Summer of Science-Final Report

# Materials Related to Electronics and Photonics .

**(Core Subject – Chemistry)**


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# PHASE 1

## 1 ]INORGANIC MATERIALS:

### 1.1 Zone refining process of purification of germanium with integrated analysis.

Hyper pure Germanium is important for nuclear spectroscopy. This Hyper pure Germanium is obtained from the zone refining purification process. In this paper, there is a detailed discussion of computational analysis in the Zone refining process. This computational analysis is based on the velocity of heater, size and shape of heater and ingot, the quantity of impurity. In this topic, the heater is basically made up of reflectors on both sides and heat in the form of light radiation is coming from those lamps through reflectors. It is a powerful technique.

### 1.2 Writing a computer program for calculation of the zone refining process.

Calculations of the zone refining process is in the form of computer code.It is mainly based on K(equilibrium distribution coefficient of an impurity), Cs ,Co (both are impurity concentration in solid and liquid state resp.),no. of passes etc.

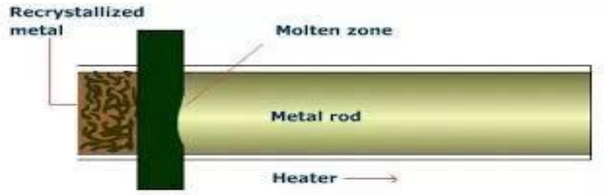


Fig 1 : Zone Refining Process

### 1.3 Germanium buffer layer on silicon. (factors affecting it.)

Silicon is important in lasers and photonic integrated circuits which are low cost, low power and have high bandwidth. Ge buffer layer is preferred over GeAs layer on silicon due to its thinness and lower dislocation densities in crystals. This process is done by annealing (heating at high temperature and cooling it slowly). There are different factors affecting it such that,

i]annealing effect: mainly based on temperature
ii]effect of thickness: As thickness increases thread dislocation density decreases so we have to keep the thickness at a moderate level.
iii]Effect of doping: Doping affects the dislocation density and roughness (measured in RMS). for e.g. in case of Sb roughness is lesser than boron-doped silicon.

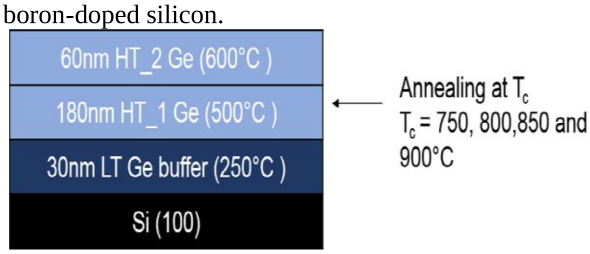


Fig.2 : Annealing Tempretures

### 1.4 Growth of heavily doped Germanium single crystals for mid-infrared applications.

Heavily-doped germanium (Ge) represents a futuristic material which displays plasma frequencies in the mid-infrared (IR) range. This doping is done by PH3 and B2H6 as a dopant (n-type and p-type resp.) A high doping concentration of the order of 10^18 cm^3 could be obtained while retaining high crystalline quality.

## 2]ORGANIC MATERIALS

### 2.1 PCBM - Uses of PCBM, organic solar cells, PCBM based n-type semiconductors.

- [6,6] phenyl C-61 butyric acid methyl ester. It is mainly used in organic solar cells. It is an electron acceptor. It is a more environmentally friendly and low-cost solar cell than a normal silicon solar cell. but it has low efficiency and strength .

Some important terms

**Organic solar cells** –

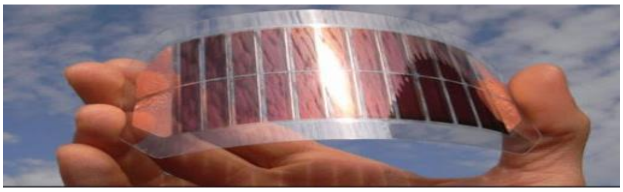

Fig.3: Organic solar cell Model

1**] Perovskite:** A perovskite is any material with the same type of crystal structure as calcium titanium dioxide($CaTiO_3$). (It has mainly 8 atoms on corners.6 atoms at phase centres and 1 atom is at bodycentre)

**2]PEDOT: PSS**-(poly(3,4-ethylene dioxythiophene) polystyrene sulfonate ).It is an organic thermoelectric material which can convert heat in electricity. Also, it is a very good antistatic agent to prevent electric discharges

Along with PCMB, in solar cells, *methylamine lead halide* ($CH_3NH_3PbX_3$) is also used in organic solar cells.

For depositing a homogeneous layer on substrate various methods are used.

1] Spin coating method

2]Dual thermal evaporation method (spin coating is better than this)

3]Vapour assassination method (a mixture of spin coating and dip coating methods)

**Theory:**In this paper, I learnt about the above terms and fabrication of organic solar cells. There are 6 layers in this solar cell. First in IOT layer, second is Pedot-Pss layer, third is perovskite, fourth is PCBM, a fifth is a calcium, and the 6th is an aluminium layer. Through electron microscopy and X-ray diffraction technique, we can detect total morphology of Organic solar cells.

### 2.2 Synthesis of triphenylenes:

This is a facile method for synthesis of substituted triphenylene and their heteroaryl analogues using ceric ammonium nitrate (CAN) via an oxidative biaryl coupling. Many Aromatic hydrocarbons, triphenylene has extremely great importance in organic electronics .The CAN oxidized Scholl reaction of various o-ter-phenyls with tolerance for a broad range of functional groups and the heteroaromatic system gave good to excellent yields.

Scholl Reaction: It is a coupling reaction between two arene compounds with the aid of lewis acid and a protic acid.

In this paper there are many more reactions similar to Scholl reaction.

## 3]NANOSTRUCTURED MATERIALS:

### 3.1 Nanostructured materials – Definition.

Nanostructured materials are the materials whose size is in the range of micrometre to nanometre. It includes nanotextured surfaces whose one dimension is only in nanoscale, Nanotubes whose two dimensions are in nanoscale and nanoparticles whose three dimensions are in nanoscale.

I will describe every nanomaterial in brief-

### 3.2 Types of nanostructured materials- definition, applications.

**1]Nanotextured surfaces:** A nanotextured surface (NTS) is a surface which is covered with nano-sized structures. Such surfaces have one dimension on the nanoscale, i.e., only the thickness of the surface of an object is between 0.1 and 100 nm. They are currently gaining popularity because of their special applications due to their unique physical properties

Fig 4 : Nanotextured Surfaces

**2]Nanotubes**: Two dimensions are in nanoscale. Like diameter in nanoscale. Length can be any.

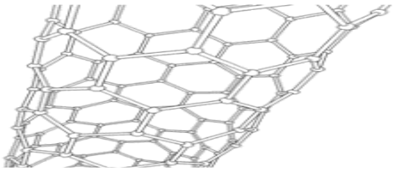

Fig.5 :Nanotubes

(CNTs) are tubes made of carbon with diameters typically measured in nanometres.

**3]Spherical nanoparticles:** All three dimensions are in nanoscale. The radius of a sphere in nanometres. Ultrafine particles (UFPs) are a particulate matter of nanoscale size (less than 0.1 micrometres or 100 nm in diameter).

**4]Gradient multilayer nanofilm**: Gradient multilayer (GML) nanofilm is an assembly of Quantum dots layer

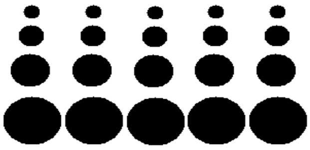

Fig.6 : Quantum Dots

with a built-in gradient of nanoparticle size, composition or density. Properties of such nanostructures are finding its applications in the design of solar cells and energy storage devices.

**5]Icosahedral Structures:** An icosahedral is a nanostructure appearing for atomic clusters. These clusters are twenty-faced, made of ten interlinked dual-tetrahedron (bowtie) crystals, typic

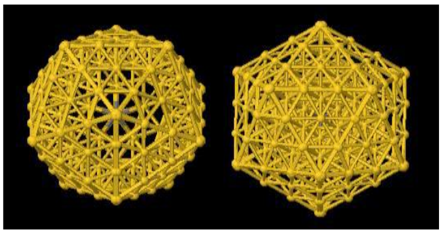

Fig 7 : Icosahedral Structures

having three-fold symmetry. It is like the self-assembly of material at the nanoscale.

## 3.3Research Papers

**1] Nanostructure material, basic concepts and microstructure**

Categories of nanostructured materials

1]The *first category* comprises materials and/or devices with reduced dimensions and/or dimensionality in the form of (isolated, substrate-supported or embedded)

2]The *second category* comprises materials and/or devices in which the nanometre-sized microstructure is limited to a thin (nanometre-sized) surface region of bulk material.

*3]The third category* of bulk solids with a nanometre-scale microstructure. In fact, we shall focus on bulk solids in which the chemical composition, the atomic arrangement and/or the size of the building blocks.

Two classes of such solids may be distinguished.

1] In the first class, the atomic structure and/or the chemical composition *varies in space continuously* throughout the solid on an atomic scale.

2]. These materials are assembled of nanometre-sized building blocks—mostly crystallites Effects controlling the properties of nanostructured materials

a]Size effects

b] Change of the dimensionality of the system

c]Changes in the atomic structure

d]Alloying of components (e.g. elements) that are immiscible in the solid and/or the molten state

**2]Microwave-assisted synthesis of C-doped TiO2 and ZnO hybrid nanostructured materials as quantum-dots sensitized solar cells**

1]Microwave-assisted solvothermal synthesis of C-doped TiO2 and ZnO hybrid materials.

2]C-doped TiO2 and ZnO showed a red-shift in the bandgap and electrochemical response to UV light irradiation.

3]Eco-friendly synthesis of nanostructured materials as photoelectrodes for quantum-dots sensitized solar cells.

# 4]IONIC CRYSTALS

## 4.1 'Williams' book- write up on photonics and electronics related to semiconductors and ionic materials.

This write- up is all about how electronics and Photonics properties are seen in ionic crystals and semiconductors. There are two theories to explain this task. But later Mott (Scientist name) suggested that both theories are true and applied wherever its conditions hold true.
1]Band Theory
2] Hitler and London Theory.

**1]Band theory:** The band theory was originally investigated by Bloch, Brillouin and Wilson. It is essentially a molecular orbital method applied to the periodic lattice. The approximate one-electron wave functions involve the product of a periodic function and atomic wave functions
**2]Hitlor and London theory**: The Heider-London method is, of course, the familiar atomic orbital method and is applicable to systems in which the electrons are localized (on particular atoms. The approximate crystal wave functions are formed anti symmetrical linear combinations of permutations of products of atomic wave functions) Mr. Mott suggested that Hitler and London theory is a good approximation for that crystal where electron and holes don't form easily that is substances having Frankl defect (like ZnS) and band theory is a good approximation for substances where Schottky defect is present (like NaCl).

**IONIC CRYSTALS**: In Ionic crystals, Lattice energy is defined by dipole and Quadrupole term with approximation and using electron wave Functions.
Solid-state luminescence. -The alkali halide phosphors have been extensively investigated to determine the mechanism of solid-state luminescence. In ionic crystals, luminescence is generally by the presence of impurity (like $Tl+$ ion present in KCl ion at some places of $K+$). Johnson & Williams have formulated a general theory of the dependence of luminescent efficiency on activator concentration, based on the idea that activator ions are capable of efficient emission only if isolated from other activator ions. The presence of nearby activator ions reduces the activation energy for radiation less de-excitation, probably by overlap of wave functions; therefore, the efficiency-concentration interrelation is markedly temperature dependent

**SEMICONDUCTORS:** In semiconductors Band theory is very useful. It is assumed that at absolute zero temp there are no any electronics in conduction band. As temp. increases electron hole pairs increases but not significantly hence the concept of Doping is arrived and with this extrinsic semiconductor, the word 'electronics' takes a new path and now become of 'Heart' of every electronic material.
Germanium and silicon have been investigated as intrinsic and as N and P-type semiconductors. Both substances have the diamond structure with each atom making Sp3 tetrahedral covalent bonds with the four nearest neighbours. Thermal excitation of an intrinsic semiconductor to produce an electron in the conduction band and a positive hole in the valence band corresponds, as emphasized by Shockley (51), to removing an electron from a covalent bond.

# 5]ALLOYS

## 5.1 Basics of alloys-properties, uses etc.

1] An alloy is a combination of metals or metals combined with one or more other elements. For example, combining the metallic elements gold and copper produces red gold, gold and silver becomes white gold, and silver combined with copper produces sterling silver. Elemental iron, combined with non-metallic carbon or silicon, produces alloys called steel or silicon steel. The resulting mixture forms a substance with properties that often differ from those of the pure metals, such as increased strength or hardness.
Some important alloys-
Pewter, Stainless Steel, Solder, Brass, Duralium etc.

Fig 8 : Duralium

2] Some important terms:

**1] IR emitting diodes**: An IR LED (infrared light-emitting diode) is a solid-state lighting (SSL) device that emits light in the infrared range of the electromagnetic radiation spectrum.IR LEDs allow for cheap, efficient production of infrared light, which is electromagnetic radiation in the 700 nm to 1mm range

Fig 9 : IR emitting Diode

**2]Laser Diodes**: A laser diode, (LD), an injection laser diode (ILD), or diode laser is a semiconductor device similar to a light-emitting diode in which a diode-pumped directly with electrical current can create lasing conditions at the diode's junction. Ultraviolet Wavelength of laser diodes is between 180nm to 400 nm.

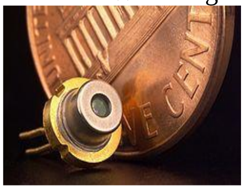

Fig 10: Lasor Diode

**3]Integrated Circuits (IC's):** An integrated circuit or monolithic integrated circuit (also referred to as an IC, a chip, or a microchip) is a set of electronic circuits on one small flat piece (or "chip") of semiconductor material that is normally silicon.

Fig 11 : IC Chips

### 5.2 Gallium Arsenide compound:

In the Gallium arsenide (GaAs) Wafer, each gallium atom is bordered by arsenic atoms. 5 valence electrons of arsenic atoms and 3 valence electrons of gallium atoms share each other. So, each of the gallium and arsenic atom gets 8 valence electrons in the outer shell. The main use of gallium arsenide (GaAs) is found in: Computers, Photovoltaic cells, Optoelectronic communications, Aerospace and defence, Integrated Circuits, High-Frequency Technology (because it cannot melt up to 450-degree Celsius temp.), Transistors .

**Advantages** of Gallium arsenide over silicon chips:

The advantage of gallium arsenide wafers over solar-grade silicon wafers is that it offers almost twice the efficiency. Another advantage of GaAs wafer refers to the increase in efficiency. In solar cells, we can give more than one layer of GaAs so surface area is increased and it acquires efficiency more than silicon solar cells.

**Disadvantages** of Gallium arsenide:

The big disadvantage, which explains its low utilization, is the price. To solve this dilemma, engineers and researchers say they have achieved new methods of manufacturing thin films of low-cost gallium arsenide, which would create devices that replace silicon and are as much as efficient like GaAs.

### 5.3 Silicon-Germanium Alloy

Siege or silicon-germanium is an alloy with any molar ratio of silicon and germanium, i.e. with a molecular formula of the form $Si_{1-x}Ge_x$. It is commonly used as a semiconductor material in integrated circuits (ICs) for heterojunction bipolar transistors or as a strain-inducing layer for CMOS transistors.

SiGe allows CMOS logic to be integrated with heterojunction bipolar transistors, making it suitable for mixed-signal circuits.[7] Heterojunction bipolar transistors have higher forward gain and lower reverse gain than traditional homojunction bipolar transistors. This translates into better low current and high frequency performance

## 6]2D STRUCTURES

### 6.1 Definition of 2D structures with some examples and their properties.

Two-dimensional (2D) materials, sometimes referred to as single-layer materials, are crystalline materials consisting of a single layer of atoms. These materials have found use in applications such as photovoltaics, semiconductors, electrodes and water purification.
Some definitions and terms:

**1]Graphene**: First 2D structure which is a single layer of Graphite isolated in 2004.Graphene is a crystalline allotrope of carbon in the form of a nearly transparent (to visible light) one atom thick sheet. It is hundreds of times stronger than most steels by weight
Uses: Graphene has a lot of other promising applications: anti-corrosion coatings and paints, efficient and precise sensors, faster and efficient electronics, flexible displays, efficient solar panels, faster DNA sequencing, drug delivery.
**2]Maxine**: In materials science, MXenes are a class of two-dimensional inorganic compounds. These materials consist of few-atoms-thick layers of transition metal carbides, nitrides, or carbonitrides.
Uses: It has supper biological properties, water purification properties. It is mainly used in lithium-ion batteries and sodium-ion batteries, Supercapacitors, Optoelectronic devices, Antennas, Porous Mxenes etc.
**3]Silicene:**
Silicene is a two-dimensional allotrope of silicon, with a hexagonal honeycomb structure similar to that of graphene. Contrary to graphene, silicene is not flat, but has a periodically buckled topology; the coupling between layers in silicene is much stronger than in multi-layered graphene
**4]Graphyne:**
another 2-dimensional carbon allotrope whose structure is similar to graphene. It can be seen as a lattice of benzene rings connected by acetylene bonds. Depending on the content of the acetylene groups, graphyne can be considered a mixed hybridization, $sp^n$, where $1 < n < 2$. Recently it has been claimed to be a competitor for graphene, due to the potential of direction-dependent Dirac cones.

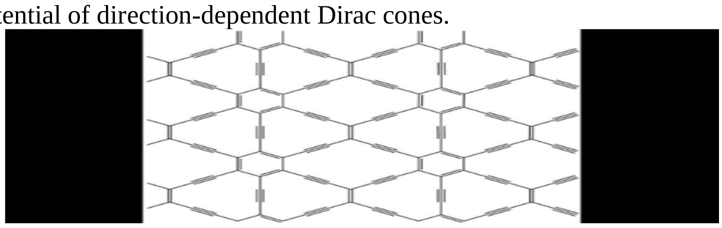

Fig 12: Graphyne

**5]Borophene**: Borophene is a crystalline atomic monolayer of boron and also known as boron sheet.
Uses - The alkali metal ion batteries, Li-S batteries, hydrogen storage, supercapacitor, sensor and catalytic in hydrogen evolution, oxygen reduction, oxygen evolution, and CO2 electroreduction reaction.

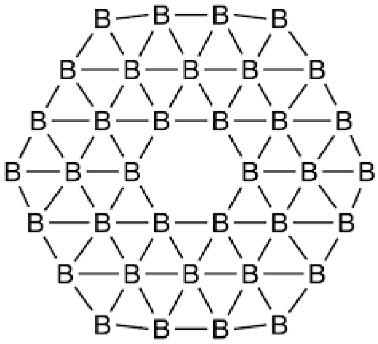

Fig.13:Borophene

Uses: solar cell material donor material(optoelectronics),transistor, inverter, flexible circuits.

### 6.2 2D semiconductors:

i]Graphene
ii]Hexagonal Boron Nitride
iii]Transition metal Dichalcogenides( like MoS2 )
Applications:
**i] Electronic Devices**: 2D Semiconductors can be used as transistors for digital electronics.
**ii] Energy and Harvesting Devices**: 2D semiconductors have the potential for application in the harvesting of solar energy. The atomically thin structure allows for lower surface recombination velocity, which leads to better photocurrent conduction. An improvement in solar cell performance has been shown while stacking 2D semiconductors with multilayers of graphene.

**iii] Flexible and Transparent Substrates**: The thin layer of 2D materials can be used for flexible electronics. In particular, 2D MoS2 can be used to create thin displays and wearable electronics due to its out of plane flexibility, strong covalent bonds, and diverse electronic properties.
**iv]Magnetic NEMS**: 2D layered magnetic materials are attractive building blocks for nanoelectromechanical systems (NEMS): while they share high stiffness and strength and low mass with other 2D materials, they are magnetically active.

### 6.3 Research paper:

**2D organic semiconductors, the future of green nanotechnology.**
Some important terms:
Ballistic transportation: In mesoscopic physics, ballistic conduction (ballistic transport) is the transport of charge carriers (usually electrons) in a medium, having negligible electrical resistivity caused by scattering. Without scattering, electrons simply obey Newton's second law of motion at non-relativistic speeds.
Coffee ring effect: In physics, a "coffee ring" is a pattern left by a puddle of particle-laden liquid after it evaporates. The phenomenon is named for the characteristic ring-like deposit along the perimeter of a spill of coffee. It is also commonly seen after spilling red wine. The mechanism behind the formation of these and similar rings is known as the coffee ring effect or in some instances, the coffee stain effect, or simply ring stain.
Introduction:
This paper mainly focuses on organic 2D crystals and their electronic, optical, mechatronics properties etc and also different synthesis methods for this material.
Also, organic 2D crystals have great advantages on inorganic 2D materials because it is economic and ecological benefits. The properties like depending on no.of layers, how they are arranged so we can vary properties according to our need. There are two types of organic 2D materials 1]Small molecules like pentacene , rubrene and 2] large polymers.
Different synthesis methods of organic 2D crystals:

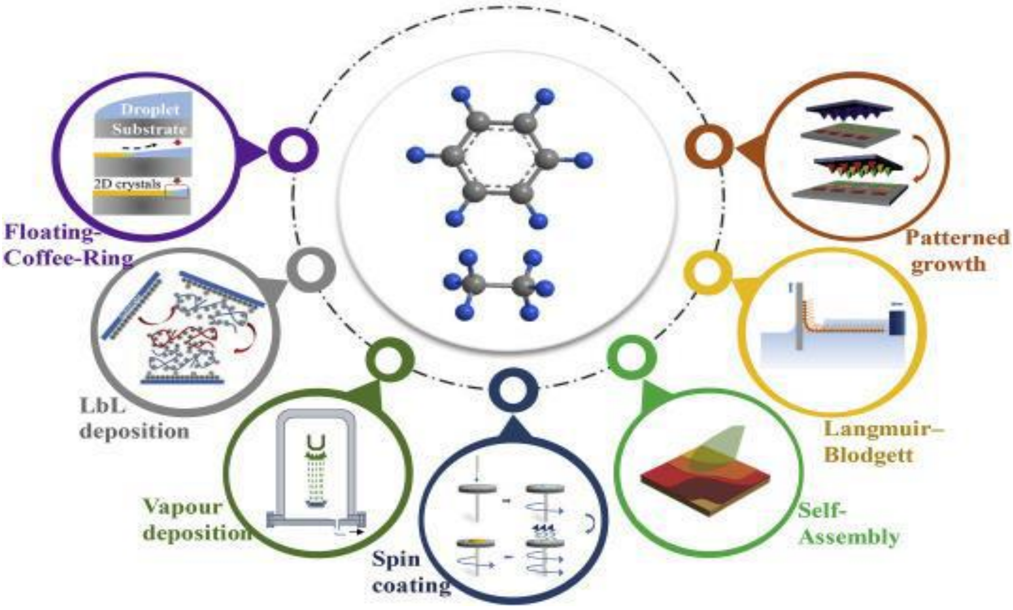

Fig 14 : Synthesis Methods Of 2D Crystals

**GeAs and SiAs monolayers: Novel 2D semiconductors with suitable band structures**
Some important points:
1]The structure and electronic properties of GeAs and SiAs monolayers by first-principles calculations.
2]Their monoclinic structures are dynamically stable. The interlayer cohesive energies are of moderate strength.
3]The bandgap of GeAs and SiAs monolayers are 1.66 eV (2.06 eV by HSE06) and 1.84 eV (2.50 eV by HSE06), respectively.
4]Their carrier effective masses are relatively small. SiAs monolayer is a suitable photocatalyst for water splitting.

## 7]CONDUCTING POLYMERS:

### 7.1 Definition of conducting polymers, Types and applications

Conductive polymers or, more precisely, intrinsically conducting polymers (ICPs) are organic polymers that conduct electricity. Such compounds may have metallic conductivity or can be semiconductors. The biggest advantage of conductive polymers is their processability, mainly by dispersion. Conductive polymers are generally not thermoplastics, *i.e.*, they are not thermoformable.

**Applications:** Due to their poor processability, conductive polymers have few large-scale applications. They have promise in antistatic materials[3] and they have been incorporated into commercial displays and batteries, but there have been limitations due to the manufacturing costs, material inconsistencies, toxicity, poor solubility in solvents, and inability to directly melt process. Literature suggests they are also promising in organic solar cells, printing electronic circuits, organic light emitting diodes, actuators, supercapacitors, chemical sensors, biosensors etc.

### 7.2 Research paper:

**Preparation of elastic polymer slices have the semiconductors properties for use in solar cells as a source of new and renewable energy**

To prepare elastic polymer slices that have semiconductors properties for use in solar cells based on charge transfer (CT) complexation. For this purposefirst six derivatives of 1,8–naphthalimide fluorescent dyes were synthesized. Secondly, the synthesized fluorescent dyes were complexed with *p*–chloranil acceptor via CT interaction in methanol solvent. The obtained CT complexes were dispersed in poly (methyl methacrylate) (PMMA) matrixes using methylene chloride solvent at room temperature. The obtained polymer sheets were characterized by several spectroscopic and physicochemical techniques, such as IR and UV–vis spectroscopies; and SEM technique. The microstructural and morphological changes occurred in the sheets of the PMMA matrix blended with the CT products were observed using the positron annihilation Doppler broadening (PADB) and the positron annihilation lifetime (PAL) techniques. Finally, the photostability and the direct current (DC) electrical characteristics as a function of the temperature for the CT products dispersed in PMMA matrixes have been studied.

Some terms:
1]1,8–naphthalimide fluorescent dyes:
Dye is used for generating CT .
2]SEM technique: A scanning electron microscope(SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample.
3]positron annihilation Doppler broadening-Doppler broadening positron annihilation spectroscopy is used to measure the concentration, spatial distribution, and size of open-volume defects in low dielectric constant (low-k) hydrogen-and methyl-silsesquioxane thin films.

# Phase 2:

## 8. DIODES

### 8.1 Structure of Silicon and Concepts related to semiconductors

Silicon has 4 valence electrons in outermost shell.So it is neither good conductor nor good insulator.In polycrystalline form,silicon make 4 covalent bonds with other four silicon atoms.As temperature increases one electron leave the original position and make hole in that position.then another electron fill that hole and process continues. So there is current due to both electrons and holes.But this current is in microamperes.This is called itrinsic semiconductors.

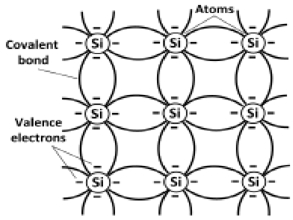


Fig 15 :Silicon Structure.

So for overcoming this challenge ,doping was invented.

### 8.2 Doping in silicon- i] N-type and P-type

**i]N type Semiconductors**: In original silicon sample, the elements like arsenic,phosphorus are added as an impurity.These elements have 5 valence elctrons.So 4 electrons formed a bond and one is roaming.That electron contributes to the electric current.So, in N-type semiconductors no. of electrons are greater than holes.

**ii] P-type semiconductors**: In original silicon sample ,Elements like boron,gallium are added as an impurity.These elements have 3 valence electrons.So 1 hole is remained their.That hole movement contributes to current as positive charge.So. in p-type semiconductors ho. Of holes are greater than no. of electrons

### 8.3 P-N junction diode & Types.

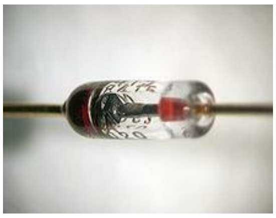

Fig. 16: Diode

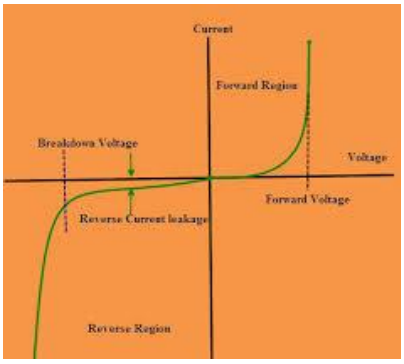


Fig 17: I-V charecteristics of Diode.

**1] Forward Bias:**

In N material, the majority carriers are electrons and it is easy for these electrons to move through the N material. Upon entering the depletion region, if the supplied potential is high enough, the electrons can diffuse into the P material where there are a large number of lower energy holes. From here, the electrons can migrate through to the positive terminal of the source, completing the circuit (the resistor has been added to limit maximum current flow). The “trick” here is to assure that the supplied potential is large enough to overcome the effect of Energy bands in PN junction.That is, a certain voltage will be dropped across the depletion region in order to achieve current flow. This required potential is called the barrier potential or forward voltage drop. The precise value depends on the material used. For silicon devices the barrier potential is usually estimated at around 0.7 volts. For germanium devices it is closer to 0.3 volts while LEDs may exhibit barrier potentials in the vicinity of 1.5 to 3 volts, partly depending on the colour.

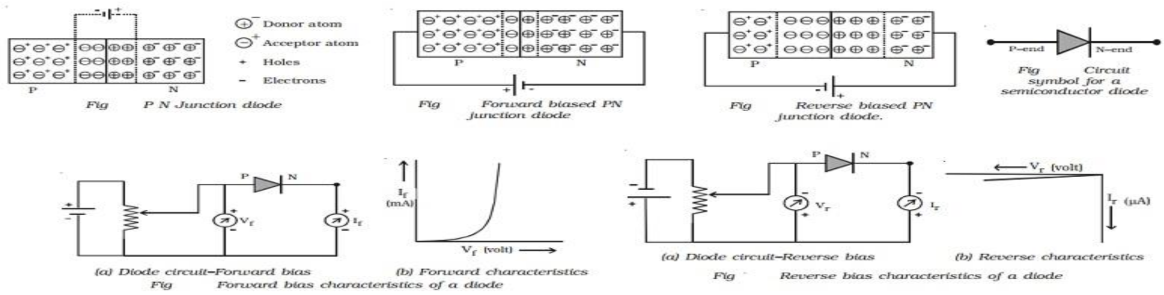


Fig .18: Forward and reverse biasing of Diode.

**2] Reverse Bias:**

In this case, the electrons in the N material will be drawn toward the positive terminal of the source while the P material holes will be drawn toward the negative terminal, creating a small, short-lived current. This has the effect of widening the depletion region and once it reaches the supplied potential, the flow of current ceases. In essence, we have increased the size of the energy hill. Further increases in the source voltage only serve to make the situation worse. The depletion region simply expands to fill the void, so to speak. Ideally, the PN junction acts like an open circuit with an applied reverse-bias voltage.

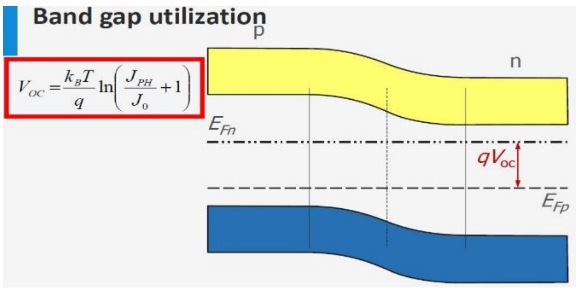


Fig 19 :band gap utilization and Voc Equation

**Shockley Equation :**
We can quantify the behavior of the PN junction through the use of an equation derived by William Shockley.

$$I = I_S \left( e^{\frac{V_D}{nV_T}} - 1 \right)$$

I is the diode current,
IS is the reverse saturation current,
VD is the voltage across the diode,
q is the charge on an electron, 1.6E−19 coulombs,
n is the quality factor (typically between 1 and 2),
k is the Boltzmann constant,
1.38E−23 joules/kelvin,
T is the temperature in kelvin.

**Types of Diodes:**

1]Rectifiers:
Rectifier is one which converts AC into DC.There are two types of rectifiers.Half wave and full wave rectifier.

Fig 20 : rectifier

*Half wave rectifier:*

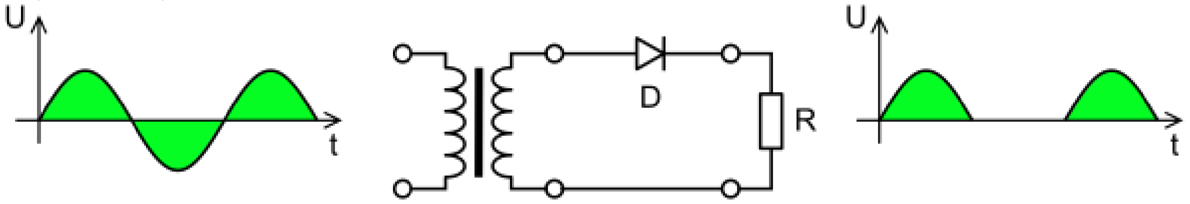


Fig 21. Half wave Rectifier.

*Full wave rectifier*:

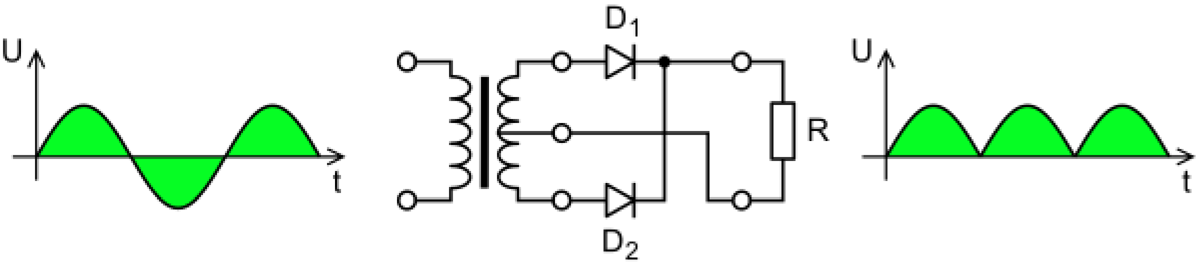


Fig 22 : Full wave Rectifier.

2]Zener Diodes:

Fig 23 : Zener Diode.

A Zener diode is a type of diode that allows current to flow in the conventional manner - from its anode to its cathode i.e. when the anode is positive with respect to the cathode. When the voltage across the terminals is reversed and the potential reaches the Zener voltage (or "knee"), the junction will break down and current will flow in the reverse direction - a desired characteristic.

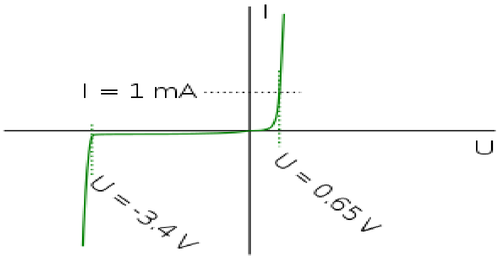


Fig 24.:Zener Diode-I-V charectristics.

3]Avalanche Diodes:

The Zener diode exhibits an apparently similar effect in addition to Zener breakdown. Both effects are present in any such diode, but one usually dominates the other. Avalanche diodes are optimized for avalanche effect so they exhibit small but significant voltage drop under breakdown conditions, unlike Zener diodes that always maintain a voltage higher than breakdown. This feature provides better surge protection than a simple Zener diode and acts more like a gas discharge tube replacement.

Fig 25. Avalanche Diode.

I-V characteristics:

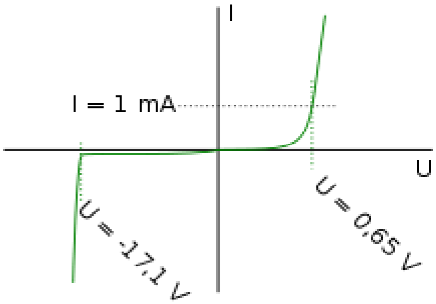


Fig 26 : Avalanche Diode : I-V characteristics.

# 9. LIGHT EMITTING DIODES

## 9.1 Basics of the diode and LED, Different Equations.

Basically LED is a normal p-n junction diode. In every p-n junction diode, when an electron jumps in a hole, from the conduction band to valence band, the specific amount of energy is released in the form of photons. In normal diodes, it is in the form of heat so both are called radiative and non -radiative transitions resp. (Detail Explanation in topic 2)

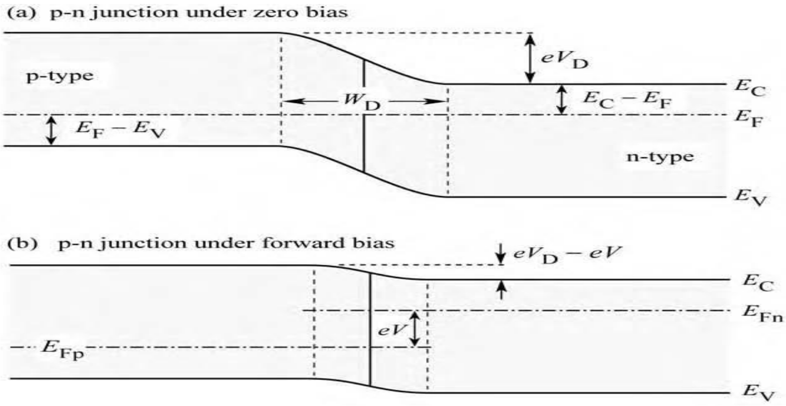


Fig. 4.1. P-n junction under (a) zero bias and (b) forward bias. Under forward-bias conditions, minority carriers diffuse into the neutral regions where they recombine.

Fig 27:Zero bias & forward bias conditions.

1] **Diffusion voltage(Vd)** is given by,

$$V_d = KT/e * \ln(N_d N_a/n_i^2)$$

K=Boltzmann constant
T=temperature
e=Algebraic constant(2.73)
Nd=Concentration of Donor
Na=Concentration of acceptor
ni=Intrinsic carrier concentration

**2]Poisson's equation**

The width of the depletion region, the charge in the depletion region, and the diffusion voltage are related by the Poisson equation. It is, therefore, possible to determine the depletion layer width from the diffusion voltage. The depletion layer width is given by

$$W_d = \sqrt{2\epsilon/e\,(V_d - V)(1/N_a + 1/N_d)}$$

$$\epsilon = \epsilon r \epsilon o$$

Vd=Diffusion Voltage
V=Biased Voltage
Nd=Concentration of Donor
Na=Concentration of acceptor

**3] Shockley Equation**

The current-voltage (I–V) characteristic of a p-n junction was first developed by Shockley and the equation describing the I–V curve of a p-n junction diode is therefore referred to as the Shockley equation.

$$I = eA\left(\sqrt{Dp/\zeta p} \times ni^2 \ /\mathrm{Nd} + \sqrt{Dn/\zeta n} \times ni^2/\mathrm{Na}\right)\left(e^{ev/kT} - 1\right)$$

Dn,p =electron and hole diffusion constants

$\zeta n, p$ = electron and hole minority-carrier lifetimes.

**4]Difference between Homojunction and Heterojunction:**

Junctions between differently doped regions of the same semiconductor material are called a homojunction, while a junction between two different types of materials is called a heterojunction. A heterojunction is an interface that befalls within two layers or regions of different crystalline semiconductors.

**5]Carrier Distribution in homojunction semiconductors:**

Einstein relation for Diffusion length:

Dn=(KT/e)$\mu n$ $\quad\quad$ $Dp = (KT/e)\mu p$

The diffusion length is given by

Ln=Dn$\zeta n$ $\quad\quad$ $Lp = Dp\zeta p$

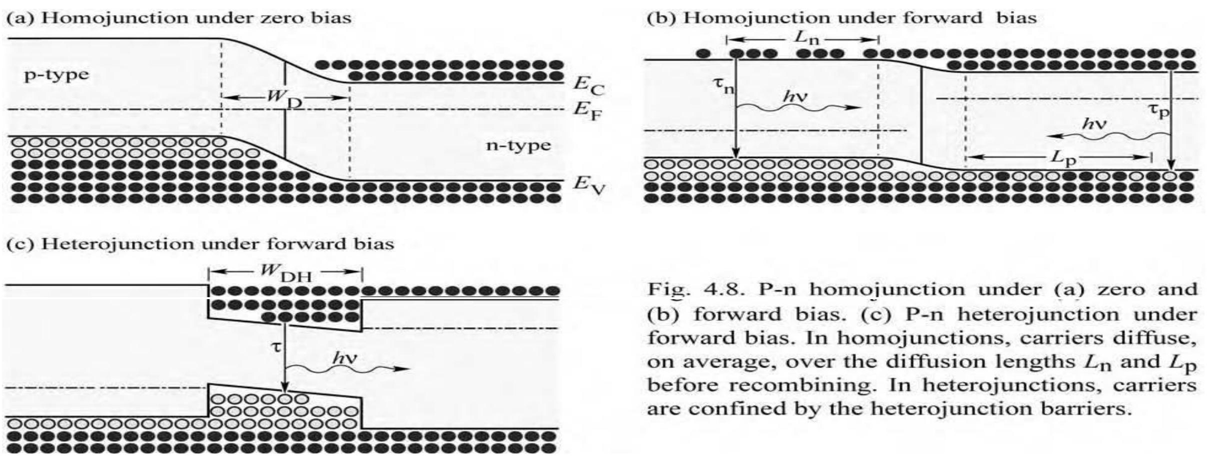


Fig. 4.8. P-n homojunction under (a) zero and (b) forward bias. (c) P-n heterojunction under forward bias. In homojunctions, carriers diffuse, on average, over the diffusion lengths $L_n$ and $L_p$ before recombining. In heterojunctions, carriers are confined by the heterojunction barriers.

Fig 28 :Homojnction & Heterojunctions

## 9.2 Radiative and Nonradiative Recombination:

**1]Radiative Recombination:** Radiative recombination is the mechanism responsible for photoemission in the semiconductor light-emitting diodes and is mainly associated with band to band recombination as a result of the high energy differences associated with a complete bandgap transition. Direct band to band recombination is only possible in materials with extremely low defect concentrations due to the fact that strain fields in the crystal structure will alter atomic interaction distances and strengths. This difference is directly related to electron interaction density in the material which, according to the band theory of semiconductors, will alter the band structure of the material. Direct bandgap Extrinsic semiconductors, like GaAs, are manufactured to have little to no crystalline defects so as to prevent the creation of defect levels within the bandgap.

**2] Non-Radiative Recombination:** When intermediate energy levels are introduced into the bandgap of material through defects in the crystal structure, charge carriers have the possibility of becoming trapped, thus making recombination extremely less favourable. When an electron or a hole is captured in an energy level close to the conduction or valence bands respectively, it is said that the carrier is trapped. The probabilities for electron occupation and hole occupation are represented by equations one and two respectively. For an electron trap, the energy required for an electron to occupy that energy state is significantly higher than the chance for a hole to occupy said state

# 10.TRANSISTORS

## 10.1 Bipolar junction transistors , BJT BIASING.

**i]n-p-n transistor**

In the following figure, the basic outline of the transistor is given

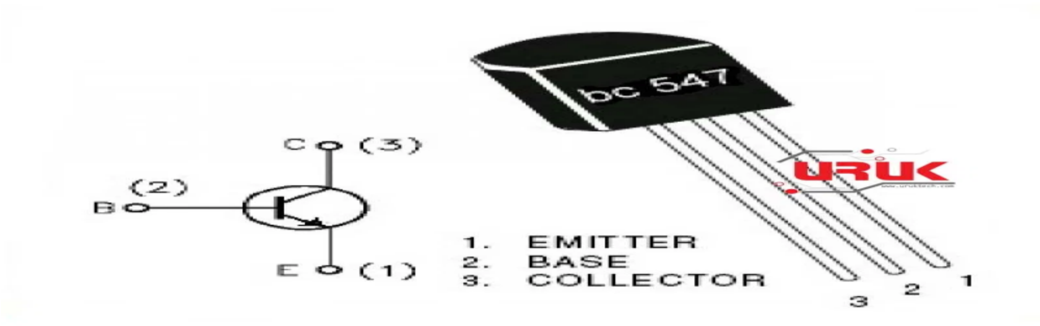


Fig 29: Transistor symbol & model.

Working:

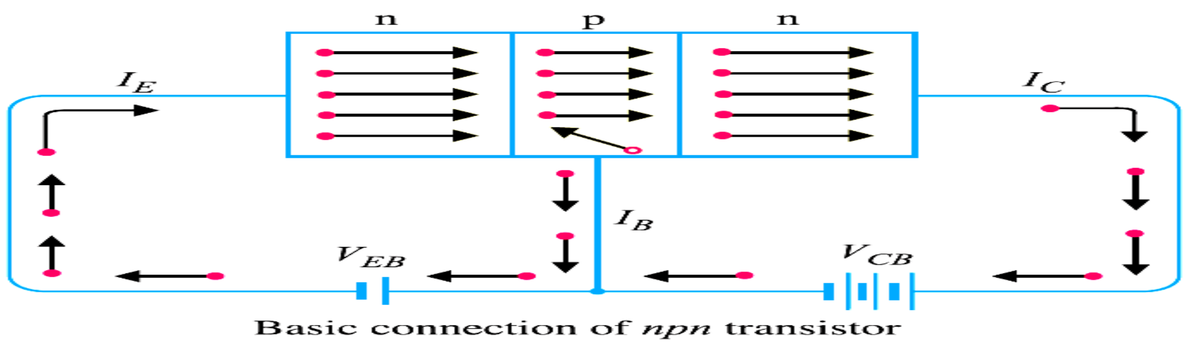


Fig 30 : Connection of n-p-n transistor.

In the n-p-n transistor, there are three regions. First is the highest n-doped semiconductor region. Second is lightly doped p-type semiconductor.Third region is n-type highly doped semiconductor material. 1st region is the emitter,2nd region is base and 3rd region is a collector.In specifically n-p-n transistor emitter and base are forward biased and collector and base are reverse biased.So first thought in our mind is current should be zero in collector -base region but it is not.  First in emitter and base region, electron exit from battery from negative electrode and flows through the diode.It is the same as forward-biased p-n junction diode.In the depletion region, electron jumps into holes of p-type semiconductor.but no. of electrons are very much greater than holes present in the p-type semiconductor. So there is low current flows from base and all other electrons enters into a highly doped emitter region.There electrons are major current carrires.So current flows from that reverse biased circuit and current flows through all over the circuit.

Some Defined term:

VBE =Voltage of base-emitter junction

VCB = Voltage of collector-base junction.

IB = Current from base

Ic =Current through collector.

Ie= Current from emitter.

<u>Some mathematical formulation of n-p-n transistors.:</u>

• From KCL, IE = IC + IB .

• IC >> IB, therefore IE ≈ IC .

• The base-emitter junction is forward-biased, therefore VBE ≈ 0.7 V (silicon).

• The base-collector junction is reverse-biased, therefore VCB is large.

• Conventional current flows into the collector and base, and out of the Emitter.

There are some terms defined on the basis of current in BJT.Typically alpha is greater than 0.95.

For normal transistors beta is in the range of 100-200.for power transistors it will be around 25.Beta is also called current gain.

$\alpha = IC / IE$ -(1)

$\beta = IC / IB$ -(2)

And with a little math,

$\alpha = \beta / (\beta+1)$ -(3)

$\beta = \alpha / (1-\alpha)$ -(4)

$IC = \beta\, IB$ -(5)

In the standard representation of n-p-n transistors the arrow points to N material and in the direction of easy conventional current flow.(It is direction of internal current flow between emitter and base)

**2]p-n-p BJT.**

The p-n-p transistor is the same as the n-p-n transistor, only regions are altered.Current direction is altered and the emitter and collector and base remains same.Equation 1 and equation 2 remains same.

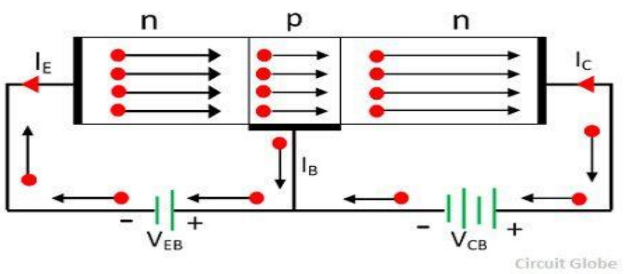


Fig 31 :p-n-p transistor Connection

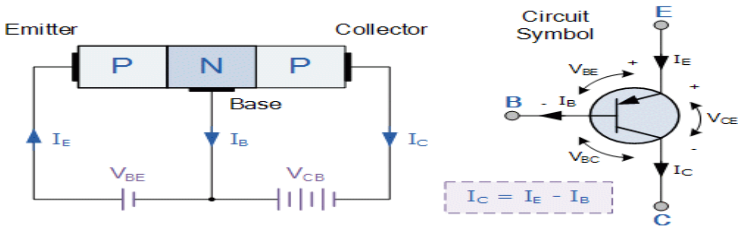

Fig 32 : p-n-p transistor connection & symbol.

IE = Ic +IB

This equation is different for both diodes.working is not different from n-p-n diodes only in the reverse direction.

**Transistor Biasing:**BJT is used for various purposes.It is used as an amplifier.The most used configuration is common emitter configuration.As in a given collector curve,there is an operating point or Q point.(It should be in active region) Stability of operating point is important and it depends on temperature.Due to temperature change there is change in current gain.The stability of operating point is important.It is defined by the term stability factor.For that there are different biasing operations.

1]Fixed Bias operation:

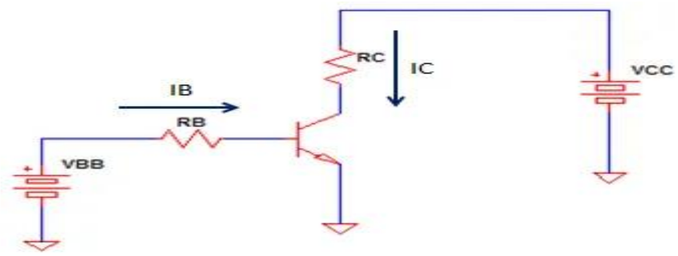


Fig 33: Fixed bias operation.

Vbe is voltage on input side and voltage Vce is voltage on the output side.Value of Ib depends on resistance Rb.For fixed value of Rb ,Base current remains constant.

Ib=Vbb-Vbe/Rb

Ic=$\beta Ib$

From KVL, Vce=Vcc-Vrc.

Vce=Vcc-(IcRc)

From the equations,if the value of Rb or Rc changes or Value of Vcc changes then operating point will also change.It is due to it being affected on output voltage which is Vce.

2]Two supply emitter bias configuration:

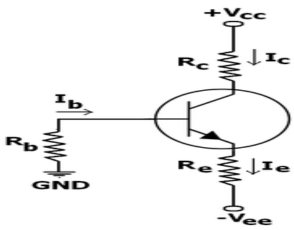


Fig 34: Two supply emitter bias configuration.

Here one extra resistor added at the emitter side to improve fixed bias configuration as given above. For fixed value of base current, as $\beta$increases Ic also increases .If Ic incenses Ie also increses.So voltage drop across Re increases.So due to that Vbe increases.

Vbe=Vbb-Vee

So as Vbe increases, Vbb also increases and due to that Ib decreases.It tries to maintain Ib and operating point.

## 10.2 JEFT(Junction field effect transistor):

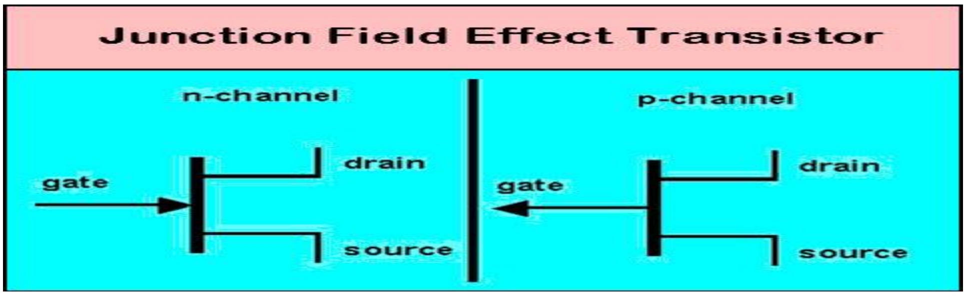


Fig 35 : JEFT

The junction gate field-effect transistor (JFET) is one of the simplest types of field-effect transistor. JFETs are three-terminal semiconductor devices that can be used as electronically-controlled switches, amplifiers, or voltage-controlled resistors.

### 10.3 Metal oxide field-effect transistor(MOSFET):

The metal–oxide–semiconductor field-effect transistor (MOSFET, MOS-FET, or MOSFET), also known as the metal–oxide–silicon transistor (MOS transistor, or MOS),[1] is a type of insulated-gate field-effect transistor (IGFET) that is fabricated by the controlled oxidation of a semiconductor, typically silicon. The voltage of the covered gate determines the electrical conductivity of the device; this ability to change conductivity with the amount of applied voltage can be used for amplifying or switching electronic signals.

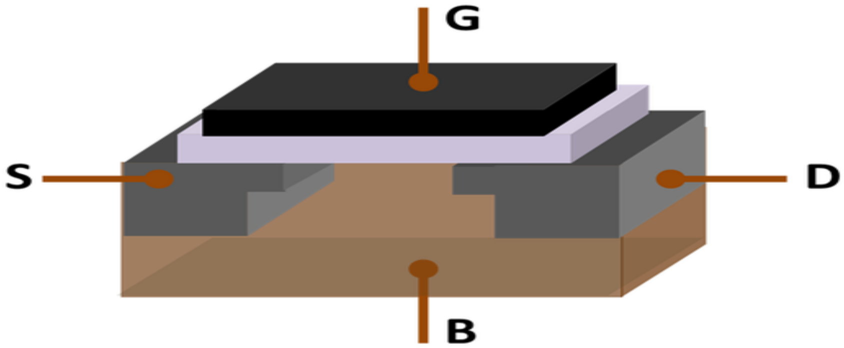


Fig 36: MOSFET

## 11. LASERS.

### 11. 1 Spontaneous and Stimulated Emission and absorption

**a]Sponteneous Emission:** Consider two energy levels in an atom E1 & E2. E1 is ground level energy state and E2 is the energy level of the first excited state. Suppose electron present in E2 and it jumps from E2 to E1 then EM wave of energy E2-E1 is emitted. It is spontaneous radiative emission. (There is not always a chance of getting EM wave from the jumping of the electron)

$$\mathrm{h}\nu o = E2 - E1$$

**b]Stimulated Emission**: Suppose one EM wave strikes the electron in the first excited state with frequency $\nu o$ in the spontaneous emission, then the there is the probability that on another EM wave adds to an incident one with frequency $\nu o$. This is called stimulated emission.

There is a fundamental difference between the spontaneous and stimulated emission processes. In the case of spontaneous emission, the atoms emit an e.m. wave that has no definite phase relation with that emitted by another atom. Furthermore, the wave can be emitted in any direction. In the case of stimulated emission, since the process is forced by the incident e.m. wave, the emission of any atom adds in phase to that of the incoming wave and along the same direction.

**c]Absorption**: Suppose electron present in the ground level and one EM wave with frequency $\nu o$ strikes to it, then the electron absorbs the energy and jump onto the next energy level which is E2. This is called absorption.

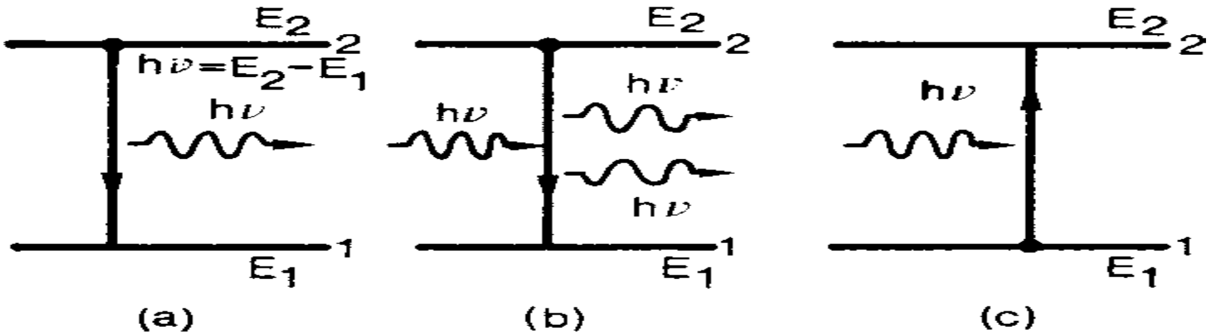


Fig 37 : Types of emissions and absorptions

What is the probability of happening this various thing??

For spontaneous emissions:

N is no. of atoms per unit volume in the specific energy state. The rate of change of N is given by the following expression,

$( \mathrm{d}N2/dt)sp = -AN2$ --(1)

where the minus sign accounts for the fact that the time derivative is negative. The coefficient A, introduced in this way, is a positive constant and is called the rate of spontaneous emission or the Einstein A coefficient (an expression for A was in fact first obtained by Einstein from thermodynamic considerations). The quantity $\zeta sp = 1/A$ is called the spontaneous emission (or radiative) lifetime. Similarly, for non-radiative decay, we can often write

$( \mathrm{d}N2/dt)nr = -N2/\zeta nr$ --(2)

For stimulated radiative transition eq. is written as follows,

(dN2/dt)st=$W12N2$ --(3)

where .dN2=dt/st is the rate at which transitions 2 -> 1 occur as a result of stimulated emission and W21 is called the rate of stimulated emission. Just as in the case of the A coefficient defined by Eq. (1) the coefficient W21 also has the dimension of .time/1. Unlike A, however, W21 depends not only on the particular transition but also on the intensity of the incident e.m. wave. More precisely, for a plane wave, it will be shown that we can write,

W21= $\sigma$21F

W12=$\sigma$12 F

## 11.2 Laser:Properties of laser beams,Types.

**Properties:**

Monochromacity,coherence,Directionality,Brightness,Short time duration.

**Types of Lasers:**

1]Helium-Neon laser:

The first CW system was the helium-neon (HeNe) gas mixture. Although its first successful operation was at an infrared wavelength of 1.15 µm, the HeNe laser is most well known operating at the red 633 nm transition. Some HeNe lasers today also can emit operate at other wavelengths (594 nm, 612 nm, 543 nm). Some earlier HeNe lasers were excited by radio frequency (RF) discharge but virtually all HeNe lasers today are driven by a small DC discharge between electrodes in the laser tube.

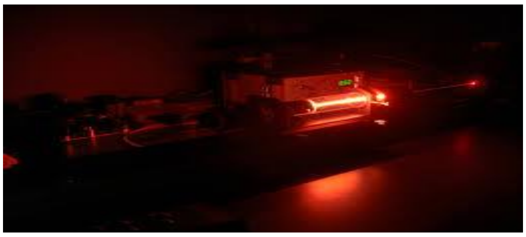

Fig 38 : Helium ion laser

2] Argon, Krypton, and Xenon Ion Lasers

The family of ion lasers utilize argon, krypton, xenon, and neon gases to provides a source for over 35 different laser frequencies, ranging from the near-ultraviolet (neon at 0.322 µm) to the near-infrared (krypton at 0.799 µm). It is possible to mix the gases, for example, argon and krypton, to produce either single frequency or simultaneous emission at ten different wavelengths, ranging from the violet through the red end of the spectrum.

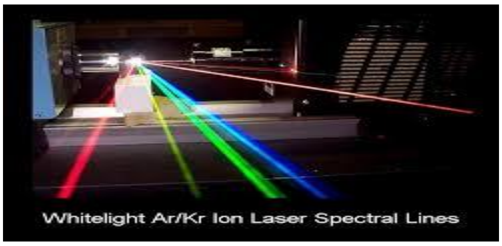


Fig 39 : Ar, Kr & Xe ion laser.

# 12.SOLAR PANELS.

## 12.1 Basic of solar panels:

It is a special cell which can convert light radiations into electricity. It is very useful in harness solar energy. There are many types of solar cells. Nowadays semiconductor solar cells are often used for industrial and domestic purpose. I am going deep into semiconductor solar cells.

**Photodiode:**

The basic things are the same as a semiconductor diode. If the photons with energy greater than the bandgap of semiconductor then the electron is pushed in the conduction band and hole is created in the valence band. This leads to electricity generation. The diode used for electricity generation commonly called as a photodiode and represented in a circuit by an above symbol. Working is as given in the following figure:

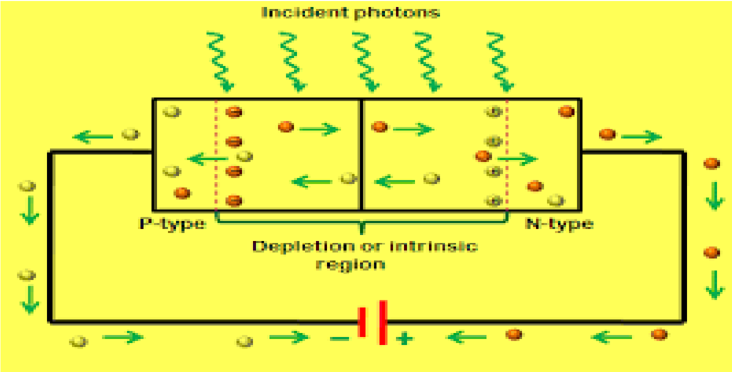


Fig 40 : Photodiode connection

**Light absorption and Carrier generation:**

As we know that energy given by one single photon,

E= h$\nu = hc/\lambda = 1.24/\lambda(\mu m)$

If h$\nu > Eg$ then the photon is absorbed and used for pushing electron from valence to conduction band. Remaining energy dissipate into heat. If h$\nu < Eg$ then the photon is not absorbed. The following graph shows the dependence of photocurrent on the bandgap of semiconduction for different air mass coefficient(Air mass coefficient: The **air mass** coefficient defines the direct optical path length through the Earth's atmosphere, expressed as a ratio relative to the path length vertically upwards, i.e. at the zenith.)

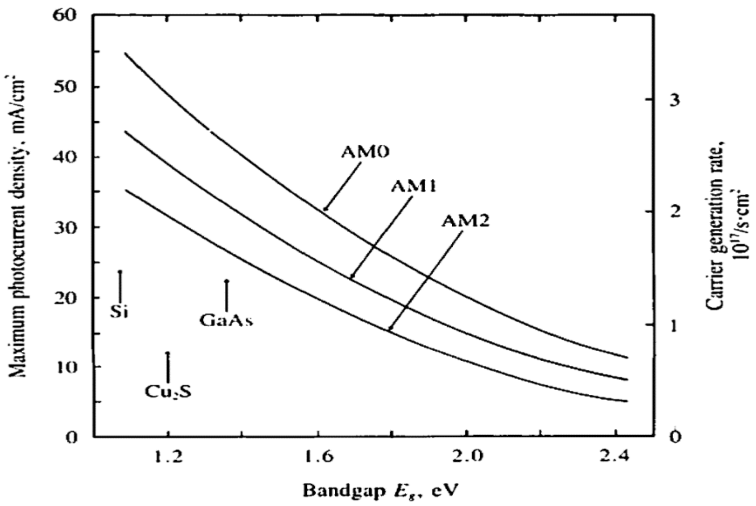


Fig 41 : Max. PC density vs Bandgap

The theory of absorption is not very simple. the photon is not absorbed immediately by the material. Some photons travelled some distance before absorption. The photon flux is given by no. of photons per square cm per second decreases exponentially with distance x given by the following equation,

$$F(x) = F(0)e^{-\alpha x}$$

therefor rate of photon absorption and rate of carrier generation is given by,

$$G(x) = \frac{-dF(x)}{dx} = \alpha F(0)e^{-\alpha x}$$

Where $\alpha$ is the absorption coefficient & it is inverse of proton penetration depth$\alpha$is a function of h$\nu$or $\lambda$.

**Carrier Recombination:**

If carrier concentrations are made to exceed their equilibrium values , such as by photocarrier generation, the excess carriers die away by recombination.The rate at which excess electrons and holes recombine and annihilate each other in pairs is recombination rate,

$$\text{Recombination rate, per volume per second} = \frac{n - n_0}{\tau} = \frac{p - p_0}{\tau} (\mathrm{cm}^{-3}\mathrm{s}^{-1}$$

no & po are the equilibrium electron and hole densities;ς is the recombination lifetime or simply the lifetime of the carriers.

$$\tau_{\text{band-band}} = \frac{C}{\text{doping density}}$$

Where c is the concentration of semiconductor.There are 3 types of recombiantion.1st is band to band, 2nd is auger recombination and 3rd is recombination through traps.The following depicts the 3 recombinations clearly:

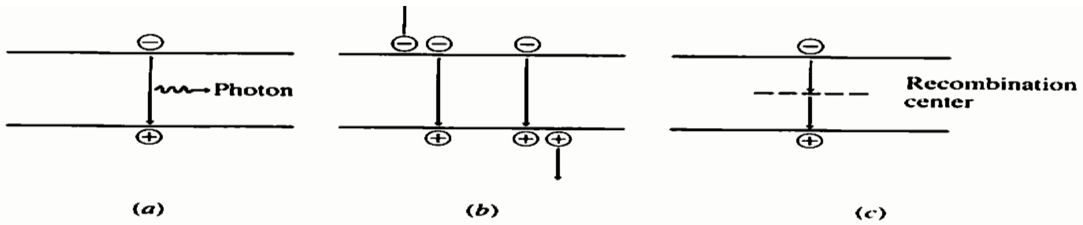


**Figure 3.8** Important recombination mechanisms: (*a*) Band-to-band recombination is the reverse of photon absorption and important in direct-gap semiconductors. (*b*) Auger recombination is dominant in heavily doped semiconductors. (*c*) Recombination through traps is dominant in lightly doped Si.

Fig 42:Important Recombination Mechanisms

Time-lapse of auger recombination is given by:

$$\tau_{\text{Auger}} = \frac{D}{(\text{doping density})^2}$$

Time-lapse of trape recombination is given by:

$$\tau_{\text{trap}} = \frac{1}{v\sigma_T N_T}$$

Where v is thermal velocity of carriers,$\sigma T$ is capture cross-section of traps and NT is trap concentration

Finally, the total recombination rate is equal to the sum of all three recombination rates given by,

$$\frac{1}{\tau} = \frac{1}{\tau_{\text{band-band}}} + \frac{1}{\tau_{\text{Auger}}} + \frac{1}{\tau_{\text{trap}}}$$

## 12.2 SOLAR CONCENTRATORS:

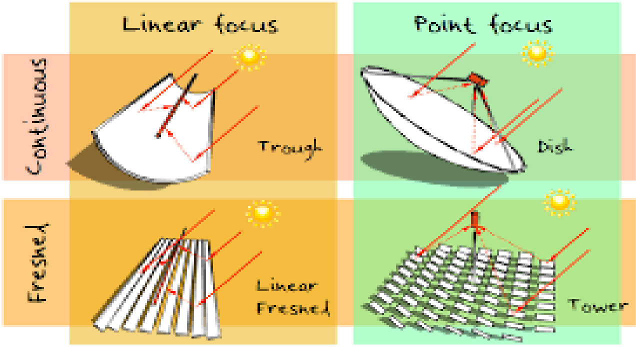


Fig 43 : Types of solar concentrators.

Solar concentrators are used for the heating purpose since the 19th century.

**Concentration ratio:** It is the ration of collecting area or reflector and solar cell area. If concentration ratio is 100 then its reflector area is 100 times more than solar cell area.

**1]Parabolic Trough**: A parabolic trough is a type of solar thermal collector that is straight in one dimension and curved as a parabola in the other two, lined with a polished metal mirror. The sunlight which enters the mirror parallel to its plane of symmetry is focused along the focal line, where objects are positioned that are intended to be heated. In a solar cooker, for example, food is placed at the focal line of a trough, which is cooked when the trough is aimed so the Sun is in its plane of symmetry.

**2]Fresnel lens**: The succession of concentric rings, each consisting of an element of a simple lens, assembled in a proper relationship on a flat surface to provide a short focal length. The Fresnel lens is used particularly in lighthouses and searchlights to concentrate the light into a relatively narrow beam. It would be almost impossible to make a large lighthouse lens of the usual solid glass-disk type because the thickness and weight would be prohibitive; the lighter Fresnel lens is constructed of elements that are separately ground and polished from suitable glass blanks and assembled to make up the complete lens.

**3]Flat plate concentrator**:In this type of solar concentrators, the mirrors are used to reflect radiation to the absorber plate. It is quite simple in design and has a good concentration ratio. It is important to note that with a single collector, it is always possible to use four reflectors simultaneously.

# 13. RADIO TRANSCEIVERS

## 13.1 Transceiver: Introduction ,RF Transceiver module-working.

In radio communication, the transceiver is a device which is able to transmit and receive information through the transmission medium. It is a combination of transceiver and receiver hence it is called a transceiver. Transmission is done by communication satellites, radio waves, optical fibre and wired connections. Radiofrequency (RF) transceivers are widely used in wireless devices. For example, cell phones use them to connect to cellular networks. Other common examples include walkie-talkies and CB radios(Connection band radio: CB Radios are utilized during disasters and emergencies and can save lives. Police, emergency responders, volunteer responders, and many more use CBs to communicate when infrastructure is damaged or nonexistent.) By combining a receiver and transmitter in one consolidated device, a transceiver allows for greater flexibility than what either of these could provide individually.

FM radio which is readily used by us does not contain radio transceivers. In the FM radio receiving and transmitting of data are two separate jobs and done by two separate devices.


Fig 44 : Radio Transceiver : Model

**RF transceiver working:**

The size of the RF modules is very small and have an extensive range of an operating voltage that is 3V to 12V. Basically, these modules are 433 MHz RF TX and RX modules. The transmitter (TX) draws no power when transferring logic zero while fully destroying the carrier frequency, thus consuming considerable low power in battery operation. When logic1 is sent the carrier is fully onto about 4.5mA with a 3V power supply. The information is sent serially from the transmitter (TX) which is received by the receiver. Transmitter (TX) and the receiver (RX) are duly interfaced to two Microcontrollers for transferring the data. An RF transceiver module includes both a transmitter and a receiver. The circuit of the RF transceiver module is typically designed for half-duplex operation and although full-duplex modules are available, typically at a higher cost due to the added complexity.

## 13.2 Radiowaves: Spectrum ,Modulation a& propogation

**Spectrum**: Radiofrequency spectrum used for several works. It is between 3 Hz(Extremely low frequency-ELF) and 300 GHz(Extremely High frequency-EHF). The spectrum is as follows:

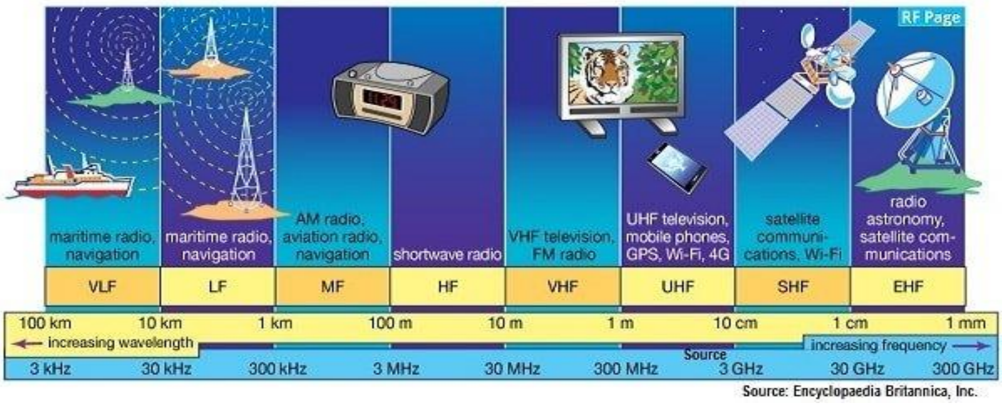


Fig 45: Radio Frequencies for different purposes.

**Propagation:**

Radio propagation is the way radio waves travel or propagate when they are transmitted from one point to another and affected by the medium in which they travel and in particular the way they propagate around the Earth in various parts of the atmosphere.

<u>Factors affecting radio propagation:</u>

There are many factors that affect the way in which radio signals or radio waves propagate. These are determined by the medium through which the radio waves travel and the various objects that may appear in the path. The properties of the path by which the radio signals will propagate govern the level and quality of the received signal.

Reflection, refraction and diffraction may occur. The resultant radio signal may also be a combination of several signals that have travelled by different paths.

Types of Propagation:

- *Free space propagation:* Here the radio waves travel in free space, or away from other objects which influence the way in which they travel. It is only the distance from the source which affects the way in which the signal strength reduces. This type of radio propagation is encountered with radio communications systems including satellites where the signals travel up to the satellite from the ground and back down again. Typically there is little influence from elements such as the atmosphere, etc.
- *Ground wave propagation:* When signals travel via the ground wave they are modified by the ground or terrain over which they travel. They also tend to follow the Earth's curvature. Signals heard on the medium wave band during the day use this form of RF propagation.
- *Ionospheric propagation:* Here the radio signals are modified and influenced by a region high in the earth's atmosphere known as the ionosphere. This form of radio propagation is used by radio communications systems that transmit on the HF or short wavebands. Using this form of propagation, stations may be heard from the other side of the globe depending upon many factors including the radio frequencies used, the time of day, and a variety of other factors
- *Tropospheric propagation:* Here the signals are influenced by the variations of refractive index in the troposphere just above the earth's surface. Tropospheric radio propagation is often the means by which signals at VHF and above are heard over extended distances.

**Modulation:**

Modulation is the process by which a sound wave is added to a basic radio wave known as the carrier wave. For example, an audio signal can be electronically added to a carrier signal to produce a new signal that has undergone amplitude modulation (AM). Amplitude modulation means that the amplitude (or size) of the wave of the original sound wave has been changed by adding it to the carrier wave.

1]Amplitude Modulaton: There are different strategies for modulating the carrier wave. First, a user can tweak the height of the carrier. If an input signal's height varies with the loudness of a user's voice and then adds this to the carrier, then the carrier's amplitude will change corresponding to the input signal that's been fed into it. This is called amplitude modulation or AM.

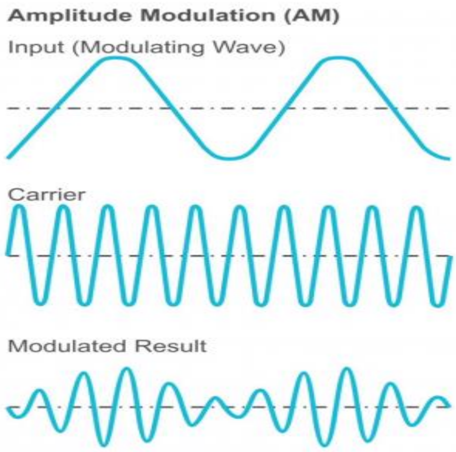


Fig 46 : Amplitude Modulation.

2]Frequency Modulation:Frequency of an input signal can also be changed. If this input signal is added to the pure carrier wave, it will thereby change the frequency of the carrier wave. In that way, users can use changes of frequency to carry speech information. This is called frequency modulation or FM.

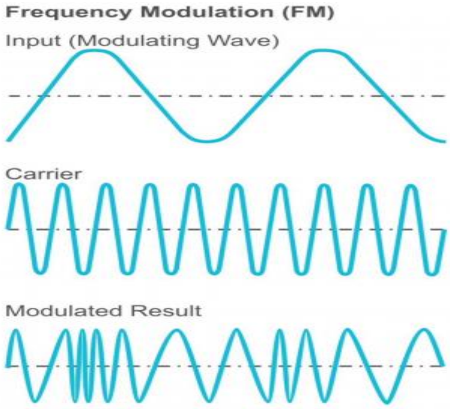


Fig 47 : Frequency Modulation

# 14. CORRELATION OF MATERIALS & DEVICES.

## 14.1 OLED:

**Introduction:**

Organic LED or Organic EL(electroluminescent).emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. This organic layer is situated between two electrodes; typically, at least one of these electrodes is transparent.OLED displays are not just thin and efficient - they provide the best image quality ever and they can also be made transparent, flexible, foldable and even rollable and stretchable in the future. OLEDs represent the future of display technology! Many popular mobile companies like Apple,gionee,Samsung use OLED in mobile phones.

**How OLED Works?**

OLED panels are made from organic materials that emit light when electricity is applied through them. Since OLEDs do not require a backlight and filters (like LCD displays do), they are more efficient, simpler to make, and much thinner - and in fact can be made flexible and even rollable.

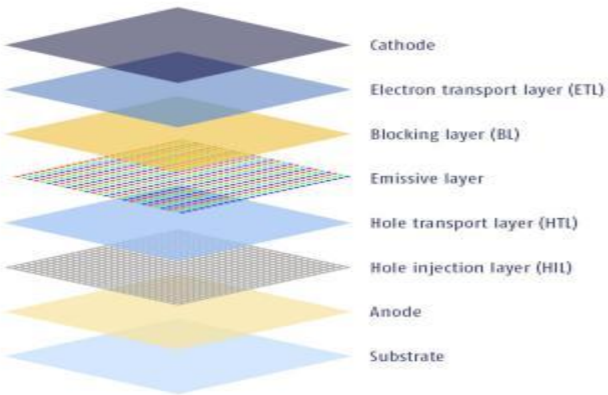


Fig 48 : OLED structure.

**Material used in OLED:**

According to OLED construction figure,

- Cathode:It is mainly made of aluminium.It can be made from Silver.Cathode (may or may not be transparent depending on the type of OLED) – Negatively charged to inject electrons into the organic layers that make up the OLED device.
- Electron transport layer(ETL):both small-molecule- and polymer-based, that have been widely used to improve OLED performance .– Supports the transport of electrons across it so they can reach the emissive layer.
- Blocking layer(BL): Commonly used to improve OLED technology by confining electrons (charge carriers) to the emissive layer
- Emissive layer: The heart of the device and where light is made, the emissive layer consists of a color defining emitter doped into a host. This is the layer where the electrical energy is directly converted into light.One conducting polymer used in OLEDs is polyaniline also One polymer used in the emissive layer is polyfluorene.
- Hole transport layer(HTL):This layer supports the transport of holes across it so they can reach the emissive layer.The organic small molecule 4,4′,4′′′-tris(N-carbazolyl)-triphenylamine (TCTA) is oftenly used for hole transport layer.
- Hole injection layer(HIL):Deposited on top of the anode this layer receives holes from the anode and injects them deeper into the device. soluble hole injection materials and inks, named ELsource, that can be used as hole injection layer in organic light-emitting diode (OLED) display.
- Anode:Indium tin oxide (ITO) is commonly used as the anode material.(may or may not be transparent depending on the type of OLED) – Positively charged to injects holes (absence of electrons) into the organic layers that make up the OLED device
- Substrate: can be plastic, glass, or metal foil– Foundation of the OLED

Fig 49: OLED Screen

### 14.2 Nd:Yag laser( Neodymium-doped Yttrium Aluminium Garnet):

**Introduction:**Nd ion is rare earth metal and it is doped with solid state host crystal like yttrium aluminium garnet (YAG – Y3Al5O12) to form Nd:YAG laser. Due to doping, yttrium ions get replaced by the Nd3+ ions. Also, the doping concentration is around 0.725% by weight.

**Construction:**Nd:YAG laser is basically categorized into 3 domains that are the active medium, pumping source and the optical resonator.

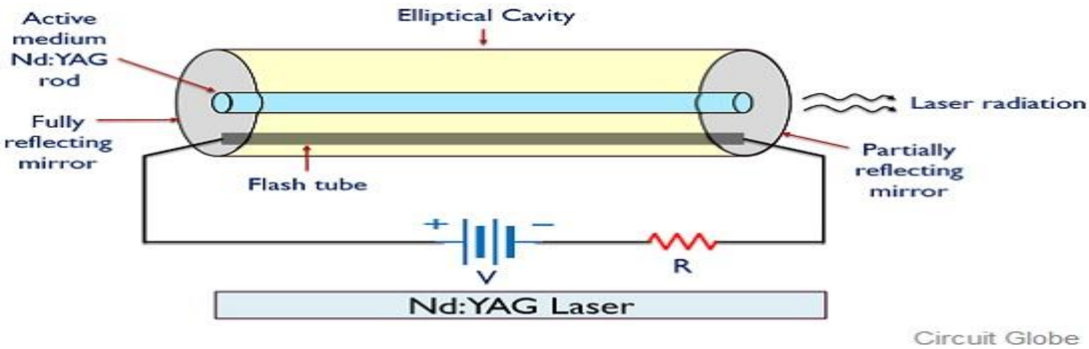


Fig 50 : Nd: YAG laser Construction

Active medium: This is also known as the laser medium and is the middle portion of the structure i.e., Nd:YAG crystal. Basically when the external energy source is provided then the electrons from lower energy state moves to higher energy state thereby causing lasing action to take place.

**External Energy source:** Due to the difference in the energy levels, the electrons need some external pumping in order to perform a transition from one state to another. So, for lasing action to take place an external pump source is required. Basically, as a source of optical pumping, xenon or krypton flash tube is taken in its case.

**Optical resonator**: The two ends of the Nd:YAG rod is coated with silver. However, one end is completely coated with silver so as to achieve maximum light reflection. While the other end is partially coated in order to provide a path for the light ray from an external source to reach the active medium. Thereby forming an optical cavity.

**Application**:These are used in military applications to find the desired target. This type of laser also finds its application in medical field for the surgical purpose. These are also used in welding and cutting of steel and in communication system also.

# CONCLUSION

This topic is related to Chemistry , Physics ,electronics and photonics. Electronic things plays crucial role in our life so ,it is important to study these topics. The research is going in each field & all are trying to improve efficiency & environmental friendliness of materials. In the last few decades we replace many photonic & electronic appliances as the progress of this field goes .for eg. Traditional bulbs replaced by LED bulbs, Vacuum tubes are replaced by silicon semiconductor materials etc. The research and progress in this topic directly affect our life so we all should know importance of this topic and try to improve the devices and their environmental friendliness.


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