the band structure relies on momentum, which is only precisely defined for large length scales. For this reason, the band diagram can only accurately depict evolution of band structures over long length scales, and has difficulty in showing the microscopic picture of sharp, atomic scale interfaces between different materials (or between a material and vacuum). Typically, an interface must be depicted as a "black box", though its long-distance effects can be shown in the band diagram as asymptotic band bending.

