1. What is intrinsic semiconductor?

ANS - Intrinsic semiconductor Semiconductors that are chemically pure, in other words, free from impurities are termed as intrinsic semiconductors. The number of holes and electrons is therefore determined by the properties of the material itself instead of the impurities. In intrinsic semiconductors, the number of excited electrons is equal to the number of holes; $\boldsymbol{n} = \boldsymbol{p}$.

2. Explain atomic structure and energy level diagram of intrinsic semiconductor?

ANS -The Intrinsic semiconductor can be defined as chemically pure material without any doping or impurity added to it. The most commonly known intrinsic or pure semiconductors available are Silicon (Si) and Germanium (Ge). The behavior of the semiconductor on applying a certain voltage is dependent on its atomic structure. The outermost shell of both Silicon and Germanium have four electrons each. To stabilize each other nearby atoms form covalent bonds based on the sharing of valence electrons. This bonding in the crystal lattice structure of Silicon is illustrated in figure 1. Here it can be seen that the valence electrons of two Si atoms pair together to form a Covalent Bond.

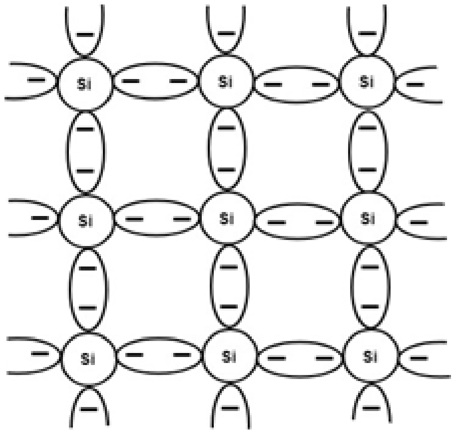
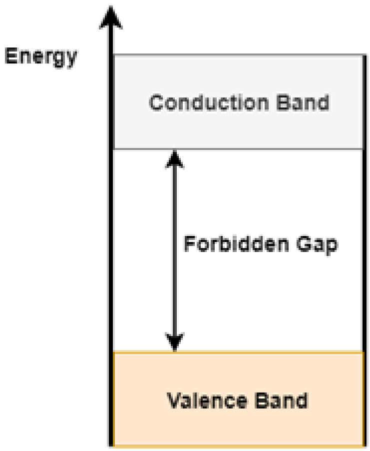


Figure 1. Covalent bonding of the Silicon atom

At all the covalent bonds are stable and no carriers are available for conduction. Here the intrinsic semiconductor behaves as an insulator or non-conductor. Now if the ambient temperature comes close to the room temperature of the covalent bonds start breaking. Thus the electrons from the valence shell are released to take part in conduction. As more carriers are released for conduction the semiconductor starts behaving as a conducting material. The energy band diagram given below explains this transition of carriers from the valence band to the conduction band.

The Energy band diagram shown in figure depicts two levels, Conduction Band and Valence Band. The space between the two bands is called the forbidden gap



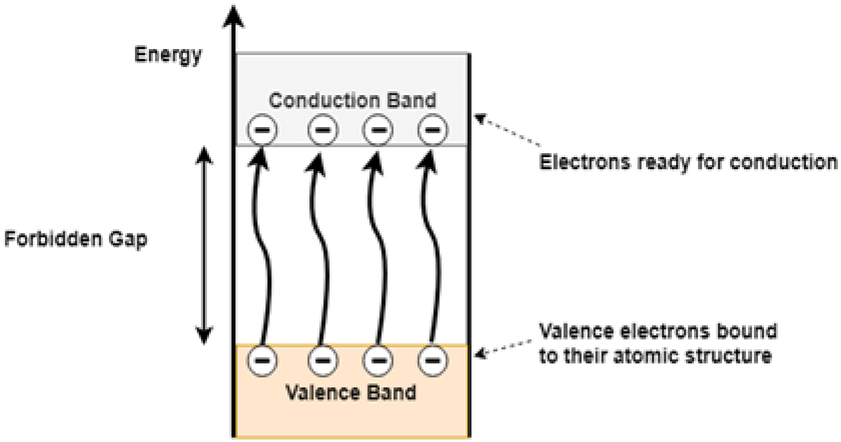


Figure 2(b). Conduction and Valence band electrons in a semiconductor

When a semiconductor material is subjected to heat or applied voltage few of the covalent bonds break, which generates free electrons as shown in figure 2 (b). These free electrons get excited and gain energy to overcome the forbidden gap and enter the conduction band from the valence band. As the electron leaves valence band, it leaves behind a hole in the valence band. In an intrinsic semiconductor always an equal number of electrons and holes will be created and hence it exhibits electrical neutrality. Both the electrons and holes are responsible for conduction of current in the intrinsic semiconductor.

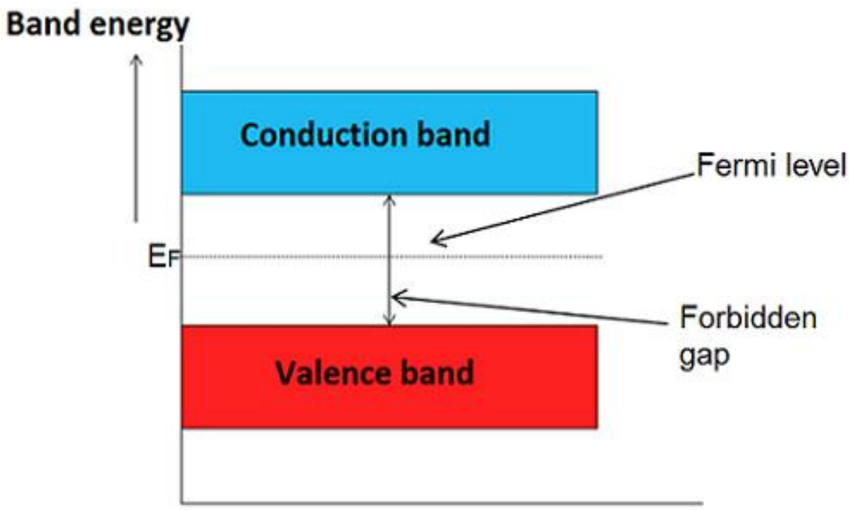
3. Where the Fermi energy level lies in intrinsic semiconductor. How does it vary with respect to temperature?

ANS -

Fermi level in intrinsic semiconductor

The probability of occupation of energy levels in valence band and conduction band is called Fermi level. At absolute zero temperature intrinsic semiconductor acts as perfect insulator. However as the temperature increases free electrons and holes gets generated.

In intrinsic or pure semiconductor, the number of holes in valence band is equal to the number of electrons in the conduction band. Hence, the probability of occupation of energy levels in conduction band and valence band are equal. Therefore, the Fermi level for the intrinsic semiconductor lies in the middle of forbidden band.



Fermi level in the middle of forbidden band indicates equal concentration of free electrons and holes.

The hole-concentration in the valence band is given as

$$p = N_V e^{\frac{-(E_F - E_V)}{K_B T}}$$

The electron-concentration in the conduction band is given as

$$n = N_c e^{\frac{-(E_C - E_F)}{K_B T}}$$

Where K_B is the Boltzmann constant

T is the absolute temperature of the intrinsic semiconductor

N_c is the effective density of states in the conduction band.

N_v is the effective density of states in the valence band.

The number of electrons in the conduction band is depends on effective density of states in the conduction band and the distance of Fermi level from the conduction band.

The number of holes in the valence band is depends on effective density of states in the valence band and the distance of Fermi level from the valence band.

For an intrinsic semiconductor, the electron-carrier concentration is equal to the hole-carrier concentration.

It can be written as

$$p = n = ni$$

Where P = hole-carrier concentration

n = electron-carrier concentration

and n_i = intrinsic carrier concentration

The fermi level for intrinsic semiconductor is given as,

$$E_F = \frac{E_C + E_V}{2}$$

Where E_F is the fermi level
E_C is the conduction band
E_V is the valence band

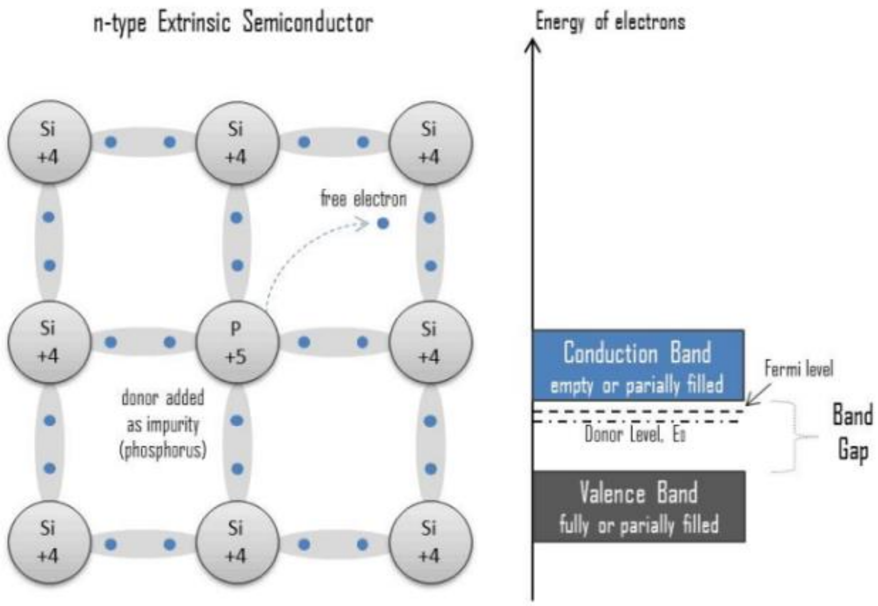
Therefore, the Fermi level in an intrinsic semiconductor lies in the middle of the forbidden gap

4. What is Extrinsic semiconductor?

A semiconducting material in which the charge carriers originate from impurity atoms added to the material is called impurity semiconductor or extrinsic semiconductor. The process of deliberate addition of controlled quantities of impurities to a pure semiconductors is called doping. The addition of impurity increases the carrier concentration leading to increase in conductivity of the conductor.

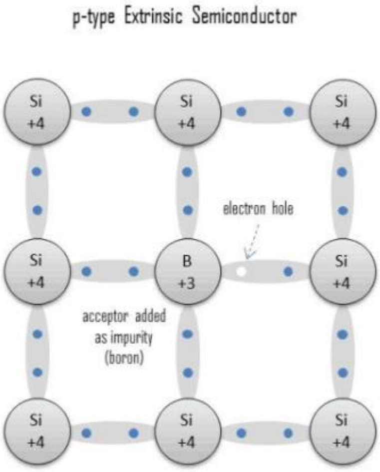
5. Explain N - type semiconductor with diagram

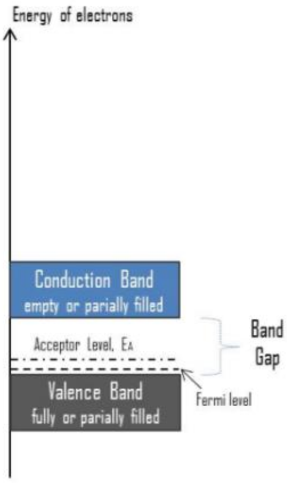
n-type semiconductor
Pentavalent impurity added to intrinsic semiconductor. Eg. P, As, Sb
Electrons are majority charge carriers
Energy level of donor atoms are very close to the bottom of conduction band
Fermi level of n-type is above intrinsic semiconductor



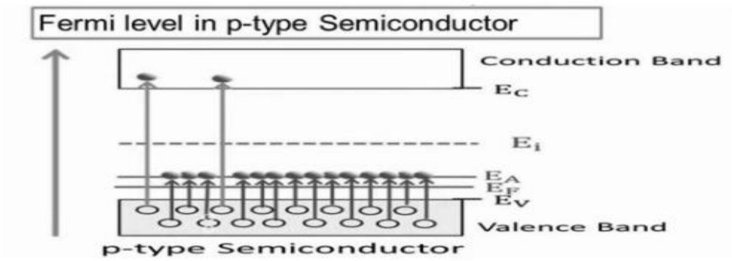
6. Explain P - type semiconductor with diagram

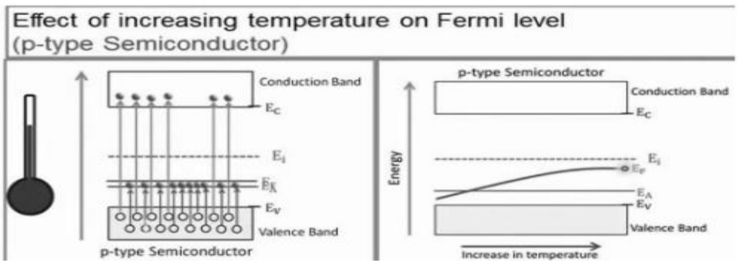
p-type semiconductor
Trivalent impurity added to intrinsic semiconductor. Eg. B, Ga, In
Holes are majority charge carriers
Energy levels of acceptor atoms are very close to the top of valence band
Fermi level of p-type is below intrinsic semiconductor





7. Where does the Fermi energy level lie in P - type semiconductor. How? does it vary with respect to temperature.





$$E_F = \frac{E_V + E_a}{2} + \frac{kT}{2} ln \left(\frac{N_y}{N_a} \right)$$

As the temperature increases, the Fermi level rises towards intrinsic Fermi level, which is also dependent on concentration of N_a atoms. More and more acceptor atoms are ionized with temperature and at a point all acceptor atoms are ionized. After this point, the generation of electron-hole pair due to the breaking of covalent bonds takes place and the material tends to behave in the intrinsic manner.

Variation in Fermi level of P-type semiconductor with temperature

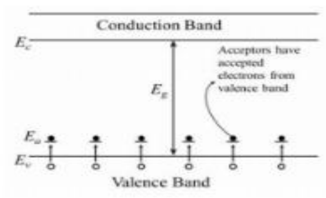


Figure 1: T > 0 K

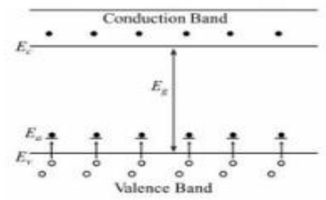


Figure 2: T = 300 K

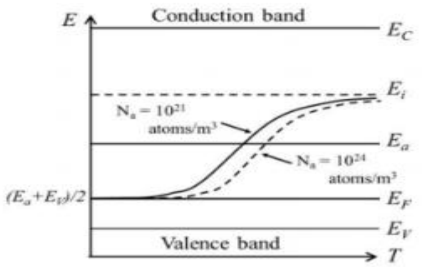


Figure 3: Variation of Fermi level with temperature - p-type semiconductor

8. Where does the Fermi energy level lie in N - type semiconductor. How does it vary with respect to temperature?

$$E_F = \frac{E_C + E_d}{2} - \frac{kT}{2} ln\left(\frac{N_x}{N_d}\right)$$

As the temperature increases, the Fermi level drops towards intrinsic Fermi level, which is also dependent on concentration of N_d atoms. More and more donor atoms are ionized with temperature and at a point all donor atoms are ionized. After this point, the generation of electron-hole pair due to the breaking of covalent bonds takes place and the material tends to behave in the intrinsic manner.

Variation in Fermi level of N-type semiconductor with temperature

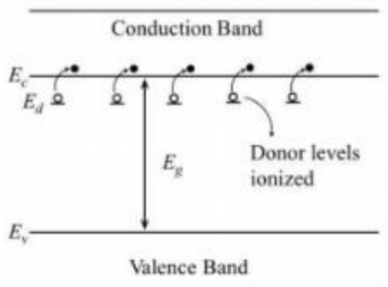


Figure 1: T > 0 K

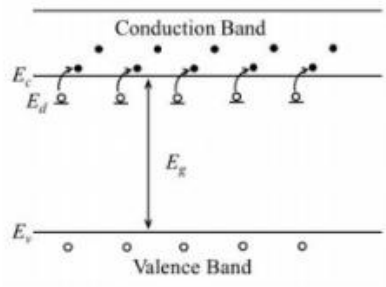
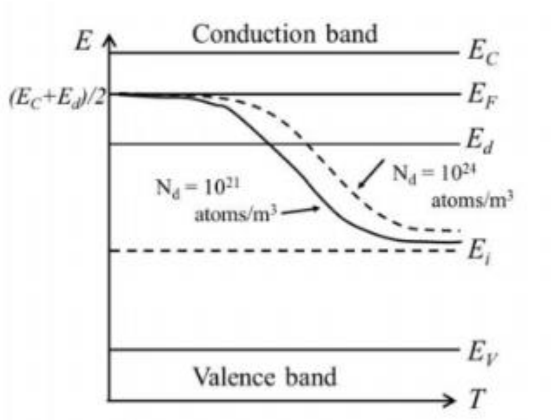


Figure 2: T = 300 K



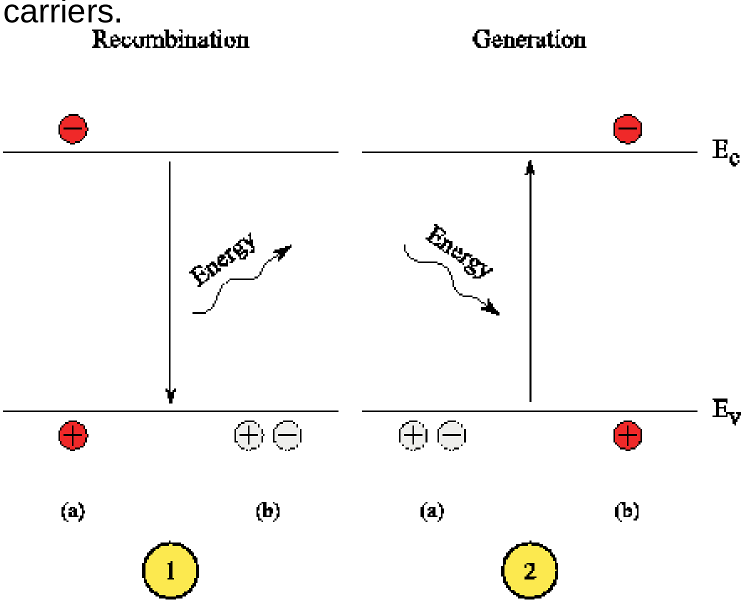
9. Describe the difference between P-type and N-type semiconductor materials?

Differentiate p-type and n-type semiconductors

	n-type semiconductor	p-type semiconductor
1	Pentavalent impurity added to intrinsic semi-conductor. Eg. P, As, Sb	Trivalent impurity added to intrinsic semi-conductor. Eg. B, Ga, In
2	Electrons are majority charge carriers	Holes are majority charge carriers
3	Energy level of donor atoms are very close to the bottom of conduction band	Energy levels of acceptor atoms are very close to the top of valence band
4	Fermi level of n-type is above intrinsic semi-conductor	Fermi level of p-type is below intrinsic semi-conductor

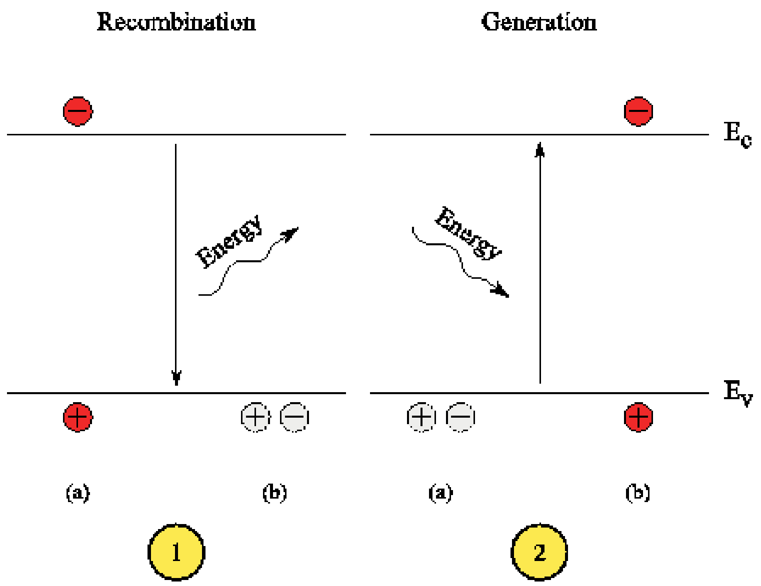
10. Explain about carrier generation

ANS - Carrier generation describes processes by which electrons gain energy and
move from the valence band to the conduction band, producing two mobile carriers.

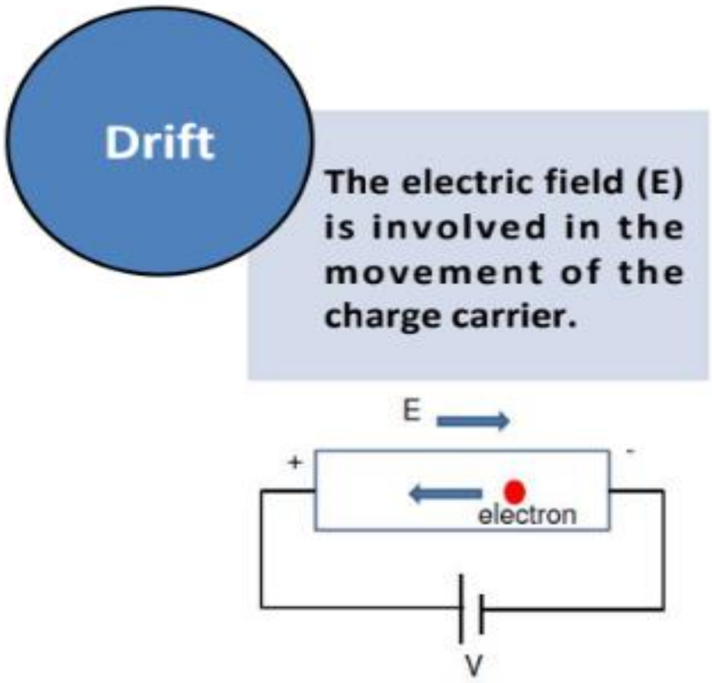


11. Explain about recombination.

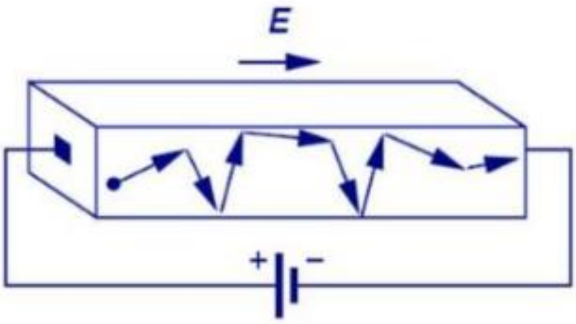
ANS - Recombination describes processes by which a conduction band electron loses energy and re-occupies the energy state of a hole in the valence band.



12. Discuss about drift current.



- The process in which charged particles move because of an electric field is called ***drift***.
- Charged particles within a semiconductor move with an average velocity proportional to the electric field.
  - The proportionality constant is the carrier ***mobility***.

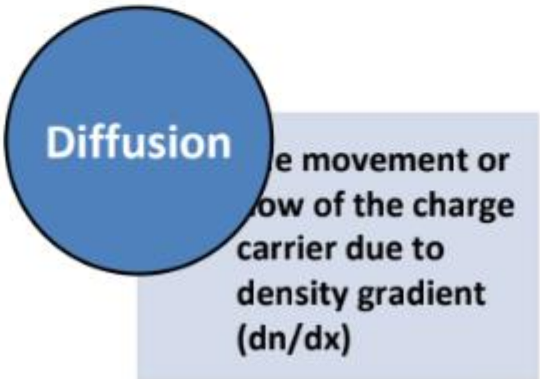


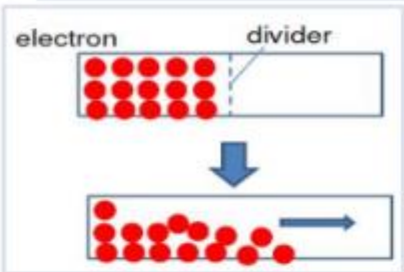
Hole velocity $\vec{v}_h = \mu_p \vec{E}$

Electron velocity $\vec{v}_e = -\mu_n \vec{E}$

Notation:
$\mu_p \equiv$ hole mobility (cm²/V·s)
$\mu_n \equiv$ electron mobility (cm²/V·s)

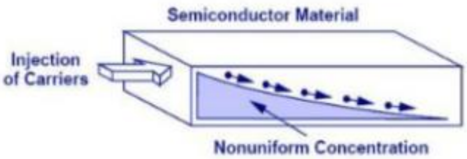
13. Discuss about diffusion current.





Carrier Diffusion

- Due to thermally induced random motion, mobile particles tend to move from a region of high concentration to a region of low concentration.
  - Analogy: ink droplet in water
- Current flow due to mobile charge diffusion is proportional to the carrier concentration gradient.
  - The proportionality constant is the ***diffusion constant***.



$$J_p = -qD_p \frac{dp}{dx}$$

Notation:
$D_p \equiv$ hole diffusion constant (cm^2/s)
$D_n \equiv$ electron diffusion constant (cm^2/s)

The unit of J is mol m-2 s-1. c is the concentration of the gradient with units molecules m-3

14. Explain concepts of p-n junction.

➢p-n junction is one of the basic building blocks of integrated circuits. Such a junction can be formed by selective diffusion or ion implantation of n-type or p-type dopant to the p-type or n-type semiconductor.

➢When p-region and n-region are brought in close contact a p-n junction forms due to the diffusion of charge carriers. While, holes diffuse from p region to n region, electrons diffuse from n region to p region.

➢Under thermal equilibrium a built in electric field directed from positive to negative charge which gives rise to drift current and no net transport of carriers due to diffusion is observed across the potential barrier(also called as depletion region).

➢At thermal equilibrium, drift and diffusion component of current must cancel each other, J_n and J_p is zero. Hence the Fermi level must be constant throughout and the electron and hole concentrations on both sides remain same.

➢While in thermal equilibrium no external voltage is applied between the *n*-type and *p*-type material, there is an internal potential, ϕ_i, which is caused by the work function difference between the *n*-type and *p*-type semiconductors. This potential equals the *built-in* potential.

2

15. Write note on forward bias p-n junction.

p-n junction under forward biasing

When the p-n junction is applied with external voltage both electrons and hole concentrations deviates from their equilibrium values. Also potential difference across depletion region deviates from its equilibrium value V_{bi} by an amount of applied bias.

When the p-n junction is forward biased by V_f ,ie., positive terminal of the battery is connected to the p-region and the negative terminal of the battery is connected to the n-region, the potential difference across the depletion region decreases by $V_{bi} - V_f$ .The width of depletion region decreases. Thus more electrons move from n region to p region and increase the diffusion current.

16. Write note on reverse bias p-n junction.

p-n junction under reverse biasing

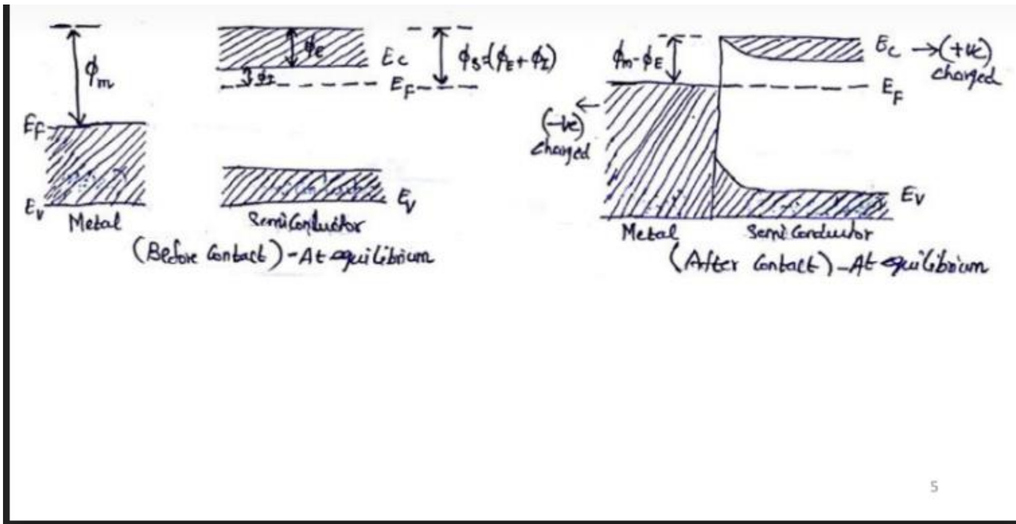
When the p-n junction is reverse biased by V_r ,ie., positive terminal of the battery is connected to the n-region and the negative terminal of the battery is connected to the p-region, the potential difference across the depletion region increases by $V_{bi} + V_r$. The width of depletion region increases. Thus no electrons from n region and no holes from p region diffuse across the junction. Now the current is due to the diffusion of minority charge carriers in the p and n region which is extremely small.

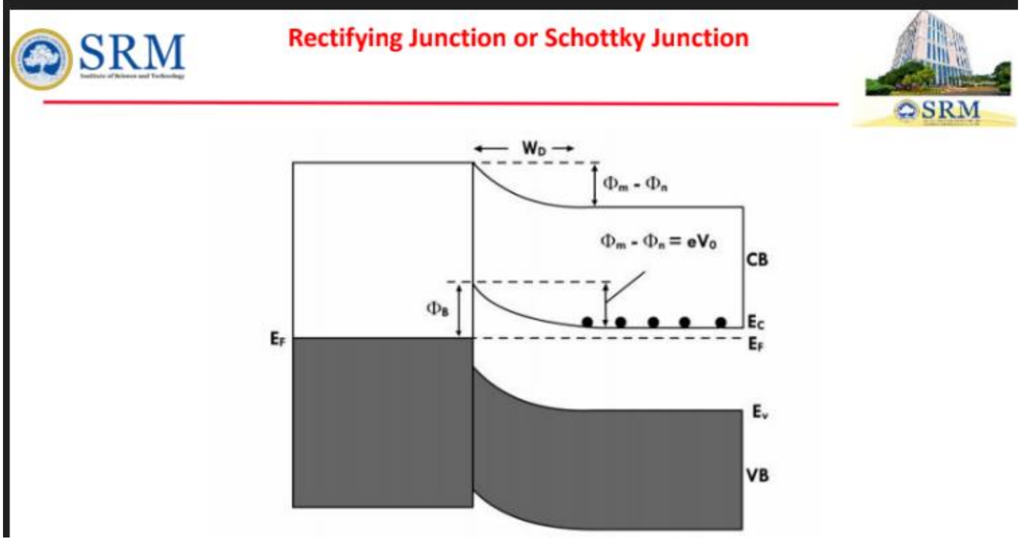
17. What happens to the bands when we make contact between metals and semiconductors?

When metal semiconductor contact is made, the conduction electrons begin to flow from the semiconductor in to the metal until the Fermi energies on both sides of the junction becomes equal. Therefore, metal becomes negative charged and the n-type semiconductor becomes positive charged. As a result potential barrier is formed at the metal semiconductor junction equal to $\phi_m - \phi_S = eV$.

18. What is a rectifying contact? Explain with diagram.

Whenever, the work function of n type semiconductor is smaller than that of metal or the work function of p type semiconductor is greater than that of metal, it forms rectifying or Schottky junction.





19. Write note on photocurrent in p-n junction?

•In a photodiode, the incident optical signal generates electron-hole pairs that gives rise to a photo current across PN junction.

•When a PN junction is illuminated with light of photon energy (E) greater than Eg , photons are absorbed in semiconductor and electron- hole pairs are generated both in n-region and p-region of the junction.

•For the electron-hole pair to contribute towards current in external circuit, the generated electron and holes must be separated before they recombine.

•Once electron-hole pairs are generated in the depletion layer, the electric field in the built-in-potential or contact potential sweeps away the electron and holes in opposite directions.

•The photo generated minority carriers which are generated within one diffusion length from the depletion layer edge, can also diffuse to the depletion region without recombining.

•They are then swept across the junction due to the electric field present in the depletion region. Due to the direction of electric field being from the n-region to p-region, the holes flow towards the p- region and electrons to the n-region. •Since the direction of this photo generated current IL is opposite to that in a forward-biased diode, the total current in the illuminated PN junction diode is PHOTO CURRENT IN PHOTO DIODE

IL= In **+ Ip + Id**

PHOTO CURRENT IN PHOTO DIODE

- The photo generated current in the depletion region is

$$I_1 = Ae\int Gdx = eGWA$$

where W is the depletion width and this current is very fast (prompt photocurrent).

- In addition to the carriers generated in the depletion region, electron-hole pairs are generated in the neutral n-region and p-region of the diode.

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PHOTO CURRENT IN PHOTO DIODE

- We may expect that holes generated within a distance L_p (the diffusion length) of the depletion region edge will be able to enter the depletion region from where the electric field will sweep them into p-side.

$$I_p = eG_L L_p A$$

- Similarly, excess electrons produced in p region will give photo current.

$$I_n = eG_L L_n A$$

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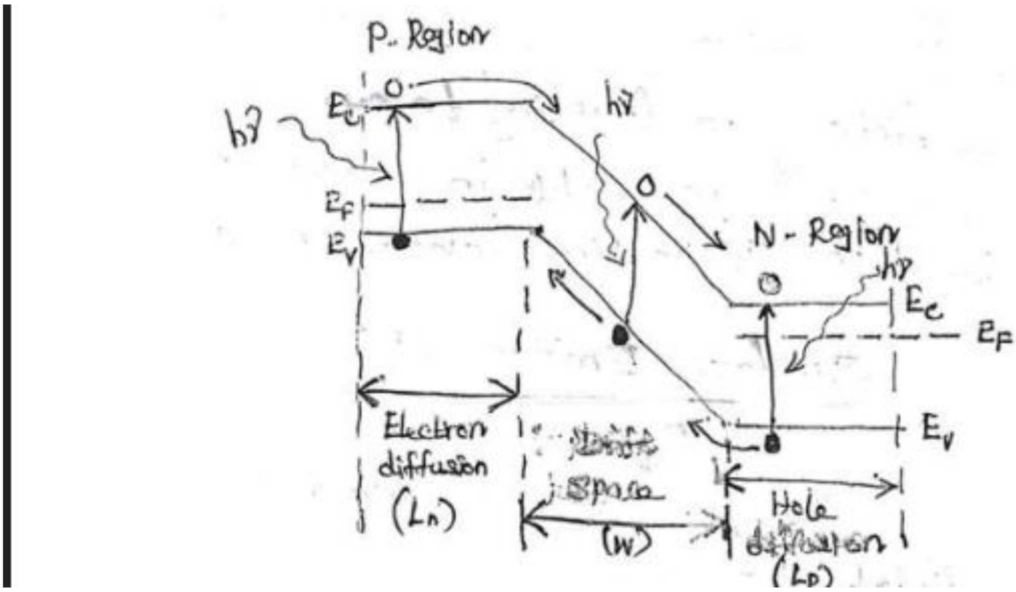
- So total current due to carriers in the neutral region and the depletion region is given by $I_L = eG_L(L_p + L_n + W)A$



20. Write note on Organic LED?

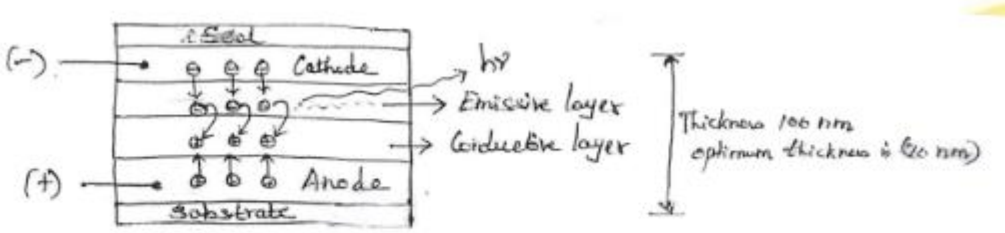
A type of LED where emissive electroluminescent layer is a film of organic compound which emit light in response to an electric current.

Structure of OLED:

A simple OLED is made of six different layers. On the top and bottom layers of protective glass or plastic. The top layer is called seal and the bottom layer is substrate. In between seal and substrate, a negative terminal (cathode) and positive terminal (anode), and finally between cathode and anode there are two layers made of organic molecules called emissive layer which produces light and the conductive layer.

1. Substrate – Clean glass / plastic
2. Anode – Positively charged (Indium Tin Oxide) which ejects holes
3. Organic layer –Emissive and Conductive layers –Polyaniline and Polyfluorene
4. Cathode – Negatively charged which injects electrons

Conjugated polymers are having characteristics of LED and having energy gap (Eg) same like semiconductors by doping with p-type/ n-type materials used for light emission.

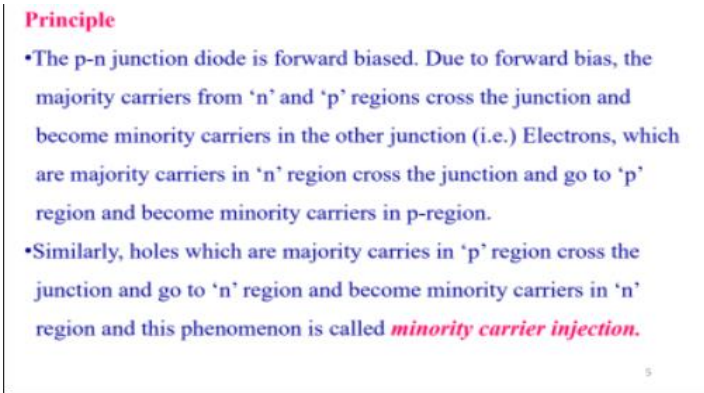


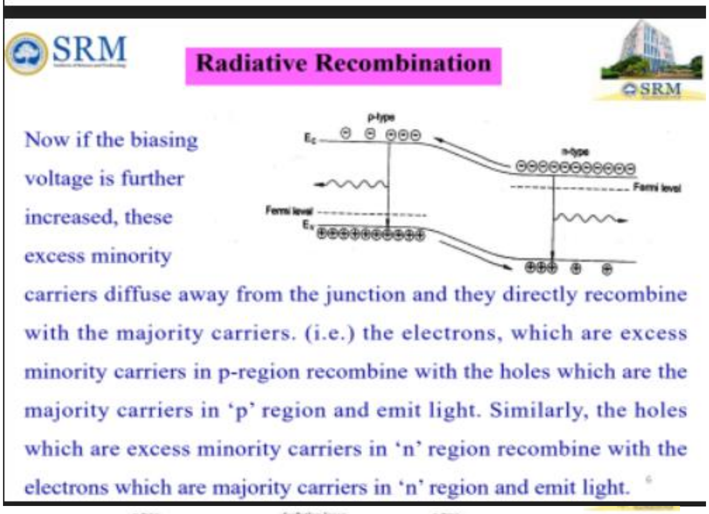
21. Write note on LED?

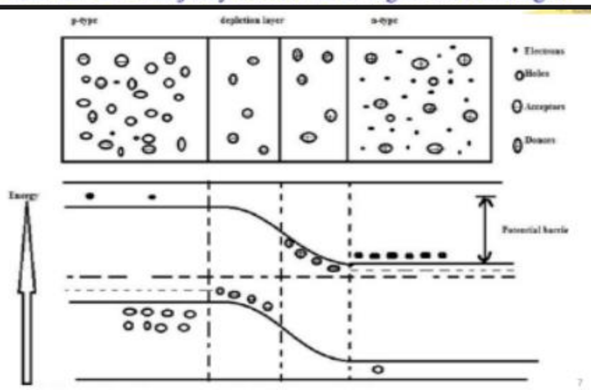
LED are semiconductor p-n junctions that under forward bias conditions can emit radiation by electroluminescence in the UV, visible or infrared regions of the electromagnetic spectrum. The quanta of light energy released is approximately proportional to the band gap of the semiconductor..

•A light emitting diode (LED) is essentially a PN junction opto- semiconductor that emits a monochromatic (single color) light when operated in a forward biased direction.

•LEDs convert electrical energy into light energy. They are frequently used as "pilot" lights in electronic appliances to indicate whether the circuit is closed or not.







22. Write the construction of LED

•LEDs can be designed as either surface or edge emitters. Surface emitting LEDs can be made such that the bottom edge reflects light back towards the top surface to enhance the output intensity. The main advantage of edge emitter LEDs is the emitted radiation is relatively direct. Hence edge emitter LEDs have a higher efficiency in coupling to an optical fibre.

•Although the internal quantum efficiency of LEDs is 100%, the external efficiencies are much lower. The main reason is that most of the emitted light radiation strikes the material interface at greater than critical angle and hence trapped with in the device. The internal critical angle at the semiconductor – air boundary is given by $\sin\theta_c = \frac{n_2}{n_1}$

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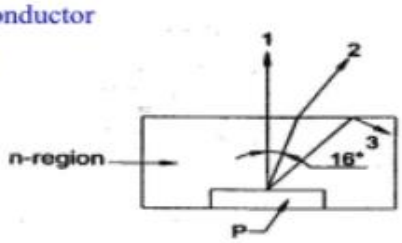
Critical angle

Where n_1- is the refractive index of air = 1.0

n_2 is the refractive index of the semiconductor

For group III semiconductor $n_2 = 3.5$

Therefore $\theta c = 16°$



Therefore all rays of light striking the surface at an angle exceeding 16° suffer total internal reflection and as a result most of the emitted light is reflected back inside the semiconductor crystal.

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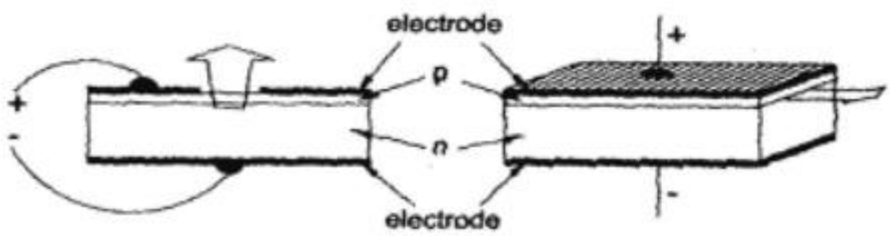
An LED must be constructed such that the light emitted by the radiative recombination events can escape the structure.



(a) Surface emitting LED (b) Edge emitting LED

23. Write the working of LED.

Principle

- The p-n junction diode is forward biased. Due to forward bias, the majority carriers from 'n' and 'p' regions cross the junction and become minority carriers in the other junction (i.e.) Electrons, which are majority carriers in 'n' region cross the junction and go to 'p' region and become minority carriers in p-region.
- Similarly, holes which are majority carries in 'p' region cross the junction and go to 'n' region and become minority carriers in 'n' region and this phenomenon is called ***minority carrier injection.***

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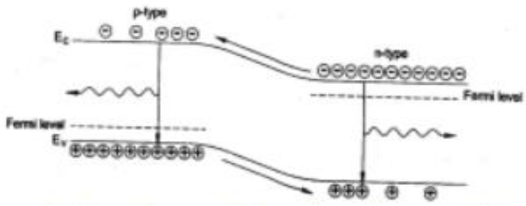
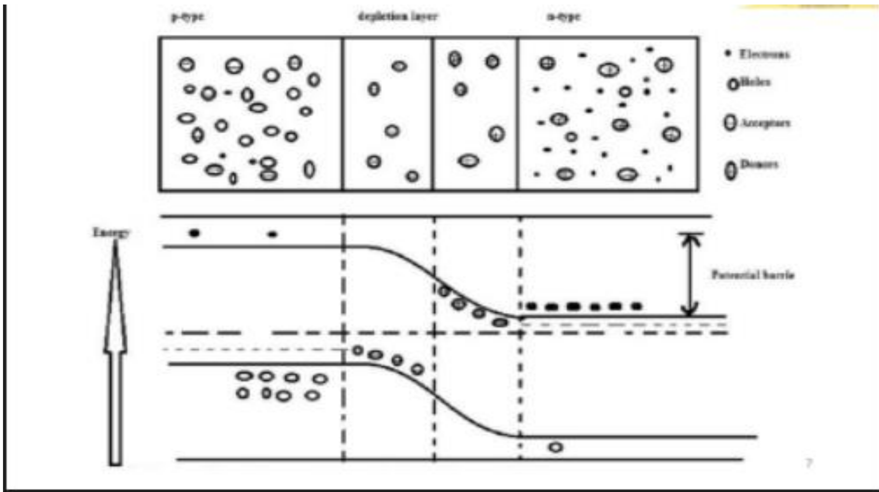
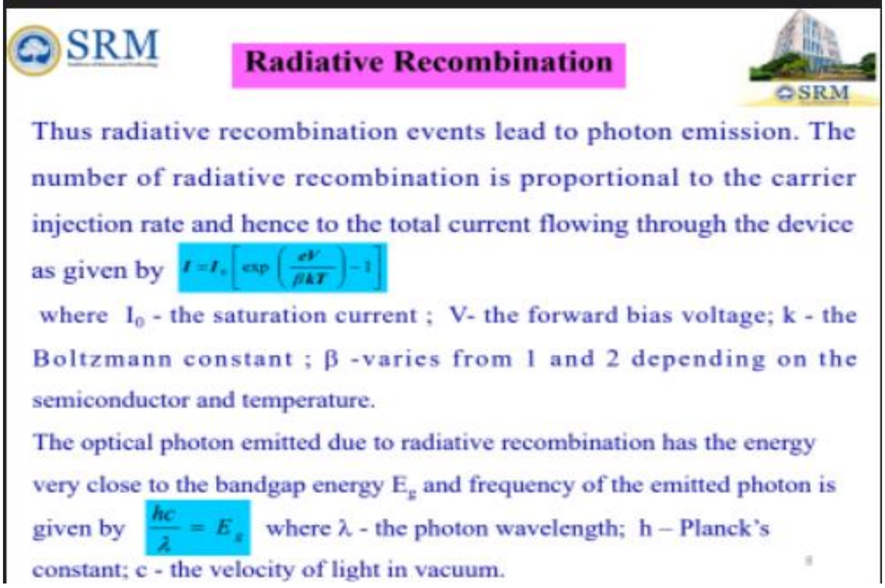
Radiative Recombination

Now if the biasing voltage is further increased, these excess minority



carriers diffuse away from the junction and they directly recombine with the majority carriers. (i.e.) the electrons, which are excess minority carriers in p-region recombine with the holes which are the majority carriers in 'p' region and emit light. Similarly, the holes which are excess minority carriers in 'n' region recombine with the electrons which are majority carriers in 'n' region and emit light.





24. Write the merits of LED.

Long help life: it is probably the best advantage of LED lights. LEDs utilized in this sort of lighting have high work productivity.

Productivity: LEDs are right now the most energy-effective wellspring of considerably less energy utilization (power) than radiant, fluorescent, metal halide or mercury lights, inside the iridescent effectiveness of 80-90% for customary lighting

Protection from effect and temperature: Rather than conventional lighting, LED lighting advantage is that it doesn't contain any fibres or glass components, which are extremely delicate to blows and knocks.

Colour: In LED innovation, we can get every brightening light tone.

25. Write the demerits of LED.

Cost: LED lighting is a more costly venture than a conventional light source.

Temperature responsiveness: The quality of diodes' lighting is profoundly reliant upon the encompassing working temperature.

Light quality: Most cool-white LEDs have spectra that contrast fundamentally from a dark body radiator like the sun or a glowing light.

26. Write the applications of LED.

Common Application

- Display lighting - compact displays are possible with low operating temperatures
- Display case, museum and shop lighting - illumination of sensitive objects at close range with ultraviolet (UV) and infrared(IR) free light
- Underwater lighting - low voltage supply for safety and low maintenance
- Outside lighting - coloured effects to enhance outdoor spaces
- Sign lighting - strips of LED's can be used to light signage in many different colours
- Low level lighting - LED luminaires are cool to touch and are therefore suitable for us in domestic situations where children may come into contact with them
- Architectural detail lighting.
- LED's can be used in applications which traditionally used neon or cold cathode.

27. Define and write the principle of LED.

Principle

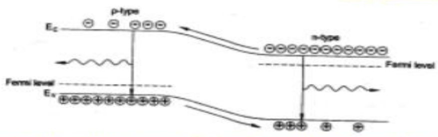
- The p-n junction diode is forward biased. Due to forward bias, the majority carriers from 'n' and 'p' regions cross the junction and become minority carriers in the other junction (i.e.) Electrons, which are majority carriers in 'n' region cross the junction and go to 'p' region and become minority carriers in p-region.
- Similarly, holes which are majority carries in 'p' region cross the junction and go to 'n' region and become minority carriers in 'n' region and this phenomenon is called ***minority carrier injection.***

SRM

Radiative Recombination

SRM

Now if the biasing voltage is further increased, these excess minority



carriers diffuse away from the junction and they directly recombine with the majority carriers. (i.e.) the electrons, which are excess minority carriers in p-region recombine with the holes which are the majority carriers in 'p' region and emit light. Similarly, the holes which are excess minority carriers in 'n' region recombine with the electrons which are majority carriers in 'n' region and emit light.

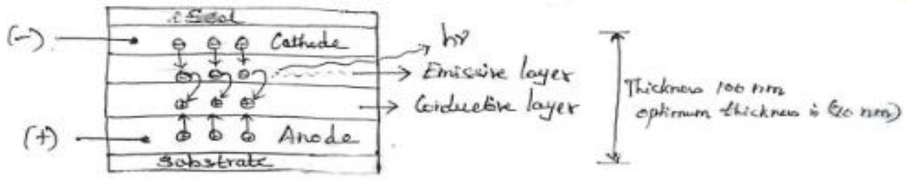
28. Write the construction of OLED.

Structure of OLED:

A simple OLED is made of six different layers. On the top and bottom layers of protective glass or plastic. The top layer is called seal and the bottom layer is substrate. In between seal and substrate, a negative terminal (cathode) and positive terminal (anode), and finally between cathode and anode there are two layers made of organic molecules called emissive layer which produces light and the conductive layer.

SRM

ORGANIC LIGHT EMITTING DIODE (OLED)



1. Substrate – Clean glass / plastic
2. Anode – Positively charged (Indium Tin Oxide) which ejects holes
3. Organic layer –Emissive and Conductive layers –Polyaniline and Polyfluorene
4. Cathode – Negatively charged which injects electrons

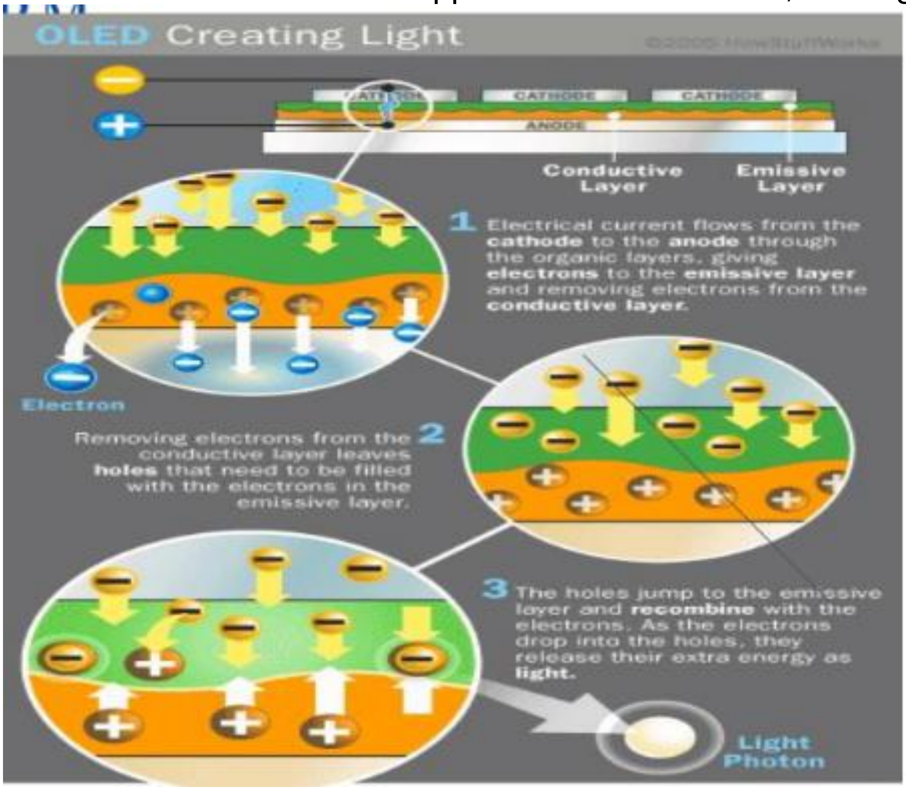
Conjugated polymers are having characteristics of LED and having energy gap (Eg) same like semiconductors by doping with p-type/ n-type materials used for light emission

29. Write the working of OLED.

OLEDs emit light in a similar manner to LEDs, through a process called electro luminescence. The process is as follows:

1. The battery or power supply of the device containing the OLED applies a voltage across the OLED.
2. An electrical current flows from the cathode to the anode through the organic layers (an electrical current is a flow of electrons). The cathode gives electrons to the emissive layer of organic molecules. The anode removes electrons from the conductive layer of organic molecules. (This is the equivalent to giving electron holes to the conductive layer.)
3. At the boundary between the emissive and the conductive layers, electrons find electron holes. When an electron finds an electron hole, the electron fills the hole (it falls into an energy level of the atom that's missing an electron). When this happens, the electron gives up energy in the form of a photon of light.
4. The OLED emits light.

5. The color of the light depends on the type of organic molecule in the emissive layer. Manufacturers place several types of organic films on the same OLED to make color displays. 6. The intensity or brightness of the light depends on the amount of electrical current applied: the more current, the brighter the light.



30. Write the merits of OLED.

The LCD is currently the display of choice in small devices and is also popular in large-screen TVs. Regular LEDs often form the digits on digital clocks and other electronic devices. OLEDs offer many advantages over both LCDs and LEDs:

1. The plastic, organic layers of an OLED are thinner, lighter and more flexible than the crystalline layers in an LED or LCD.
2. OLEDs are brighter than LEDs. Because the organic layers of an OLED are much thinner than the corresponding inorganic crystal layers of an LED, the conductive and emissive layers of an OLED can be multi-layered. Also, LEDs and LCDs require glass for support, and glass absorbs some light. OLEDs do not require glass.

SRM

OLED ADVANTAGES

3. OLEDs do not require backlighting like LCDs and hence they consume much less power than LCDs. This is especially important for battery-operated devices such as cell phones.
4. OLEDs are easier to produce and can be made to larger sizes. Because OLEDs are essentially plastics, they can be made into large, thin sheets.
5. OLEDs have large fields of view, about 70 degrees. OLEDs produce their own light, so they have a much wider viewing range.

31. Write the demerits of OLED.

OLED seems to be the perfect technology for all types of displays, but it also has some problems:

1. Lifetime - While red and green OLED films have longer lifetimes (46,000 to 230,000 hours), blue organics currently have much shorter lifetimes.
2. Manufacturing - Manufacturing processes are expensive right now.
3. Water - Water can easily damage OLEDs

32.Write the applications of OLED.

1. OLEDs are used in small-screen devices such as cell phones, PDAs and digital cameras.
2. Because OLEDs refresh faster than LCDs -- almost 1,000 times faster -- a device with an OLED display could change information almost in real time.
3. Several companies have already built prototype computer monitors and large-screen TVs that use OLED technology.

FOR MOTIVATION : https://www.reddit.com/r/bakchodi/comments/sk8she/i_uhmmmm_i_can_relate/?utm_source=share&utm_medium=web2x&context=3

CT2 pattern: Total marks: 50
10 MCQs; 10 x 1=10 marks
6 Descriptive type questions (have to write 4 out of 6); 4 x 10 =40 marks

4 QUES HAVE A LOT OF PROBABILITY TO ALREADY BE IN THIS PDF :)

ALL IMPORTANT FORMULAS WITH QUESTION:

Fermi level of Intrinsic semiconductor calculation:-

$$E_F = \frac{3kT}{4}\log_e\left(\frac{m_h^*}{m_e^*}\right) + \left(\frac{E_v + E_c}{2}\right)$$

$$E_F = \left(\frac{E_v + E_c}{2}\right)$$

4. For silicon semiconductor with band gap 1.12 eV, determine the position of the Fermi level at 300 K if $m_e^* = 0.12\ m_0$ and $m_h^* = 0.28\ m_0$.

Solution

$$E_F = \frac{E_g}{2} + \frac{3kT}{4}\left(\ln\frac{m_h^*}{m_e^*}\right)$$

$$= \frac{1.12}{2} + \frac{3 \times 1.38 \times 10^{-23} \times 300}{4 \times 1.6 \times 10^{-19}}\left(\ln\frac{0.28\ m_0}{0.12\ m_0}\right)$$

(in second term Joules is converted into eV)

$$= 0.56 + \frac{3}{4} \times 0.0258 \times \ln 2.333$$

$$= 0.56 + 0.01935 \times 0.8473$$

$$= 0.56 + .016$$

$$= 0.576\,\text{eV}$$ from the top of the valence band. (Answer)

N,P calculation:

$$n = N_C e^{-(E_C - E_F)/kT}$$

$$p = N_V e^{-(E_F - E_V)/kT}$$

Mobility Calculation :

$$\sigma = n\mu_n e + p\mu_p e$$

For an intrinsic semiconductor $n = p = n_i$

$\sigma_i = n_i e(\mu_n + \mu_p)$

1. Calculate the conductivity of intrinsic germanium at 300K using the following data:

$n_i = 2.4\times10^{19}\ \mathrm{m}^{-3}$; $\mu_e = 0.39\ \mathrm{m}^2 V^{-1}s^{-1}$; $\mu_h = 0.19\ \mathrm{m}^2 V^{-1}s^{-1}$

Solution:

$$\sigma_i = n_i e(\mu_e + \mu_h) = 2.4\times10^{19}\times1.6\times10^{-19}(0.39+0.19)$$

$= 2.2272$ (ohm metre)$^{-1}$

Number of states per unit volume having energies between E1 and E2 is given by:

$$D(E) = \frac{4\pi}{h^3}(2m)^{3/2}\int_{E_1}^{E_2} E^{1/2}\,dE$$

3. Calculate the number of states lying in an energy interval of 0.02eV above the Fermi energy for sodium crystal of unit volume (E_F = 3.22eV for sodium).

Solution

$$\begin{cases} E_F = E_1 = 3.22\,\mathrm{eV} = 5.152\times10^{-19}\,\mathrm{J} \\ E_2 = E_1 + 0.02 = 3.24\,\mathrm{eV} = 5.184\times10^{-19}\,\mathrm{J} \end{cases}$$

The number of energy states in unit volume having energies lying between $E_1(= 3.22\,\mathrm{eV})$ and $E_2(= 3.24\,\mathrm{eV})$ is given by

$$\int_{E_1}^{E_2}\left[\frac{4\pi}{h^3}(2m)^{3/2}E^{1/4}\right]dE = \frac{4\pi}{h^3}(2m)^{3/2}\int_{E_1}^{E_2}E^{1/2}\,dE$$

$$= \frac{4\pi}{h^3}(2m)^{3/2}\left[\frac{2}{3}E^{3/2}\right]_{E_1}^{E_2} = \frac{4\pi}{h^3}(2m)^{3/2}\frac{2}{3}(E_2^{3/2} - E_1^{3/2})$$

$$= \frac{4\pi}{(6.62\times10^{-34})^3}(2\times9.14\times10^{-31})^{3/2}\frac{2}{3}(5.184^{3/2} - 5.152^{3/2})(10^{-19})^{3/2}$$

$= 2.45\times10^{26}$ (Answer)

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