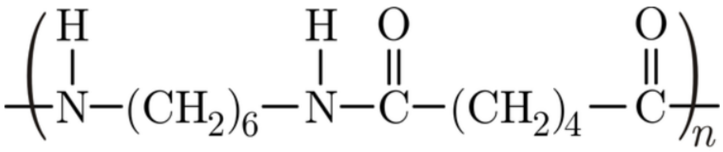
1. Discuss synthesis, properties and applications of Nylon 6,6.

Nylon 6,6

- ✓ Nylons are one of the most common polymers used as a fibre.
- ✓ Another name for this material is polyamide, due to the characteristic amide groups in the backbone chain.
- ✓ The molecules that consist of an acidic group (-COOH) on every end react with molecules that contain amino ($-NH_2$) groups at each end react to form amide bond (-CONH-).

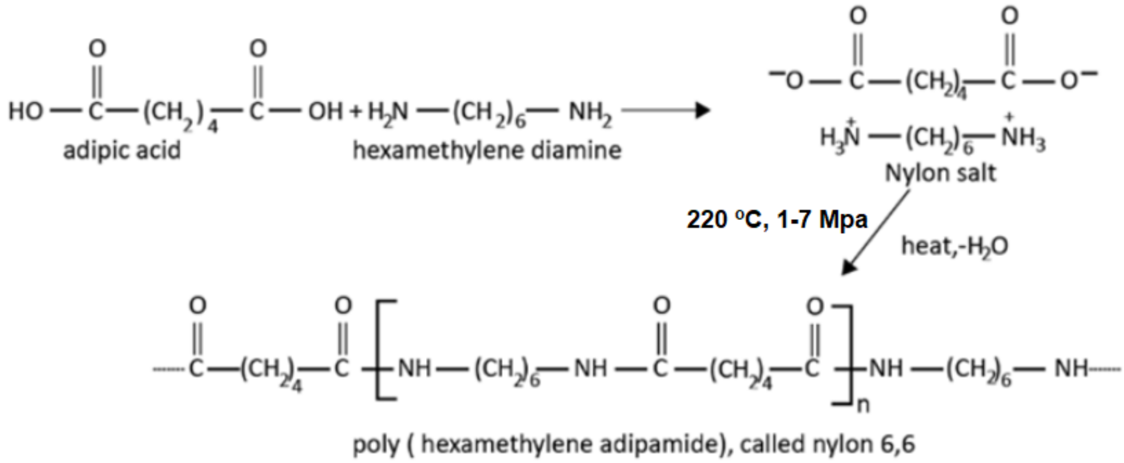
Structure of Nylon 6,6



Nylon 66

Synthetic Procedure:

- ✓ Nylon 66 is synthesized by polycondensation of hexamethylenediamine and adipic acid.
- ✓ First mixing of two monomers forms nylon salt.
- ✓ A 60 % aqueous solution of the salt is then run into a stainless steel autoclave together with a trace of acetic acid at high pressure (1-7 Mpa) and temperature (220 °C) for polymerization process.
- ✓ This polymerization process produce molten nylon-6,6.



- ✓ The molten nylon-6,6 undergoes a spinning process, where nylon-6,6 extruded and sent through a spinneret.

- ✓ The nylon is then air-cooled to form filaments

Physical Properties

- ✓ Nylon-6,6 has a melting point of 265 °C. Hence, makes it the most resistant to heat and friction.
- ✓ Its long molecular chain results is more sites for hydrogen bonds.
- ✓ It comprises dense structure with small pores. Hence, difficult to dye.
- ✓ It has 36000 psi tensile and 50000 psi flexural strength;
- ✓ Lower expansion, better dimensional stability and improved thermal conductivity and electrical conductivity.

In 3D priniting

Nylon is suitable to use when creating complex and delicate geometries. It is primarily used as filaments in FDM (Fused Deposition Modelling) or FFF (Fused Filament Fabrication) 3D printers. This material is inexpensive and recognised as one of the toughest plastic material.

Characteristic

- ✓ Variation of luster: nylon has the ability to be very lustrous, semi-lustrous or dull.
- ✓ Durability: Its high tenacity fibers are used for seatbelts, tire cords, ballistic cloth.
- ✓ Damage resistant to insects, fungai, animals molds, mildew, rot, oil and many chemicals.
- ✓ Excellent abrasion resistance.
- ✓ High elongation.
- ✓ Does not absorb water and dries quickly.
- ✓ Elastic and very strong.
- ✓ Melts instead of burning.
- ✓ Nylon has a very little warpage.
- ✓ This type of material can be easily dyed or coloured.

Disadvantages:

- ✓ Since nylon is hydroscopic, it should be kept dry.

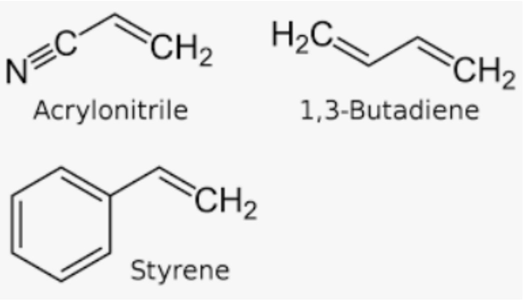
- ✓ It has a shelf life of 12 months.
- ✓ This material can shrink during cooling, thus, prints may be less precise.
- ✓ Printer suitability also varies.

Applications of Nylon-6,6

- ✓ It is used for making fabrics in textile industry. Shirts, Foundation garments, lingerie, raincoats, underwear, swimwear and cycle wear.
- ✓ It is used to prepare conveyer and seat belts, parachutes, airbags, nets and ropes, tarpaulins, thread, and tents.
- ✓ It is used to make a fishnet.
- ✓ It is used as plastic in manufacturing machine parts.
- ✓ It is blended with wool to increase the strength.
- ✓ Military applications such as parachutes, flak vests, and tires for vehicles.
- ✓ Nylon threads are used for surgical suture, dresses, under garments, ties, tapestry.

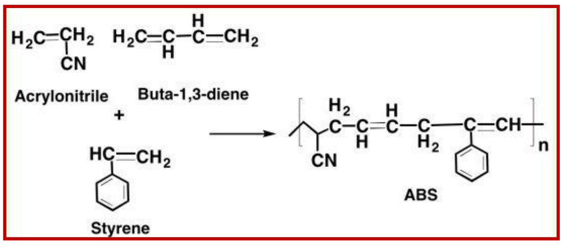
2. Discuss the synthesis and properties of ABS polymer for 3-D printing.

- ➢ ABS stands for Acrylonitrile Butadiene Styrene.
- ➢ ABS is an impact-resistant engineering thermoplastic& amorphous polymer. ABS is made up of three monomers: acrylonitrile, butadiene and styrene:



Synthesis:

- ➢ Styrene and Acrylonitrile are added to polybutadiene latex.
- ➢ Then, the mixture is warmed to about 50 °C to allow absorption of the monomers.
- ➢ A water soluble initiator such as potassium persulfate ($K_2S_2O_8$) is then added to polymerize styrene and Acrylonitrile.



- The resultant materials will be a mixture of Polybutadiene, polybutadiene grafted with Acrylonitrile and Styrene, and Styrene-Acrylonitrile copolymer.

Properties:

- ✓ High rigidity.
- ✓ Good impact resistance, even at low temperatures.
- ✓ Good insulating properties.
- ✓ Good weldability.
- ✓ Good abrasion and strain resistance.
- ✓ High dimensional stability (Mechanically strong and stable over time).
- ✓ High surface brightness and excellent surface aspect.

Chemical and Solvent resistance Properties:

- Generally, it shows very good resistant to dilute acids and alkalis
- But poor resistance towards concentrated oxidizing acids.
- Moderate resistance to aliphatic hydrocarbons.
- Dissolved by many aromatic and chlorinated hydrocarbons, esters, alcohols and ketones.

Limitations of ABS:

- ✓ Poor weathering resistance.
- ✓ Ordinary grades burn easily and continue to burn once the flame is removed.
- ✓ Scratches easily.
- ✓ Poor solvent resistance, particularly aromatic, ketones and esters.
- ✓ Can suffer from stress cracking in the presence of some greases.
- ✓ Low dielectric strength.
- ✓ Low continuous service temperature.

ABS Properties for 3D Printing:

- ✓ ABS is one of the most versatile materials for 3D printing today.
- ✓ ABS comes in the form of a long filament wound around a spool. The 3D Printing process used with ABS is the FDM (Fusion Deposition modelling) process where material is heated and squeezed through a fine nozzle to build your design in 250 micron layers.
- ✓ Objects printed with ABS boast slightly higher strength, flexibility, and durability.

- ✓ It is a great material for prototyping and it can be easily machined, sanded, glued and painted.
- ✓ One of main competitors of 3D Printing ABS is PLA.
- ✓ Unlike ABS, PLA is a renewably derived plastic. It is therefore biodegradable whereas ABS is only biocompatible. However, like many plastic materials, ABS is recyclable.
- ✓ It is one of the most accessible and cheap materials for 3D printing.
- ✓ ABS is highly available and has a wide variety of colours.
- ✓ This material has a longer lifespan compared to Nylon.
- ✓ It is also mechanically strong.
- ✓ This material is not suitable for hobbyists. It is only used for manufacturers and engineers who are looking for high-quality prototype production.

Disadvantages for 3D-printing:

- ✓ It requires heated bed when printing.
- ✓ Since ABS materials have high melting point, it has a tendency to experience warping if cooled while printing.
- ✓ This type of filament is a non-biodegradable toxic material that releases toxic fumes with awful smell at high temperature.

Applications of ABS

Automobile

- ➢ Radiator grills, head light housing, seat belt, head lamp fixtures, door knobs, two wheeler front noise, water panel, helmet, electroplated parts, mirror housing and wheel covers. In the vehicle construction industry.

Agriculture

- ➢ Drinking water system, water vent systems and irrigation systems.

Household

- ➢ Plumbing fixtures, sliding doors, window trucks, refrigerators liners, refrigerator door handles, pipe fittings, ventilator system components, picnic boxes, food processors, coffee maker leads, microwave oven tops.

Medical

- ➢ IV fluid monitoring controllers, blood glucose meter, surgical clips, emergency intravenous infusion pump, scanner body, ECG / EEG body frames, cabinets for medical kit, breathing exerciser.

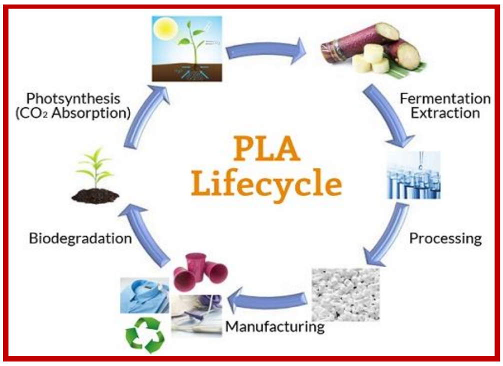
3. What is PLA? Discuss its manufacturing process. How is PLA used for 3-D printing?

***Poly Lactic Acid (*Green Plastic**)

- ✓ PLA or Polylactide (also known as Polylactic Acid, Lactic acid polymer) is a versatile commercial biodegradable thermoplastic based on lactic acid.
- ✓ Lactic acid monomers can be produced from 100% renewable resources, like corn and sugarbeets.
- ✓ Polylactide has been able to replace the conventional petroleum-based thermoplastics, thanks to the excellent combination of properties it possesses.
- ✓ It is one of the most promising biopolymers used today.

Benefits of PLA:

- ✓ ***Eco-friendly*-**It is renewably-sourced, biodegradable, recyclable and compostable.
- ✓ ***Biocompatible*** – It is non-toxic.
- ✓ It breaks down into nontoxic products during degradation and being biodegradable and biocompatible, reduce the amount of plastic waste.
- ✓ ***Processability***-It has better thermal processability compared to poly(hydroxyl alkanoate) (PHA), poly(ethylene glycol) (PEG) and poly(γ-caprolactone) (PCL).



How is Lactic Acid Manufactured?

- ✓ Lactic acid (LA or 2-hydroxypropionic acid) is the most widely occurring hydroxycarboxylic optical active acid.
- ✓ Polylactide is based on lactic acid monomers obtained from the fermentation of sugars, beet-sugar, cane-sugar etc.
- ✓ Obtained from renewable sources such as sugar cane or corn starch.

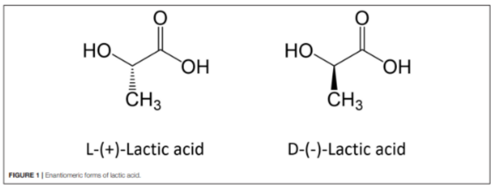


FIGURE 1 | Enantiomeric forms of lactic acid.

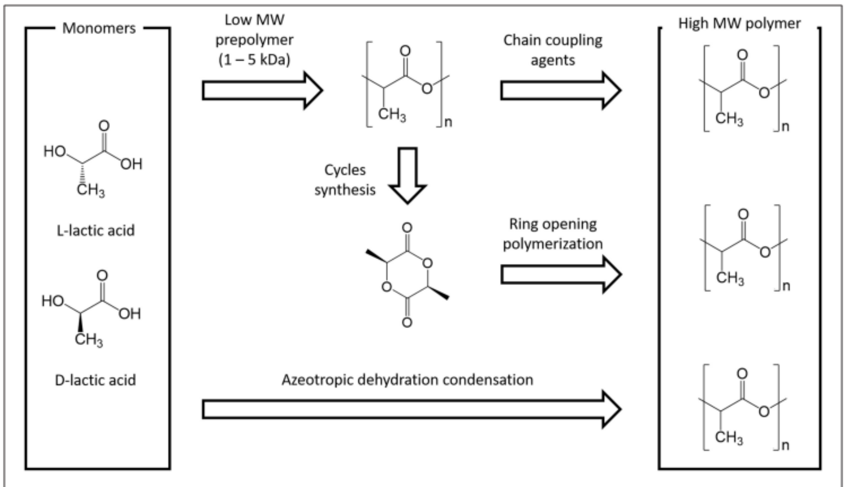


FIGURE 3 | Main PLA production routes.

- ✓ PLAs are basically synthesized in three steps;
- ✓ (i) LA production by microbial fermentation,
- ✓ (ii) LA purification followed by its cyclic dimer (lactide) preparation.
- ✓ (iii) polycondensation of LA or ring-opening polymerization (ROP) of lactides.
- ✓ At industrial scale ROP is the most popular process because of its advantages: mild process conditions, short residence times, absence of side products and high molecular weights.
- ✓ The most widely used catalyst is 2-ethylhexanoic tin(II) salt (stannous octoate [$Sn(Oct)_2$]

Types of PLA:

- ✓ Poly(L-lactide) (PLLA)
- ✓ Poly(D-lactide) (PDLA)
- ✓ Poly(DL-lactide) (PDLLA)

How is PLA used for 3-D printing?

- ✓ PLA plastic filament quickly became a popular material due to it being economically produced from renewable resources. PLA plastic material comes in the form of wire on a spool, which is fed into the extruder head where the plastic is melted and deposited in a continuous extrusion on the printing tray. This material is translucent in its natural form, but spools of coloured filament can be used to make objects in different colors.

- ✓ When cooling, this material shrinks less than ABS, which gives it good geometric stability during the manufacturing process.
- ✓ PLA can be useful for your product development, as this material can be used for rapid prototyping.
- ✓ This process opens new development using patient-specific anatomical data as well as in wide range of industrial and architectural applications.
- ✓ PLA printing was found feasible for the applications mainly by using direct or indirect 3D printing and fused deposition modelling technologies.

Properties;

- ✓ PLA is a bio-based, biodegradable and biocompatible polymer.
- ✓ PLA is a high strength and high modulus thermoplastic with good appearance.
- ✓ It has high stiffness and strength, comparable to polystyrene (PS) at room temperature.
- ✓ Less energy is required in its production when compared to other plastics and has better thermal processing.
- ✓ Most of the commercial L-PLA products are semi crystalline polymers with a high melting point, 170-180°C.
- ✓ The glass transition temperature of the PLA in the range of 55 – 60°C.

Distinct characteristics:

- PLA is easy to print since it has low warping.
- It can also be printed on a cold surface.
- It can print with sharper corners and features compared to ABS material.
- This material is available in different colours.

Disadvantages:

- ✓ Its glass transition temperature is low (Tg ~ 55°C).
- ✓ Its poor ductility, low impact strength and brittleness limits its use as compared to other thermoplastics such as ABS.
- ✓ It has low crystallization rate and processing results mainly in amorphous products.
- ✓ As compared to PET (aromatic polyester), PLA is much more susceptible to chemical and biological hydrolysis.
- ✓ It is thermally unstable and has poor gas barrier performance.
- ✓ It has low flexibility and requires long mold cycles.
- ✓ It is relatively hydrophobic.
- ✓ It has slow degradation rate.
- ✓ PLA materials are not very sturdy and can deform when exposed to extreme heat.

- ✓ This type of material is less sturdy.

Applications

- ✓ ***Consumer goods:*** PLA is used in a wide varieties of consumer products including disposable tableware, housings for kitchen appliances and electronics such as laptops and handheld devices, and microwavable trays.
- ✓ It is also used to prepare *Eco-Products* such as cups, lids, cutlery, straws and containers.
- ✓ *Agriculture:* PLA is used for monofilament fishing line and netting for vegetation and weed prevention. It is used for sandbags, planting pots, binding tape and ropes.
- ✓ *Biomedical:* Tissue engineering or regenerative medicine, cardiovascular implants, dental niches, drug carriers, orthopaedic interventions, cancer therapy, skin and tendon healing, and lastly medical tools / equipment.

4. Give any three advantages of titanium alloys over the steel.

- ✓ Given its strength, titanium is remarkably light. When compared to steel in a strength-to-weight ratio, titanium is far superior, as it is as strong as steel but 45% lighter. In fact, titanium has the highest strength-to-weight ratio of all known metals.
- ✓ Casting and machining titanium correlates more production costs regarding higher material waste, moulding and tooling acquisitions, and higher energy consumption. Whereas, 3D printing enables more efficient manufacturing of this costly metal with lower consumption of raw material and lower waste.
- ✓ As an additive technology used in titanium 3D printing typically uses only the necessary amount of material for building a part, plus a relatively low amount for support structures.

5. Elaborate any three methods for the 3-D printing of silver.

and

6. Discuss DMLS and lost PLA casting methods in detail for the 3-D printing of silver. (only 2 and 3)

1. Deposition Printing:

- ✓ Currently, there are no methods of directly 3D printing silver using an Fused Deposition Modelling (FDM) 3D printer.
- ✓ The Virtual Foundry offering several metal-infused filaments to print from, but silver currently isn’t one of them.
- ✓ Positively, the indirect methods of using FDM printing to create silver objects, such as lost-wax and lost-PLA casting.
- ✓ But in terms of directly printing, it is possible to 3D print with metal clays that come in silver. These need to be sintered in a furnace after printing to remove the substrate and leave a solid silver part.

2. ***Direct Metal Laser Sintering (DMLS)***

✓ The DMLS 3D printing process uses lasers to fuse metal powder together layer by layer to make a fully metal part. The process involve as follows;

a) The 3D printable part is designed in a 3D modelling software.

b) Then, layer of powder is first flattened over the printable area.

c) The laser beam selectively sinters the object's first layer in the bed of powder.

d) The process repeats itself with a new layer of powder being spread on top of the previous layer, which is again selectively sintered.

e) The final part is removed from the powder and a cleaning process is performed before the part is put into use.

3. ***Lost-Wax Casting/ Lost-PLA Casting:***

✓ Lost-wax casting process is used to create a wax mould of an object to cast a metal version of the object.

✓ Whereas, Lost-PLA casting is nearly the same process as lost-wax casting only exception, PLA is used in place of wax.

a) Design an object in 3D modelling software.

b) Use the PLA object to create a plaster mould.

c) Once the plaster mould has dried, put the mould into a kiln to burn out the PLA material and leave a void.

d) Once the PLA has been removed, pour liquid metal into the mould to create your silver object.

e) Once the object and mould have cooled, you can remove the plaster and cut away the sprues, sanding and polishing the object for use.

f) Once this process is done, you should have a silver part with the same properties as raw silver would have.

7. Discuss the construction and working of silicon solar cells.

What is a Solar Cell?

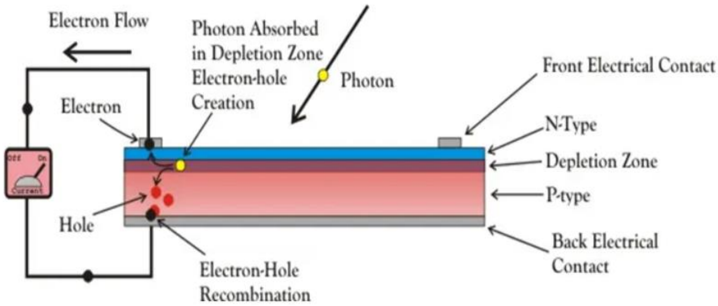
A solar cell (also known as a photovoltaic cell or PV cell) is defined as an electrical device that converts light energy into electrical energy through the photovoltaic effect. A solar cell is basically a p-n junction diode. Solar cells are a form of photoelectric cell, defined as a device whose electrical characteristics – such as current, voltage, or resistance – vary when exposed to light.

Individual solar cells can be combined to form modules commonly known as solar panels. The common single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts. By itself this isn't much – but remember these solar cells are tiny. When combined into a large solar panel, considerable amounts of renewable energy can be generated.

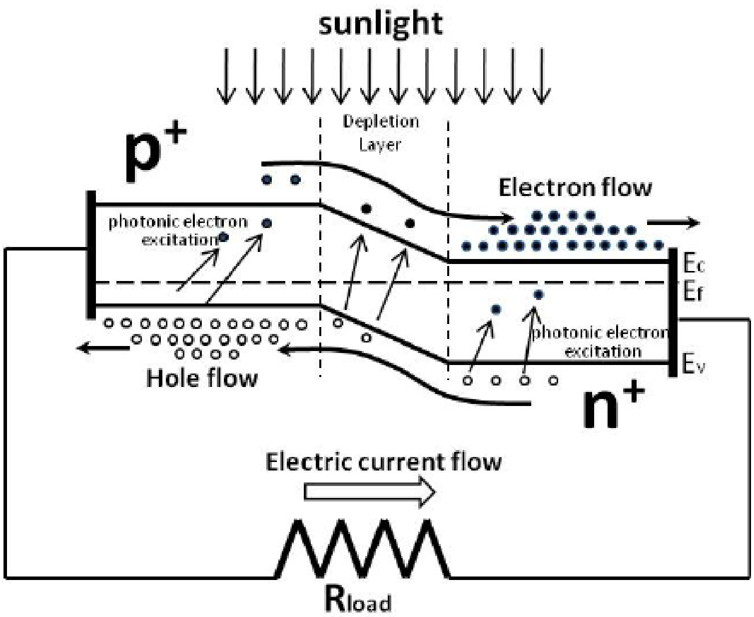
Construction of Solar Cell

A solar cell is basically a junction diode, although its construction it is little bit different from conventional p-n junction diodes. A very thin layer of n-type semiconductor is grown on a relatively thicker p-type semiconductor. We then apply a few finer electrodes on the top of the n-type semiconductor layer.

These electrodes do not obstruct light to reach the thin n-type layer. Just below the n-type layer there is a p-n junction. We also provide a current collecting electrode at the bottom of the p-type layer. We encapsulate the entire assembly by thin glass to protect the solar cell from any mechanical shock.



Working of solar cell



Solar cells, or photovoltaic cells, are devices that generate an electrical output under light irradiation. A semiconductor, typically crystalline silicon, absorbs visible light to promote an electron from the low energy valence band (VB) to the higher energy conduction band (CB), creating an electron–hole pair. In case of P-N Junction solar cell p-type semiconductor (Si doped with B) and N-type semiconductor (Si doped with P) is attached together. Generally bandgap of P-type semiconductor is less than the N-type semiconductor. When light reaches the p-n junction, the light photons can easily enter in the junction, through very thin p-type layer. The light energy, in the form of photons, supplies sufficient energy to the junction to create a number of electron-hole pairs. The incident light breaks the thermal equilibrium condition of the junction. The free electrons in the depletion region can quickly come to the n-type side of the junction. The efficiency of a photovoltaic device is highly dependent upon the semiconductor material(s) from which it is made, as well as the physical device morphology and manufacturing techniques. Similarly, the holes in the depletion can quickly come to the p-type side of the junction. Once, the newly created free electrons come to the n-type side, cannot further cross the junction because of barrier potential of the junction. Similarly, the newly created holes once come to the p-type side cannot further cross the junction became of same barrier potential of the junction. As the concentration of electrons becomes higher in one side, i.e. n-type side of the junction and concentration of holes becomes more in another side, i.e. the p-type side of the junction, the p-n junction will behave like a small battery cell. A voltage is set up which is known as photo voltage. If we connect a small load across the junction, there will be a tiny current flowing through it.

Criteria for Materials to be Used in Solar Cell

- Must have band gap from 1ev to 1.8ev.
- It must have high optical absorption.
- It must have high electrical conductivity.
- The raw material must be available in abundance and the cost of the material must be low.

Advantages of Solar Cell

- No pollution associated with it.
- It must last for a long time.
- No maintenance cost.

Disadvantages of Solar Cell

- It has high cost of installation.
- It has low efficiency.
- During cloudy day, the energy cannot be produced and also at night we will not get solar energy.

Uses of Solar Generation Systems

- It may be used to charge batteries.
- Used in light meters.
- It is used to power calculators and wrist watches.
- It can be used in spacecraft to provide electrical energy.

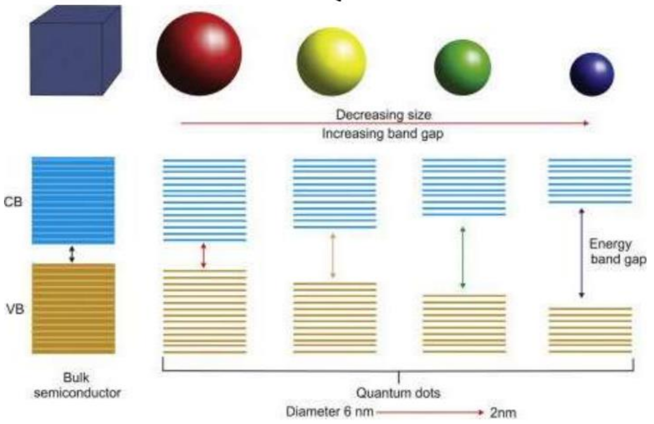
8. Mention any three limitations of solar cells.

- It has high cost of installation.
- It has low efficiency.
- During cloudy day, the energy cannot be produced and also at night we will not get solar energy.

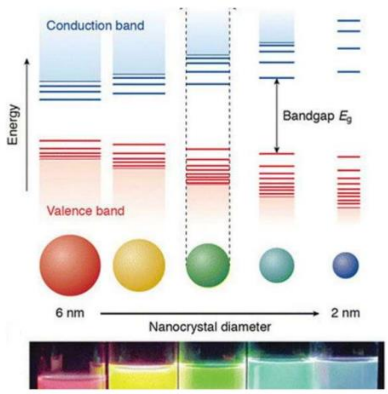
9. Write a descriptive note on quantum dots. Discuss its applications in LEDs and optical storage devices.

Quantum Confinement Effect

Size Effect



- Quantum confinement is the fundamental effect in the nanomaterials.
- Free electrons in the particular material get confined, because of the size reduction in the nanomaterial.



Quantum Confinement Effect

- Confined electrons behave as a particle in a 1D, 2D or 3D box, with energy
  $E = n^2h^2/ 8mL^2$
  Where n = 1,2,3 ...
  i.e. Energy levels are quantized or **discrete**

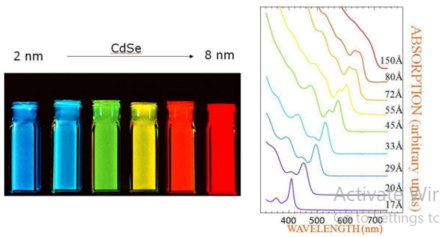
- For zero dimensional nanomaterials, electronic movement is confined in all three directions.

- Semiconductors with particle size 1-10nm show very interesting optical properties.
- Emission and absorption properties can be tuned by changing the bandgap.
- Bangap can be tuned by changing the nanoparticle size in between 1-10nm.

QUANTUM DOTS

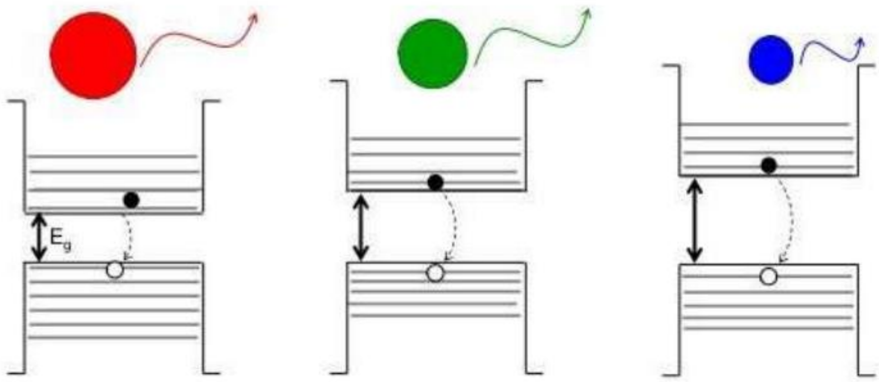
Nanoparticles made of semiconductor materials, often referred to as quantum dots (QD), absorb and emit light at certain wavelengths that depend strongly on particle size and shape due to quantum confinement effects. By changing the size and composition of the quantum dots, their emission wavelengths can be tuned from the UV through the visible to the near infrared regions of the spectrum. For example, by tuning the size of CdSe QDs from 2 nm to 8 nm in diameter, the emission wavelength can be shifted across the visible spectrum, with the smaller particles emitting in the blue and the larger particles emitting red light.

Quantum Confinement



As fluorescent materials, quantum dots offer a number of advantages over organic fluorescent dyes: in addition to the ability to easily tune optical properties by varying particle size, the QDs are less prone to photobleaching under high intensity illumination, offer comparable or larger quantum yields than organic dyes, and can be excited much further away from their emission peak, giving them a large effective Stokes shift and allowing more flexibility with imaging or choosing excitation sources to avoid auto-fluorescence in biological samples. QDs are used in a variety of applications including photodetectors, solar cells, light emitting diodes (LEDs), televisions, and for medical imaging. **NanoComposix** use QDs as components of multi-functional particles – typically for diagnostics and imaging. An example is a metal cored quantum dot composite particle that is used in lateral flow diagnostic devices.

Absorption and emission occur at specific wavelengths, which are related to QD size.



Optical Storage

- Quantum dots have been an enabling technology for the manufacture of blue lasers.
- The high energy in a blue laser allows for as much as 35 times as much data storage than conventional optical storage media.
- Less affected by temperature fluctuations, which reduces data errors.
- This technology is currently available in new high-definition DVD players, and will also be used in the new Sony PlayStation.

Light Emitting Diodes..

- Quantum Light Emitting Diodes (QLEDs) are superior to standard LEDs in the same ways the quantum dots are superior to bulk semiconductors.
- The tunability of QDs gives them the ability to emit nearly any frequency of light - a traditional LED lacks this ability.
- Traditional bulbs may be replaced using QLED technology, since QLEDs can provide a low-heat, full-spectrum source of light.

10. Discuss any three advantages of LCDs.

- ✓ LCD’s consumes less amount of power compared to CRT and LED.
- ✓ LCD’s are consist of some microwatts for display in comparison to some mill watts for LED’s.
- ✓ LCDs are of low cost.
- ✓ Provides excellent contrast.
- ✓ LCD’s are thinner and lighter when compared to cathode-ray tube and LED

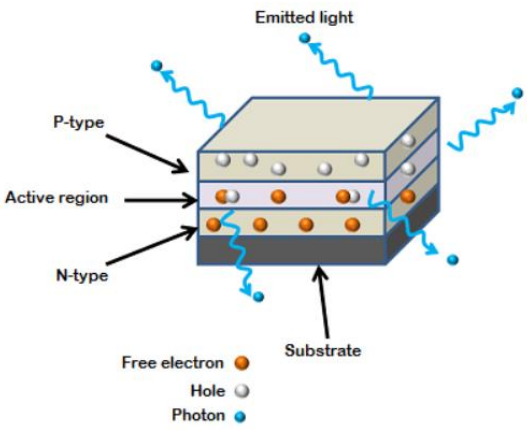
11. Point out any three disadvantages of LCDs.

- ✓ LCD’s Require additional light sources.
- ✓ Range of temperature is limited for operation.
- ✓ Low reliability.
- ✓ Speed is very low.
- ✓ LCD’s need an AC drive.

12. With a neat diagram explain the construction and working of LEDs.

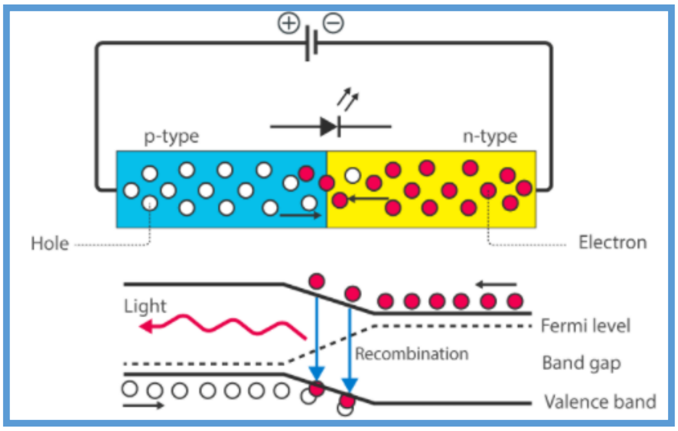
Construction of LED

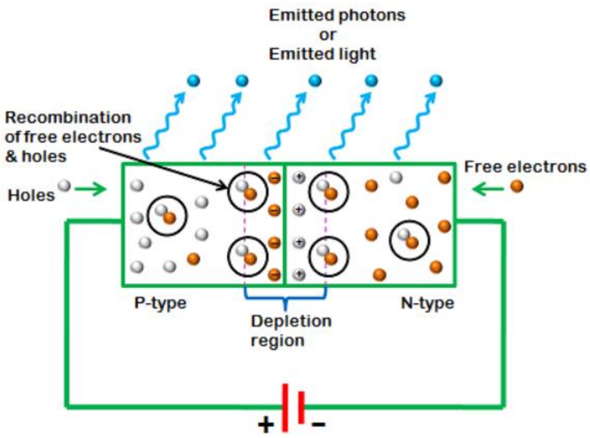
- ✓ The LED is designed through the deposition of three semiconductor material layers over a substrate.
- ✓ These three layers are arranged one by one; the top region is P-type region, the middle region (depletion region) is active and finally, the bottom region is N-type.
- ✓ The P-type region includes the holes; the N-type region includes elections whereas the active region includes both holes and electrons.
- ✓ When the voltage is not applied to the LED, then there is no flow of electrons and holes so they are stable.
- ✓ Once the voltage is applied then the LED will forward biased, so the electrons in the N-region and holes from P-region will move to the active region.
- ✓ This active region is also known as the depletion region.
- ✓ Because the charge carriers like holes include a positive charge whereas electrons have a negative charge so the light can be generated through the recombination of polarity charges.



Construction of LED

Working Principle of LED





Light Emitting Diode (LED)

- ✓ When the diode is forward biased, then the electrons and holes are moving fast across the junction and they are combined constantly, removing one another out.
- ✓ Soon after the electrons are moving from the n-type to the p-type silicon, it combines with the holes, then it disappears.
- ✓ Hence, it makes the complete atom & more stable and it gives the little burst of energy in the form of a tiny packet or photon of light.

- ✓ We call this phenomenon electroluminescence.
- ✓ Electroluminescence is an optical phenomenon, and electrical phenomenon where a material emits light in response to an electric current passed through it.
- ✓ As the forward voltage increases, the intensity of the light increases and reaches a maximum.

13. How is LED different from diode?

Diode	***LED***
The semiconductor device, conducts simply in one direction.	The LED is one type of diode, used to generate light.
The diode is designed with a semiconductor material and the flow of electrons in this material can give their energy in heat form.	The LED is designed with the gallium phosphide & gallium arsenide whose electrons can generate light while transmitting the energy.
The diode changes the AC into the DC	The LED changes the voltage into light
It has a high reverse breakdown voltage	It has a low-reverse breakdown voltage.
The on-state voltage of diode is 0.7 v for silicon whereas, for germanium, it is 0.3 v	The on-state voltage of LED approximately ranges from 1.2 to 2.0 V.
The diode is used in voltage rectifiers, clipping & clamping circuits, voltage multipliers.	LED are using in traffic signals, automotive headlamps, in medical devices, camera flashes, etc.

14. Mention any three advantages of LEDs.

- ✓ The cost of LED's is less and they are tiny.
- ✓ By using the LED's electricity is controlled.
- ✓ The intensity of the LED differs with the help of the microcontroller.
- ✓ Its has long lifetime.
- ✓ It is energy efficient.
- ✓ It does not require warm-up period.
- ✓ Doesn't affect by cold temperatures.
- ✓ Color Rendering is Excellent and environmentally friendly

15. Expand VLSI. Discuss the production of silicon wafers for VLSI.

VLSI (very large-scale integration) is the current level of computer microchip miniaturization and refers to microchips containing in the hundreds of thousands of transistors

- Electronic devices operate on the integrated circuits that are made up of silicon wafer chips.
- The basic substrate of these microchips is the silicon wafer chip upon which all the microfabrication takes place.
- Semiconductor wafers are made of silicon- that is 30% of the Earth's crust.

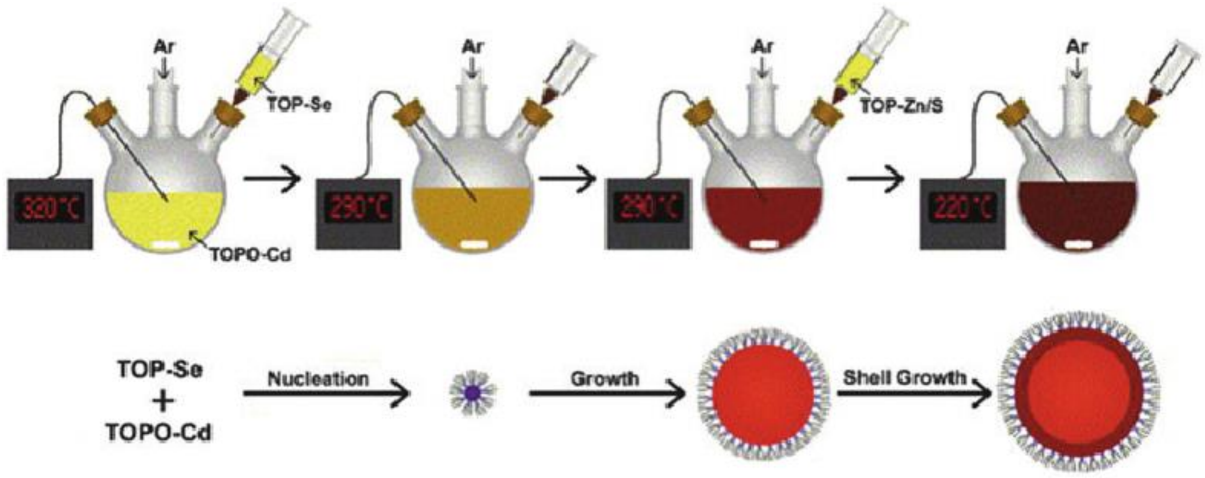
The Silicon Wafer Production Process by the Czochralski Method

- First step involves the growth of a silicon ingot, which take time of 1 week to 1 month. The time taken is determined by the size, quality, and the specification of the wafer.
- Polycrystalline silicon pieces are put in a trough made of quartz.
- Small quantities of dopants are added such as Boron, Phosphorus, Arsenic, or Antimony. These dopants are responsible for determining the properties of the resultant wafer material- it may be P type (Boron) or N type (Phosphorous, Arsenic, Antimony).
- The material is then heated above a temperature of 1500 °C until everything has liquefied.
- A silicon crystal having the same orientation is placed inside as a seed to facilitate the growth of the crystal with minimum defects.
- The resulting material is referred to as electronic grade silicon to EGS.
- This silicon ingot can subsequently be used to cut and molded into the shape needed for the final silicon wafers for the semiconductor.
- Silicon chips are then fabricated using either photolithography or chemical vapour deposition technique.

16. Discuss the colloidal synthesis of any quantum dot.

Colloidal synthesis of CdSe quantum dots

A cadmium compound is heated to 320 ^{o}C and dissolved in an organic solvent. At room temperature selenium compound dissolved in a different organic solvent is injected into the reaction vessel, causing supersaturation of the resultant CdSe solution. As the temperature drops to around 290 ^{o}C, nucleation of new crystals stops and existing crystals grow. After a period of growth, the length of which determines the size of the QDs, the solution is cooled to 220 ^{o}C, stopping growth. A small amount of zinc sulfide is injected into the reaction vessel to coat the QDs and prevent them from reacting with the environment.



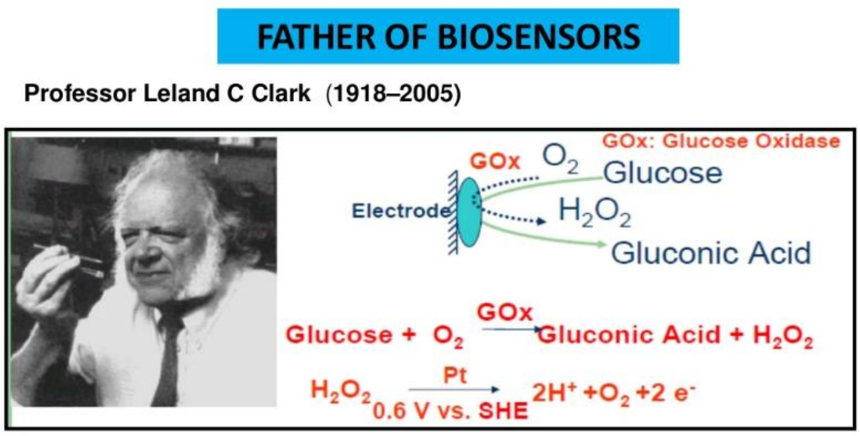
19. What is meant by biosensor? Elaborate the basic principle and components of a biosensor.

Biosensor:

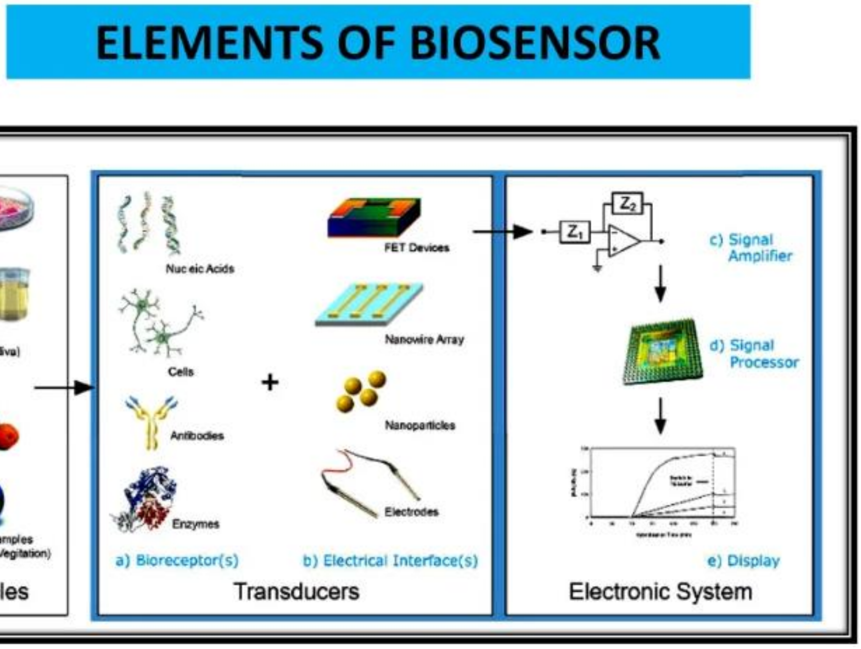
The term "biosensor" is short for "biological sensor." The device is made up of a transducer and a biological element that may be an enzyme, an antibody or a nucleic acid. The bioelement interacts with the analyte being tested and the biological response is converted into an electrical signal by the transducer.

Depending on their particular application, biosensors are also known as immunosensors, optrodes, resonant mirrors, chemical canaries, biochips, glucometers and biocomputers.

A commonly cited definition of a biosensor is: "A chemical sensing device in which a biologically derived recognition is coupled to a transducer, to allow the quantitative development of some complex biochemical parameter."

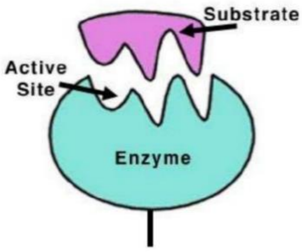


The first and the most widespreadly used commercial biosensor: the blood glucose biosensor – developed by *Leland C. Clark in 1962*

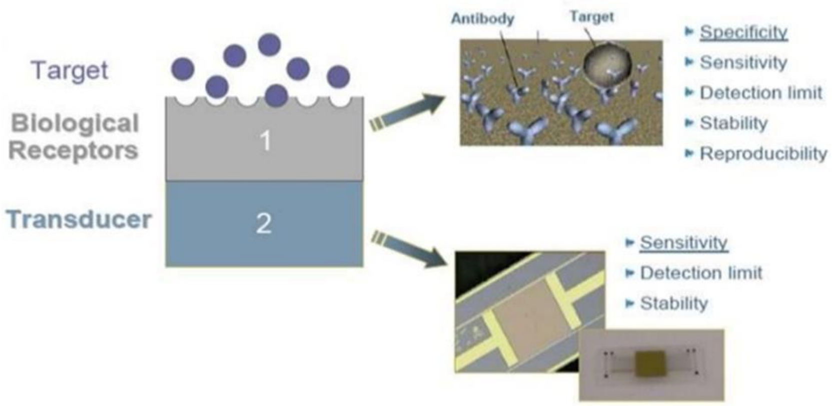


SAMPLE: The biological component or analyte which is under study.

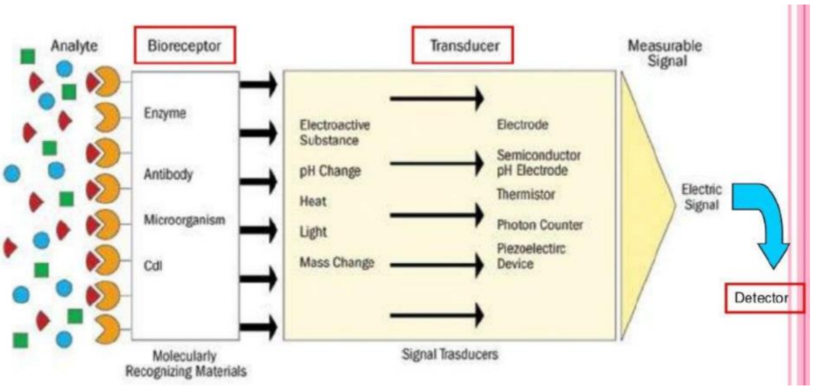
TRANSDUCER: A transducer is more generally defined as a device which converts energy from one form to another. Which is combination of, **BIORECEPTOR:** The sensitive biological element a biologically derived material or biomimetic component that interacts (binds or recognizes) the analyte under study.



ELECTRICAL INTERFACES: The detector element (works in a physicochemical way; optical, piezoelectric, electrochemical, etc.) that transforms the signal resulting from the interaction of the analyte with the biological element into electrical signal form.



ELECTRONIC SYSTEM: Combination of electronic devices i.e. Amplifier, signal processer and display device that are primarily responsible for the display of the results in a user-friendly way.



Working of Biosensors based on:

1. LINEARITY: Linearity of the sensor should be high for the detection of high substrate concentration.

2. SENSITIVITY: Value of the electrode response per substrate concentration.

3. SELECTIVITY: Chemicals Interference must be minimized for obtaining the correct result.

4. RESPONSE TIME: Time necessary for having 95% of the response.

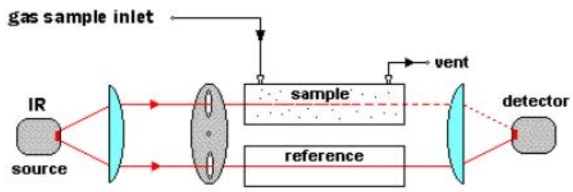
20. What is meant by a gas sensor? Give any four applications of it.

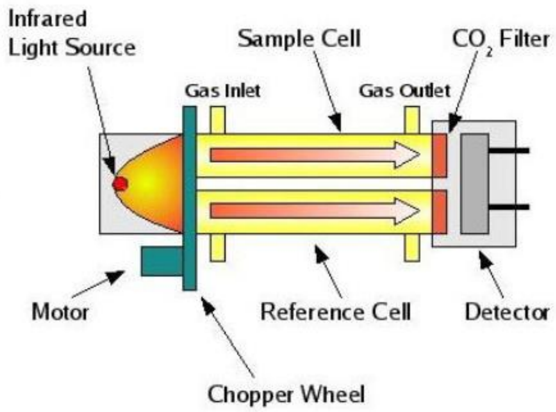
Gas Sensor:

Gas sensor is a subclass of chemical sensors. Gas sensor measures the concentration of gas in its vicinity. Gas sensor interacts with a gas to measure its concentration. Each gas has a unique breakdown voltage i.e. the electric field at which it is ionized. Sensor identifies gases by measuring these voltages. The concentration of the gas can be determined by measuring the current discharge in the device.

Eg. Carbon dioxide (CO_2) gas sensor

The Non Dispersive Infrared (NDIR) detection method is based upon the absorption of infrared radiation at specific wavelengths as it passes through a volume of sample. Non-Dispersive Infrared (NDIR) techniques for the measurement of various gases rely on the energy absorption characteristics of a particular gas in the infrared region. In a simple NDIR instrument, Infrared energy passes through two identical tubes and falls on a detector. The first tube is the reference cell and is filled with a non-absorbing gas such as nitrogen. The second tube is the measurement cell and contains the gas sample to be analyzed.





The IR Source continuously sends an IR waves through the gas tubes and detector measures the intensity of two different wavelengths, one at the sample gas absorption wavelength and the other is at reference gas absorption wavelength. As the reference gas generally contains nitrogen so the detector receives 100% signal. If the CO_2 gas is present in sample gas means the received signal will be attenuated at the detector side. The detector measures these two signals and their difference is proportional to the amount of absorbing gas in the sample cell .i.e. CO_2 gas. So Finally the CO_2 gas concentration is measured with the difference in absorption of IR radiation in the sample and reference cells. CO_2 gas concentration measuring unit is ppm.

Applications of Gas Sensor:

1. In Civil Field

The application of gas sensors in the civil field is:

(1) In the kitchen, gas sensors are used to detect the gas leak such as natural gas, liquefied petroleum gas and city gas, and automatically controlling the microwave by detecting the gas generated by the food cooked in the microwave oven;

(2) Carbon dioxide sensors, smoke sensors, ozone sensors, etc. used in houses, buildings, conference rooms, and public places for entertainment, and gas sensors used to control the automatic operation of air purifiers or electric fans;

(3) In some high buildings, gas sensors can also be used to detect fire signs and call the police.

2. In Industrial Field

(1) In the petrochemical industry

Some CO2 sensors, ammonia sensors, NO sensors, etc. can be used in specific applications for detecting harmful gases. In addition, some gas sensors can also be used to detect highly toxic gases such as organic solvents and phosphoranes in the semiconductor and microelectronics industries.

(2) In the power industry

Hydrogen sensors can detect hydrogen generated during the metamorphism process of power transformer oil. And in the food industry, gas sensors can also detect the freshness of perishable foods such as meat, etc... They are used for the oxygen detection in the exhaust gas in the automobile and furnace industries, and for the detection of the ethanol gas concentration in the exhalation of drivers.

(3) In Environmental Monitoring

Of course, when it comes to the field of environmental monitoring that is closest to life, it is naturally inseparable from gas sensors. For example, use gas sensors to detect gases that cause acid rain, such as nitrogen oxides, sulfur oxides, and hydrogen chloride; to detect greenhouse gases like carbon dioxide sensors, ozone sensors, freon, etc..

21. Discuss the features of IR touchscreens. Give its advantages and disadvantages.

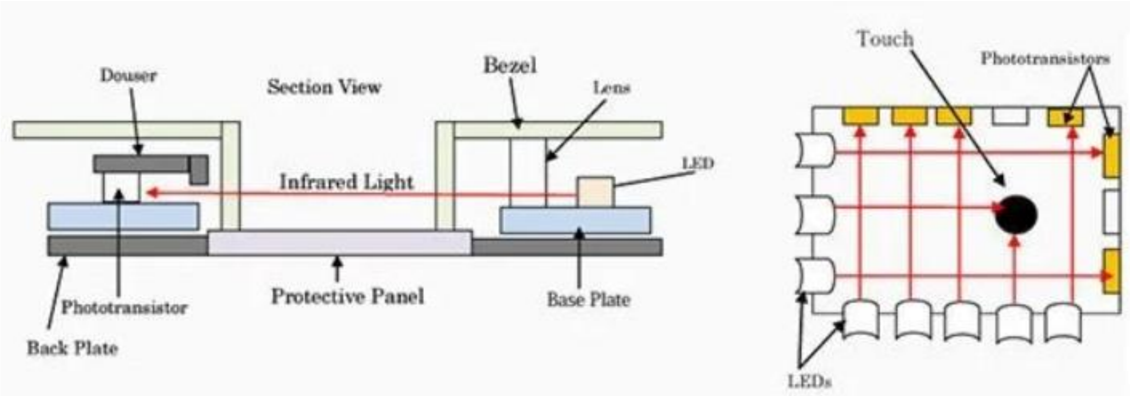
Interactive flat panel displays (IFPDs) with infrared touch screens are gaining popularity in recent years. Compared with smart projector boards, which were widely applied to education, IFPDs are more convenient and practical. You do not need to calibrate the image projector before lecturing; with LED lighting technology, IFPDs provide a clear image all the way; and thanks to IR touchscreen, you can annotate your presentation with almost anything, a dry/wet finger, pen, or stylus.

What Is An Infrared Touchscreen?

An infrared touch screen consists of an LCD monitor, IR touch frame, infrared touch overlay.

Commonly, the overlay is a piece of protective glass hemmed in by the IR touch frame, in which Infrared LEDs and photodetectors are embedded. A kind of optical bezel will be inserted between the glass and the frame to fix the frame and transmit infrared light emitted by those LEDs.

Through the optical bezel, IR LEDs emit invisible infrared beams forming grids on the surface of the overlay, Photodetectors are installed across from the LEDs to detect interruptions of beams if touch events on the overlay happen.

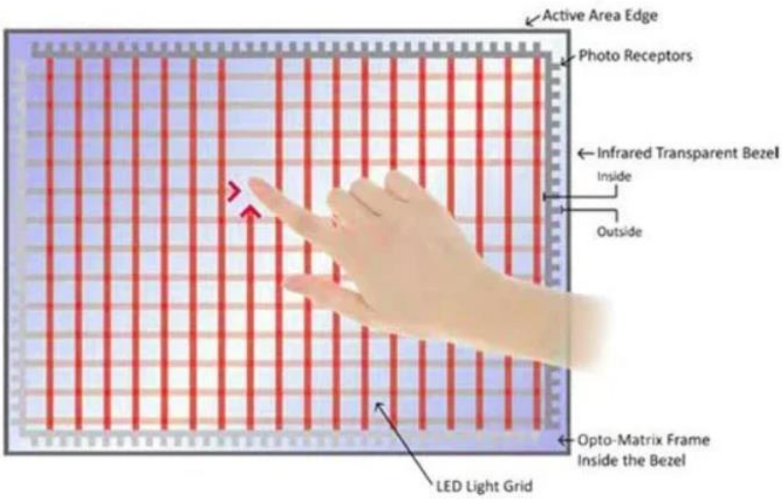


Working of Infrared Touchscreen:

The infrared touchscreen works by detecting interruptions of infrared beams emitted by LEDs embedded in the frame around the touchscreen overlay.

There are two rows of IR LEDs, which generate horizontal and vertical invisible IR beams. They form a large beam grid that covers the surface of the overlay. In the meantime, two rows of photoreceptors are installed on the opposite side of the LEDs.

As long as an opaque object touches the surface, it will blot out the light beams. Photoreceptors in both directions (vertical and horizontal) can detect this interruption by that object, and finally localize the x and y coordinates, and then send the signal to the processor to respond with relevant action.



Advantages:

Economical option; Better display, Supports multi-touch; Short response time; Better writing experience; Free of scratches; More flexible in customizing screen sizes; Maintenance; Clear images; 4K resolution; No loss of screen display; Write with any object; No calibration; No pressure is required to write.

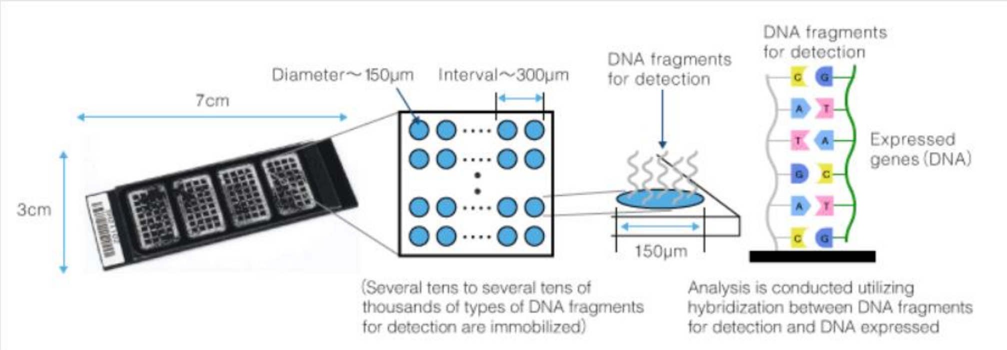
Disadvantages to using infrared touchscreen technology:

Erroneously triggered commands. If a foreign object comes into contact with the interface, it will block the infrared light just like your finger. And like your finger, the object will also trigger the command. Infrared devices also cost more than other touchscreen devices, which may deter some companies and individuals from buying them. Furthermore, they can be sensitive to water and moisture, as even small amounts of moisture may interfere with their operation.

22. Write a descriptive note on DNA microarray chips.

Microarray is a common laboratory tool for detecting gene expression or gene mutations in a high throughput manner. These slides are also known as gene chips or DNA chips. Thousands of probes (with known identity) are immobilized on a microscope slides or silicon chips or nylon membrane, with thousands of tiny spots containing a known DNA sequence or gene. With the advent of DNA sequencing technologies, some tests for which microarrays were used in the past now use sequencing technologies instead. But microarray is less expensive sequencing, so they are still used for very large studies and some clinical tests.

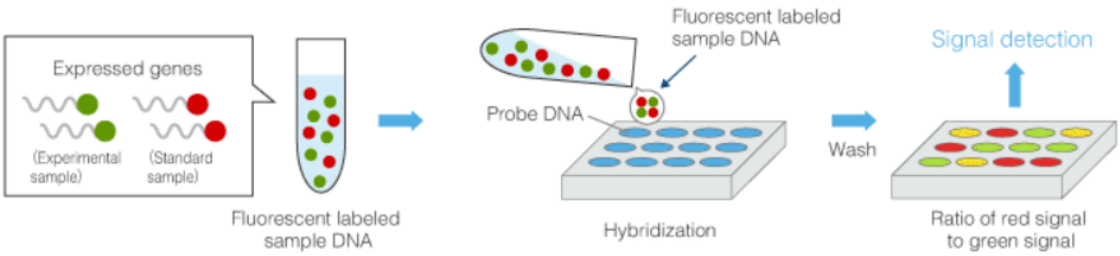
A DNA chip can be manufactured to contain hundreds of thousands of synthetic single-stranded DNA sequences.



Unknown DNA from a patient is separated into single strands, enzymatically cut and labeled with a fluorescent dye.

The unknown DNA is inserted into the chip and allowed to hybridize with the DNA on the chip.

The tagged DNA will bind only to the complementary DNA on the chip. The bound DNA will be detected by its fluorescent dye and analyzed by a computer. The red light is a gene expressed in normal cells; green is a mutated gene expressed in tumor cells; and yellow, in both cells.



Principle:

The principle of DNA microarrays lies on the hybridization between the nucleotide. Using this technology, the presence of one genomic or cDNA sequence in 1,00,000 or more sequences can be screened in a single hybridization. The property of complementary nucleic acid sequences is to specifically pair with each other by forming hydrogen bonds between complementary nucleotide base pairs. The basic principle behind the DNA microarray is "nucleic acid hybridization". In this process, two complementary strands of a DNA are joined together by hydrogen bonds to form a double-stranded molecule. This helps researchers to compare and analyze the DNA or RNA molecules of identical sequences Types of DNA microarrays

DNA microarrays are of four types:

a. cDNA microarrays: uses complementary DNA strands formed by transcription of mRNA

b. Oligo DNA microarrays: uses chemically synthesized oligo DNA as probes

c. BAC microarrays: uses template amplified by polymerase chain reaction as the probe d. SNP microarrays: used to detect polymorphisms within a population

Applications

- ✓ To study transcriptomes and proteomes
- ✓ To diagnose pathogenic as well as genetic diseases in man
- ✓ To identify microbes in the environment with the help of species-specific probes
- ✓ To genotype genomes through single nucleotide polymorphism (SNP) analysis
- ✓ To detect gene expression of mRNAs of a particular cell at different times
- ✓ To measure changes in the level of gene expression
- ✓ To observe DNA mutations
- ✓ To study genomic gains and losses

Limitations of DNA microarrays

- ✓ The results take a lot of time to analyze as the amount of data collected from each array will be huge
- ✓ The results may be too complex to interpret and are not always quantitative
- ✓ The results are not always reproducible
- ✓ The technology is too expensive
- ✓ The arrays provide an indirect measure of relative concentration
- ✓ Especially for complex mammalian genomes, it is often difficult to design arrays in which multiple related DNA/RNA sequences do not bind to the same probe on the array
- ✓ A DNA array can only detect sequences that the array was designed to detect

23. Explain the principle and working of ring sensors. Mention any two advantages and disadvantages of it.

Wearable Biosensor

Ring Sensor:

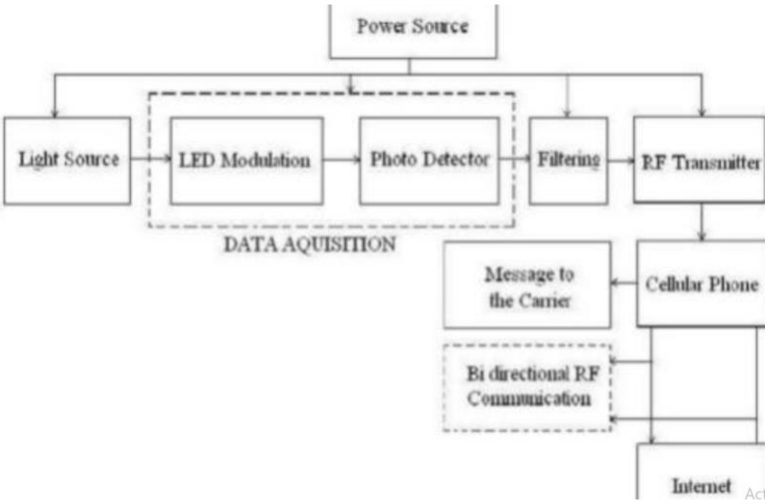
It allows one to continuously monitor heart rate and oxygen saturation. The device is shaped like a ring.

About Ring Sensor

- It is a pulse oximetry, i.e. it monitors the oxygen saturation.
- It is based on the concept of photoconductor.

Principles :-

- Blood pressure pulse causes vessel wall displacement.
- Detection pulsatile blood volume changes by photoelectric method by photo resistor
- Connected as a part of voltage divider circuit and produces a voltage that varies with the amount of blood in the finger.



Working Of Ring Sensor

- In order to detect blood volume changes due to heart contraction and expansion by photoelectric method, normally photo resistors are used.
- Light is emitted by LED and transmitted through the artery and the resistance of photo resistor is determined by the amount of light reaching it.
- Oxygenated blood absorb more light than deoxygenated blood
- A noise cancellation filter is used to cancel the noise due to motion of the finger.

Applications

- Wireless supervision of people during hazardous operations.
- In an overcrowded emergency department.
- Chronic surveillance of abnormal heart failure.
- In cardio-vascular disease for monitoring the hyper tension.

Advantages

- Continuous monitoring.
- Easy to use.
- Reducing hospitalization fee

Disadvantages

- Initial cost is high.
- Limited number of physiological parameters can be monitored.

24. Write a note on potentiometric MOSFET gas sensors.

As an introduction, describe the basic principles of hydrogen sensitive Pd (or Pt) –Si – SiO_2 structures is an example gas sensitive **potentiometric** MOSFET (gate electrode) sensor, such structures are shown schematically in Figure 1. In Figure 2, the hydrogen sensitivity is achieved in the following way hydrogen molecules in air are dissociated on the catalytic metal surface and the atoms are adsorbed on the metal surface. Some of the hydrogen atoms diffuse through the thin metal film and are adsorbed onto the metal—insulator interface. We will see later that there is an equilibrium between the number of adsorbed hydrogen atoms on the surface and those at the interface. The number of adsorbed hydrogen atoms on the surface depends not only on the hydrogen pressure in the atmosphere but also on the other gases in the atmosphere. In an inert atmosphere (such as argon) only dissociation of hydrogen takes place on the surface.

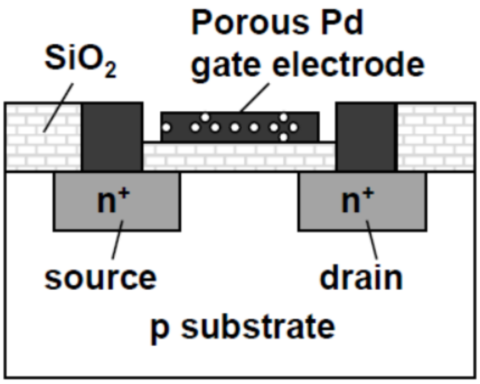


Figure 1.

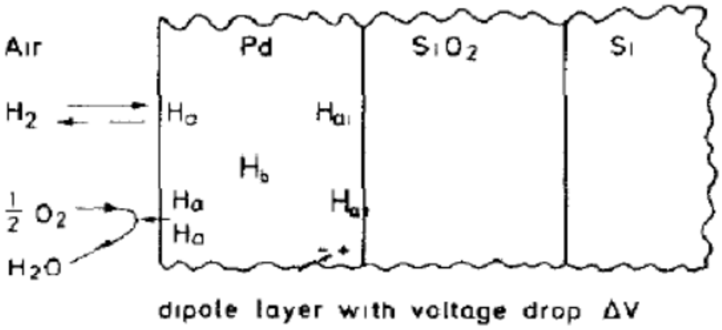


Figure 2.

Hydrogen atoms adsorbed at the interface (and on the surface) are polarized (Fig 2) and give rise to a dipole layer. The dipole layer at the interface corresponds to a voltage drop (ΔV, hydrogen would dissociate and diffuse through to the interface, causing a shift in the threshold voltage V_{th}), which is added to the externally applied voltage, V_G. By using a constant current source to drive the transistor $\Delta V = \Delta V_{th}$. (Figure 3.)

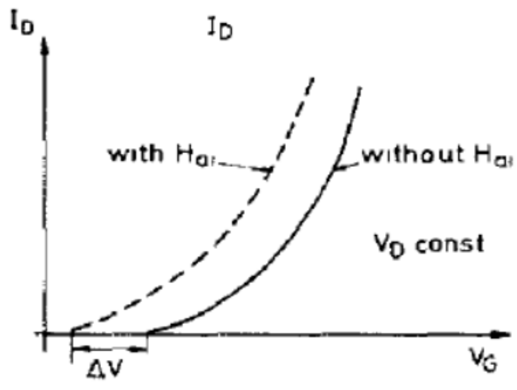


Figure 3.

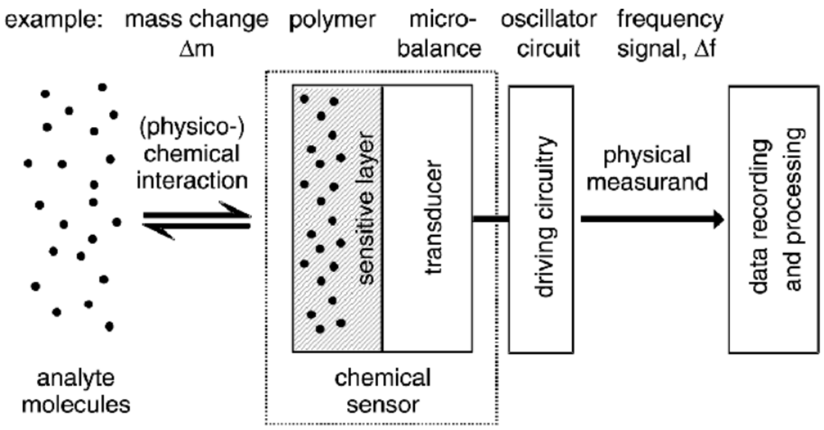
Other gate materials: 1. Platinum, iridium: typically operated at high temperature.

2. Polymer (PolFET): roomtemperature operation; susceptible to humidity.

25. What is meant by the chemical sensor? Discuss its features. Give any four examples.

A chemical sensor is a device that measures and detects chemical qualities in an analyte (the scientific term for a chemical substance being observed) and converts the sensed chemical data into electronic data. Chemical sensors are used in myriad applications, such as medical, automotive, nanotechnology and home detection systems (i.e. carbon monoxide detectors).

There are many different types of chemical sensors—which are specifically designed for their intended functions)—but they all share two components: receptors and transducers. The receptor is the component of the chemical sensor that comes into physical contact with the analyte. Depending on the sensor, the receptor interacts with the analyte in distinct ways. For instance, some receptors trigger chemical reactions with the analyte as a whole, while others can single out specific molecules. The latter (sensors that target molecules in an analyte) are referred to as more “selective.”



The second component held in common with all chemical sensors is the transducer. Transducers are responsible for intaking the chemical information of the interaction between the receptor and analyte and converting it into corresponding electrical information. This information is then sent to a computer or a mechanical component. The transducer may increase or decrease resistance, trigger an audible alarm, or present the data on a screen (interface).

A perfect example of a commonly used chemical sensor in action is a breathalyzer. When people consume alcohol, they exhale an amount of alcohol molecules directly proportional to the amount they drink. A breathalyzer is a chemical sensor that is specifically designed to measure a person's blood alcohol content (BAC), often to determine whether or not they are safely capable of driving a vehicle. When the alcohol molecules interact with the receptor, they encounter another chemical substance contained in the receptor (namely: sulfuric acid, potassium dichromate, silver nitrate and water). This triggers a chemical reaction, and when the chemical difference between the two chambers (one not affected by the reaction) is perceived, an electric signal is produced and it indicates via screen or needle the suspect’s BAC.

26. Write a short note on the IR sensor. Give any four applications of it.

In the electromagnetic spectrum, the infrared portion divided into three regions: near infrared region, mid infrared region and far infrared region.

What is an IR Sensor?

IR sensor is an electronic device, that emits the light in order to sense some object of the surroundings. An IR sensor can measure the heat of an object as well as detects the motion. Usually, in the infrared spectrum, all the objects radiate some form of thermal radiation. These types of radiations are invisible to our eyes, but infrared sensor can detect these radiations.

The emitter is simply an IR LED (Light Emitting Diode) and the detector is simply an IR photodiode. Photodiode is sensitive to IR light of the same wavelength which is emitted by the IR LED. When IR light falls on the photodiode, the resistances and the output voltages will change in proportion to the magnitude of the IR light received.

There are five basic elements used in a typical infrared detection system: an infrared source, a transmission medium, optical component, infrared detectors or receivers and signal processing. Infrared lasers and Infrared LED’s of specific wavelength used as infrared sources.

The three main types of media used for infrared transmission are vacuum, atmosphere and optical fibers. Optical components are used to focus the infrared radiation or to limit the spectral response.

Types of IR Sensor

There are two types of IR sensors are available and they are,

Active Infrared Sensor

Active infrared sensors consist of two elements: infrared source and infrared detector. Infrared sources include the LED or infrared laser diode. Infrared detectors include photodiodes or phototransistors. The energy emitted by the infrared source is reflected by an object and falls on the infrared detector.

Passive Infrared Sensor

Passive infrared sensors are basically Infrared detectors. Passive infrared sensors do not use any infrared source and detector. They are of two types: quantum and thermal. Thermal infrared sensors use infrared energy as the source of heat. Thermocouples, pyroelectric detectors and bolometers are the common types of thermal infrared detectors. Quantum type infrared sensors offer higher detection performance. It is faster than thermal type infrared detectors. The photo sensitivity of quantum type detectors is wavelength dependent.

IR Sensor Working Principle

There are different types of infrared transmitters depending on their wavelengths, output power and response time. An IR sensor consists of an IR LED and an IR Photodiode, together they are called as PhotoCoupler or OptoCoupler.

IR Transmitter or IR LED

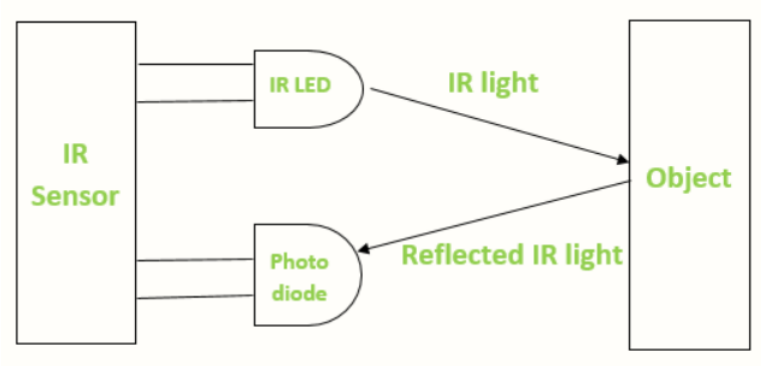
Infrared Transmitter is a light emitting diode (LED) which emits infrared radiations called as IR LED’s. Even though an IR LED looks like a normal LED, the radiation emitted by it is invisible to the human eye. The picture of an Infrared LED is shown below.

IR Receiver or Photodiode

Infrared receivers or infrared sensors detect the radiation from an IR transmitter. IR receivers come in the form of photodiodes and phototransistors. Infrared Photodiodes are different from normal photo diodes as they detect only infrared radiation. Below image shows the picture of an IR receiver or a photodiode,

Different types of IR receivers exist based on the wavelength, voltage, package, etc. When used in an infrared transmitter – receiver combination, the wavelength of the receiver should match with that of the transmitter.

The emitter is an IR LED and the detector is an IR photodiode. The IR photodiode is sensitive to the IR light emitted by an IR LED. The photo-diode's resistance and output voltage change in proportion to the IR light received. This is the underlying working principle of the IR sensor.



When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects back to the IR receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor defines.

Applications of IR Sensor

IR sensors use in various projects and also in various electronic devices. They all are as follow,

Night Vision Devices

An Infrared technology implemented in night vision equipment if there is not enough visible light available to see unaided. Night vision devices convert ambient photons of light into electrons and then amplify them using a chemical and electrical process before finally converting them back into visible light.

Radiation Thermometers

IR sensos uses in radiation thermometers to measure the temperature depend upon the temperature and the material of the object and these thermometers have some of the following features

- Measurement without direct contact with the object
- Faster response
- Easy pattern measurements

Infrared Tracking

An Infrared tracking or Infrared homing, is a missile guidance system which operates using the infrared electromagnetic radiation emitted from a target to track it.

27. Give any four applications of wireless sensors.

Industrial and Commercial Uses:

1. Inventory Tracking – RFID
2. Automated Machinery Monitoring

Smart Home or Smart Office:

1. Energy Conservation
2. Automated Lighting

Military Surveillance and Troop Support

1. Chemical or Biological Weapons Detection
2. Enemy Troop Tracking

Traffic Management and Monitoring

Biomedical / Medical

Health Monitors: Glucose, Heart rate and Cancer detection.

Chronic Diseases: Artificial retina and Cochlear implants.

Hospital Sensors: Monitor vital signs and Record anomalies.