

CBCS SCHEME

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First Semester B.E./B.Tech. Degree Examination, Dec.2025/Jan.2026 Applied Chemistry for Emerging Electronics and Futuristic Devices (EEE, ECE)

Max. Marks: 100

Time: 3 hrs.

*Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks, L: Bloom's level, C: Course outcomes.
3. VTU formula handbook is permitted.*

Module - 1			M	L	C
Q.1	a.	Distinguish between organic and inorganic semiconductors.	6	L3	CO1
	b.	Discuss construction and working principle of Poly (3-hexylthiophene) (P3HT) as a donor and Phenyl-C61-butyric acid methyl ester (PCBM) as an acceptor.	7	L2	CO1
	c.	Explain working principle and applications of Micro-electromechanical systems (MEMS)-based energy harvesters.	7	L2	CO1
OR					
Q.2	a.	What is battery? Explain the battery characteristics: capacity, power density, shelf life & cycle life.	6	L2	CO1
	b.	Explain construction and working of ultra-small asymmetric super capacitor and its applications in IoT/wearable devices.	7	L2	CO1
	c.	Discuss construction, working principle and advantages of solar photovoltaic cell (PV cell).	7	L2	CO1
Module - 2					
Q.3	a.	Explain the size dependent properties: catalytic, optical properties and electrical conductivity.	6	L2	CO2
	b.	Explain synthesis of silicon based Quantum Dots by sol gel method and Cd-Se Quantum Dots by hot injection method.	7	L2	CO2
	c.	Discuss synthesis and properties of chitosan-carbon quantum dots hydrogel and its applications in next-generation flexible and wearable electronics.	7	L2	CO2
OR					
Q.4	a.	What are Quantum dots (QDs)? Explain optical and electronic properties of quantum dots (QDs).	6	L2	CO2
	b.	Explain synthesis of TiO ₂ nano particles by sol-gel method and its uses in sensor applications.	7	L2	CO2
	c.	Discuss synthesis and properties of Graphene Quantum Dots using citric acid method and its applications in emerging electronics.	7	L2	CO2

Module - 3					
Q.5	a.	Explain synthesis and conduction mechanism of polyaniline.	6	L2	CO3
	b.	A sample of polymer contains 20 molecules of molecular mass 3000, 30 molecules of molecular mass 5000 and the remaining molecules of molecular mass 7000. Calculate number average, weight average molecular mass and poly dispersity index.	7	L3	CO3
	c.	Discuss working principle of lithography for micro-patterned copper deposition.	7	L2	CO3
OR					
Q.6	a.	What are polymer composite? Explain synthesis and properties of epoxy resin magnetite (Fe_3O_4) composite from ultra-sonication method.	6	L2	CO3
	b.	Discuss the synthesis and properties of Kevlar Fiber Reinforced Polymer (KFRP) for smart electronic devices applications.	7	L2	CO3
	c.	Explain the synthesis, properties of PDMS (Polydimethylsiloxane) and its uses in e-skin (electronic skin).	7	L2	CO3
Module - 4					
Q.7	a.	Discuss types of electrodes with examples.	6	L2	CO4
	b.	Discuss instrumentation and application of potentiometric sensor for the estimation of iron in steel.	7	L2	CO4
	c.	What is concentration cell? A zinc concentration cell is obtained by combining two zinc electrodes of concentrations 0.2M and 0.4 M immersed in zinc sulphate solution at 298K. Write the cell reactions and calculate EMF of the cell.	7	L3	CO4
OR					
Q.8	a.	Discuss construction and working of glass electrode.	6	L2	CO4
	b.	Describe instrumentation and application of colorimetric sensor in the estimation of copper in PCBs with diagram.	7	L2	CO4
	c.	Explain the principle and instrumentation of conductometric sensor and its application in the estimation of acid mixture.	7	L2	CO4
Module - 5					
Q.9	a.	What is e-waste? explain the need for e-waste management.	6	L2	CO4
	b.	Apply the principles of electroplating to explain the process of chromium plating used for hard and decorative coatings.	7	L2	CO4
	c.	What is CPR? A thick steel sheet of area 80 inch ² is exposed to moist air. After 6 months it was found to experience a weight loss of 340 g due to corrosion, if the density of the steel is 7.9 g/cm ³ . Calculate the corrosion penetration rate in mpy and mmpy (Given K = 534 in mpy and 87.6 mmpy).	7	L3	CO4

CBSE- SCHEME

First Semester BE/ BTech Degree Examination

Dec 2025 / Jan. 2026

Applied Chemistry for Emerging

Electronics and Futuristic Devices
(EEE, ECE)

Q1 a) Distinguish between organic
and inorganic Semiconductors.

(6 Marks) L3 CO1

Ans:-

Organic Semiconductors

Inorganic

Semiconductors

Composition: Made of
Carbon based molecules

Polymers or pi-bonded

structures often including

heteroatoms like hydrogen
nitrogen and oxygen

Composition: Consist

of non-carbon
based materials

such as silicon
germanium and

Gallium arsenide.

Structure and Bonding

Molecules are held together by weak van der Waals forces forming amorphous or polycrystalline thin films rather than highly ordered crystals.

Typically have

crystalline structures with strong covalent bonds forming well defined energy bands.

Processing & Cost

Can be processed using low cost solution based wet chemistry methods and offer high yields

Require more complex manufacturing processes often involving single crystal forms.

flexibility

Inherently flexible and can conform to various shapes

~~Exhibit~~ Exhibit high electron mobility due to their optimal crystalline structure.

Mobility

Lower electron mobility compared to Inorganic Semiconductors.

More stable and durable in various environmental conditions.

Applications

Used in flexible displays (OLEDs) Solar cells & Sensors

Widely used in transistors diodes and integrated circuits for traditional ~~electronic~~ electronics.

b) Discuss construction and working principle of Poly(3-hexylthiophene) (P3HT) as a donor and Phenyl-1-(61-butanoic acid methyl ester (PCBM) as an acceptor. (7 marks) 22/01.

Ans:-

Principle :- There are four important steps for the conversion of solar illumination into photocurrent in organic solar cells (i) absorption of a photon to create an exciton (ii) diffusion of the exciton to a donor-acceptor interface (iii) charge transfer of an exciton into an electron

in the acceptor and a hole in the donor

(iv) collection of the charges at the electrodes.

Construction

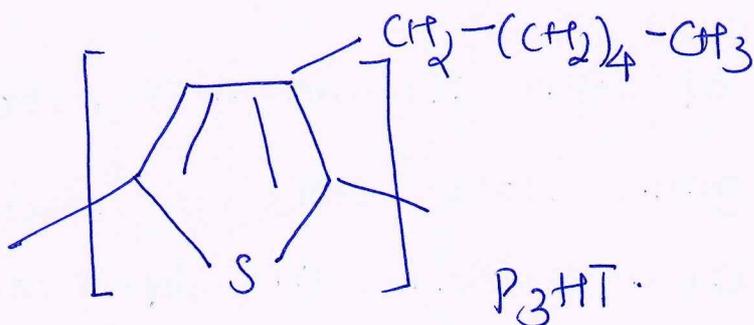
The anode consists of a semitransparent oxide layer, usually indium tin oxide (ITO)

sewing as positive electrode that allows light to pass through and collect holes from the device.

A layer of the conductive polymer poly(3,4 ethylene dioxy thiophene) poly(styrene sulfonate)

(PEDOT:PSS) is coated on top of the ITO surface sewing as hole transport buffer layer that prevents electrons from reaching the

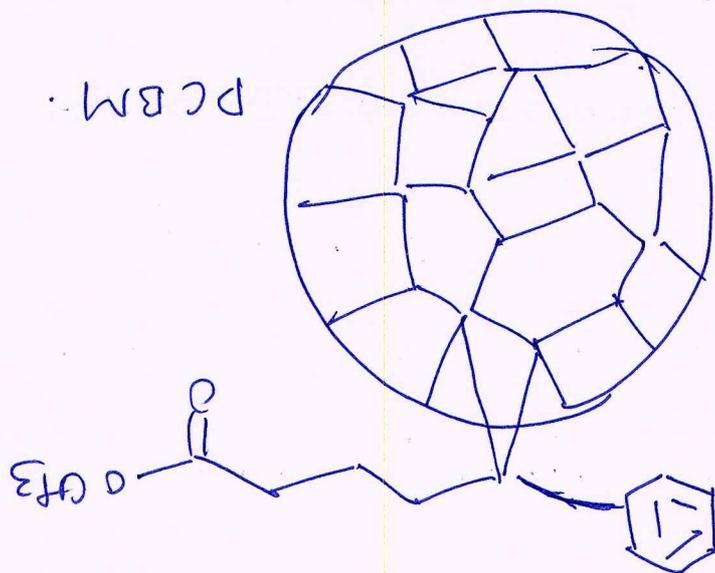
anode and prevents the anode material from ~~de~~ diffusing into the photoactive layer.



PCBM as an acceptor and P3HT as a donor used in organic solar cell.

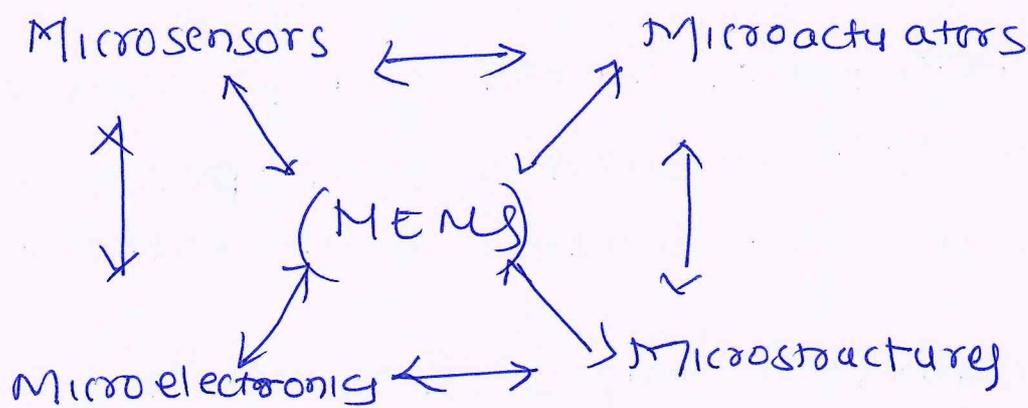
The Active material used is P3HT-PCBM Blend. P3HT acts as the p-type donor polymer and ~~PCBM~~ PCBM as the n-type acceptor in the active layer. A blend of P3HT:PCBM was made in chlorobenzene in the ratio 1:1

The Cathode usually used to collect electrons from the device is aluminum although silver or calcium may also be used.



c4 Explain working principles and applications of Micro-electromechanical Systems (MEMS) based energy harvesters (7 marks) L2 CO1.

Ans:- Micro-Electromechanical Systems (MEMS) are miniaturized devices that integrate mechanical elements, sensors, actuators, and electronics onto a single chip using micro fabrication techniques.

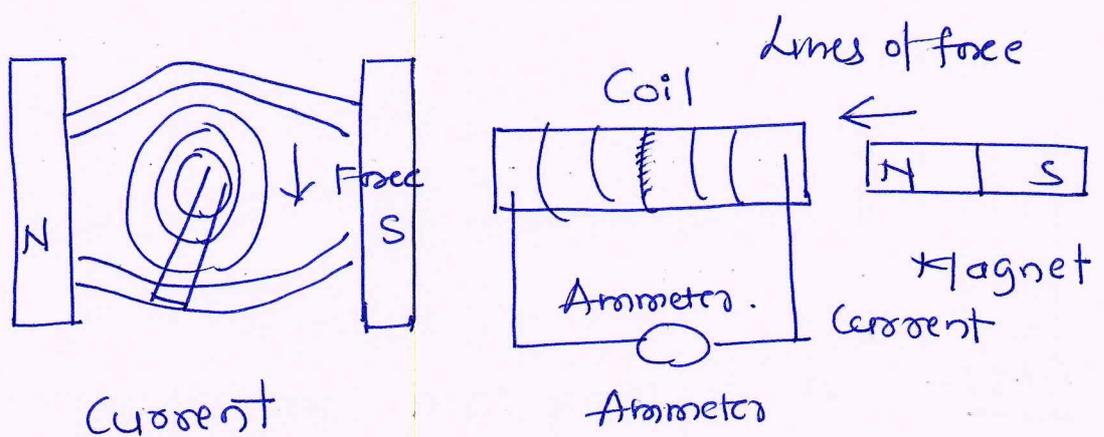


MEMS-based energy harvesters convert ambient energy (Mechanical, thermal, electromagnetic) into electrical energy, often using piezoelectric, electromagnetic or electrostatic principles.

The principle

Electromagnetic principle

The principle of an electromagnetic MEMS based energy harvester is based on Faraday's law of electromagnetic induction, which states that a voltage is induced in a coil when there is a change in magnetic flux through it.



Working

MEMS energy harvester consists of a stationary permanent magnet and a coil mounted on a movable proof mass. When ambient mechanical energy (like vibrations) acts on the device the proof mass oscillates, causing the coil to move back and forth through the static magnetic field of the fixed magnet.

This relative motion between the moving coil and the magnetic field causes the magnetic flux through the coil to change over time. which induces a voltage across the coil according to Faradays law of Electromagnetic Induction. The induced voltage is then harvested as electrical energy.

Q2e What is battery? Explain the battery characteristics, capacity, power density, shelf life and cycle life (6 marks) L2 CO1.

Ans:- A battery is a combination of cells connected either in series or parallel or both in order to get the ~~desi~~ desired output voltage.

Battery Characteristics

Capacity :- It is defined as the amount of current generated in unit time. It is measured in terms of ampere-hour. (Ah)

$$C = \frac{wnF}{M}$$

Where w = weight of the active material.

M = molecular weight of the active material.

Power density

Power density is the ratio of the power available from a battery to its mass. Power density is expressed as Watts per unit mass (W/kg) or per unit volume (W/L). It quantifies the "speed" of power delivery, rather than the total energy stored. Ideal for applications requiring rapid burst of power. Such as camera flashes or electric vehicles needing quick acceleration.

Shelf life

→ It is the period of storage under specified conditions during which a battery retains its performance level. Shelf life is affected by shelf conditions.

→ Self-discharge occurs when there is a reaction between electrodes and electrolyte or corrosion of current collectors.

→ Cool, dry and stable conditions are ideal. Freezing temperatures can alter the cells molecular structures, while heat causes stress and speeds up aging.

Cycle life

It is applicable only to secondary batteries.

For a battery one complete discharge and one complete charging constitutes a cycle.

Theoretically cycle life of a battery is defined as number of charge-discharge cycles that can be achieved before failure of the battery occurs.

2b) Explain construction and working of ultra-small asymmetric super capacitor and its applications of IoT/wearable devices. (7 marks) d2 c01

Ans:- An ultra-small asymmetric supercapacitor uses two distinct electrode materials—one for electrostatic energy storage (like activated carbon) and another for faradaic reactions (like metal oxides) - separated by a separator and filled with an electrolyte.

Construction involves sandwiching the separator between the two different electrodes and immersing them in the electrolyte, all within a compact device suitable for size constrained.

Electrodes

The two electrodes are the core components and are made from different materials.

Negative Electrode :- Typically uses an Electric Double Layer Capacitor (EDLC) material with high surface area such as activated Carbon.

Positive Electrode : Employs a pseudocapactive material like a metal oxide (eg. MnO_2) or a conducting polymer, which stores energy through fast Faradaic reactions.

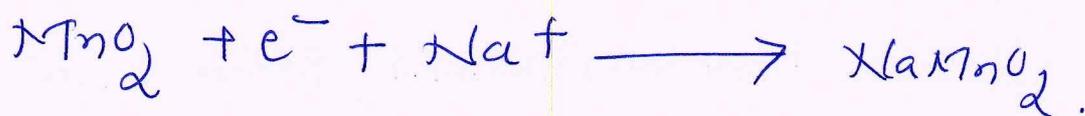
Separator : A porous separator is placed between the positive and negative electrodes to prevent short circuits while allowing ions to move freely between them.

Electrolyte : The electrodes and separator are immersed in an electrolyte solution that conducts ions. Common electrolytes can be aqueous or organic.

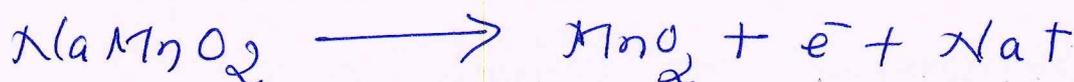
Current Collectors: Metal foils coated with the electrode materials are used to collect current and provide the connection to the external terminals.

Compact Form Factor: The ultra small aspect refers to the miniaturized size of this entire layered structure enabling integration into small devices.

Discharge Discharge Reactions



Charging Processes.



Applications :

Wearable devices

- Power source for flexible and stretchable devices (smart watches, fitness bands, health patches)
- Can be embedded in smart textiles to enable energy storage within clothing
- Integration with biosensors for real time health monitoring (ECG)

IOT

IOT devices that can benefit from ultra-smart asymmetric supercapacitors.

- Smart home sensors (temperature, humidity,
- Environmental sensors (Air quality monitors)
- Industrial IOT sensors (vibration, pressure)
- Asset tracking tags (RFID and GPS trackers).

Q2 Discuss Construction and Working

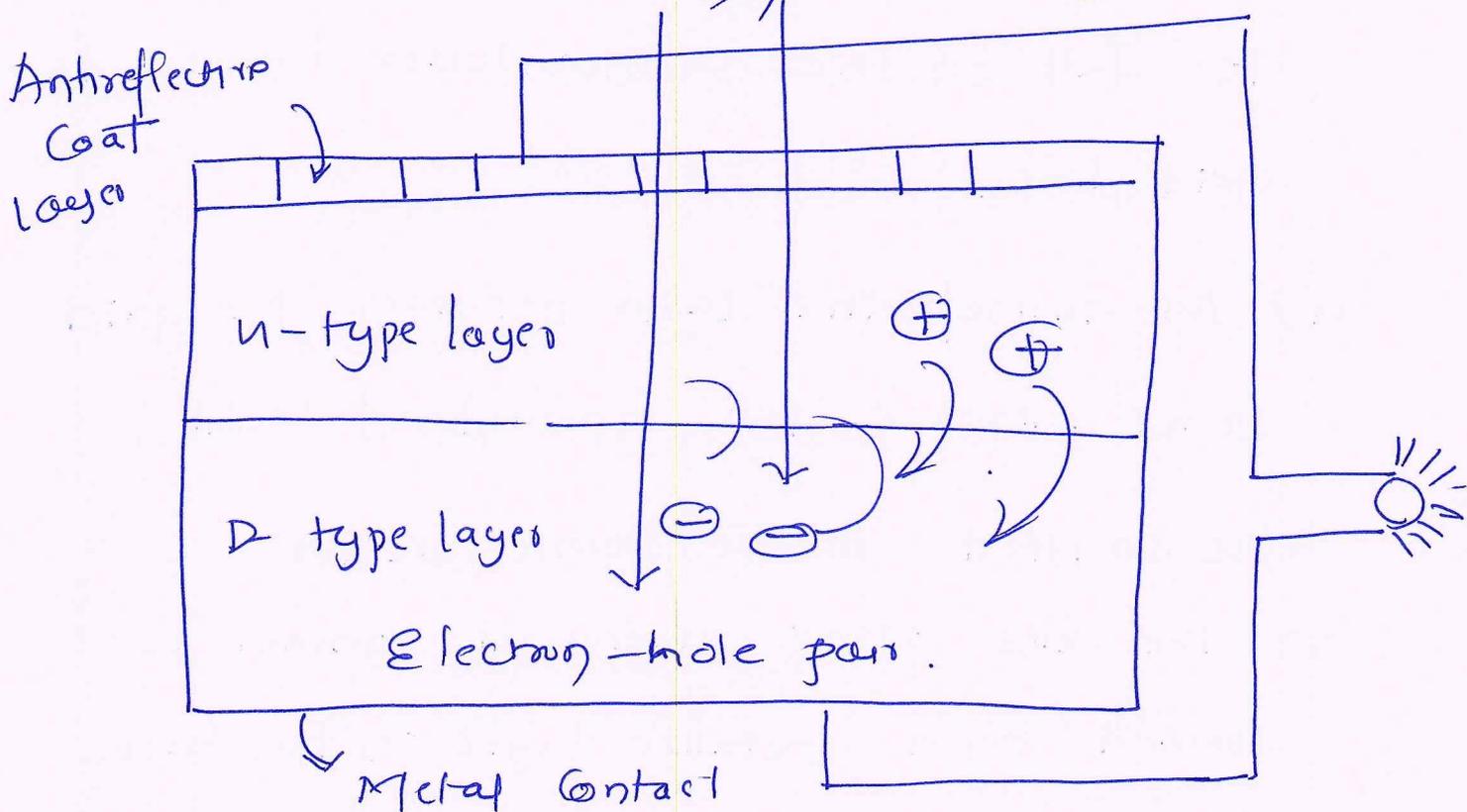
Principle and advantages of Solar

Photovoltaic cell (PV cell)

7marks L2 Q1.

Ans: — ~~Pro~~ Photovoltaic cells are
Semiconductor device which convert solar
energy into electrical energy

Photovoltaic cell is based on the principle
of Photovoltaic cell  - Sunlight



Construction and Working

- 1) A typical Silicon Photovoltaic cell is composed of a thin wafer consisting of an ultra thin layer of Phosphorous doped (n-type) Silicon on top of the boron doped (p-type) Silicon.
- 2) Hence p-n junction is formed between the two.
- 3) A metallic grid forms one of the electrical contacts of the diode and allows light to fall on the semiconductor between the grid lines.
- 4) An antireflective layer between the grid lines increase the amount of light transmitted to the Semiconductor.
- 5) The cells other electrical contact is formed by a metallic layer on the back of the Solar cells.

The sol-gel method is one of the most widely used approaches for preparing titanium dioxide (TiO_2)

1) Preparation of the sol and hydrolysis.

A titanium precursor such as titanium alkoxide is dissolved in ethanol. Controlled addition of water initiates hydrolysis, which breaks the metal-alkoxide bonds. This step must be well regulated because fast hydrolysis can cause large, uncontrolled particles, while slow hydrolysis helps to form nanosized TiO_2 particles.



2) Condensation

After hydrolysis, condensation reaction takes place. They link the hydrolyzed molecules through Ti-O-Ti bridges, forming small polymeric clusters. These clusters are evenly distributed within the

Sol giving the materials its uniformity



3) Gel formation

As condensation reaction progress,

small clusters of TiO_2 join together forming a continuous solid network dispersed in liquid. This semi-solid structure is known as a gel. The gel contains the titanium oxide precursor in a non-crystalline form.

4) Drying of the gel

The gel is dried to remove the solvent and volatile compounds. Drying leads to the formation of a porous, brittle solid called xerogel which contains the titanium oxide precursor in a non-crystalline form.

5) Heat treatment

The xerogel is then heated to convert the amorphous precursor into crystalline TiO_2 .

2) Cooling and dilution

After sufficient carbonization the beaker is removed from the heat source and allowed to cool slightly. The viscous coloured product is then carefully diluted with distilled water. This step converts the carbonized material into a water dispersed foam and produces a yellowish solution containing Q&D's.

3) Neutralization

Because the product is highly acidic due to residual citric acid and carboxyl group, it must be neutralized. A dilute solution of NaOH or ammonia is added drop wise until the pH reaches around 7. At this stage the solution becomes more stable and suitable for handling or further use.

Storage

The final QSD solution is generally stored in a closed container, preferably at low temperature (around 4°C), to maintain its optical properties to prevent microbial growth.

Applications of quantum dots in emerging electronics.

- ① Used in QLED displays
- ② Applied in quantum dot solar cells.
- ③ Serve as active layers in photodetectors.
- ④ Used in transistors and logic devices.
- ⑤ Integrated in LEDs
- ⑥ Employed in flexible and wearable electronics.

Module -2

Q3a Explain the size dependent properties (catalytic, optical properties and electrical conductivity) (6 Marks) L2 CO2.

Ans:- Catalytic Properties

The catalytic behaviour of nanomaterials is strongly dependent on size. The smaller nanoparticles expose more surface atoms and defect sites, which serves as active centres for chemical reactions. The presence of these high energy surface atoms facilitates faster reaction kinetics, lower activation energy and higher selectivity. Nanocatalysts like Pt, Au or Pd nanoparticles show remarkably higher ~~cat~~ catalytic activity in hydrogenation, oxidation and environmental pollutant degradation compared to their ~~bulk~~ bulk counterparts. The small size also allows uniform dispersion of nanoparticles on supports.

6) When light radiation falls on the p-n junction diode, electron-hole pairs are generated by the absorption of the radiation.

7) The electrons are drifted to and collected at the n-type end and the holes are drifted to and collected at the p-type end.

8) When these two ends are electrically connected through a conductor, there is a flow of current between the two ends through the external circuit.

9) Thus photovoltaic current is produced and available for use.

Electrical Conductivity

The electrical conductivity of nanomaterials depends on size, surface states and electron transport mechanisms. In metallic or semiconducting nanomaterials, electron can scatter off surface defects or grain boundaries more frequently as size decreases, which can reduce conductivity in some cases. However, in well structured nanowires, nanotubes or graphene sheets, electrons can travel over short distances with minimal scattering (ballistic transport) resulting in enhanced conductivity.

Q3b Explain Synthesis of Silicon based Quantum Dots by sol-gel method and Cd-Se quantum Dots by hot injection Method. (7 marks)

Ans:- Synthesis of TiO_2 nanoparticles by sol-gel method.

further, improving efficiency and stability.

Optical properties

Nanomaterials exhibit unique optical properties due to quantum confinement effects, which arise when the particle size approaches the exciton Bohr radius. In this regime, the electronic energy levels become discrete rather than continuous, leading to a size dependent band gap. Smaller nanoparticles have a larger band gap, which causes blue shifts in absorption and emission spectra, while larger nanoparticles show red shifts. The property is exploited in quantum dots (QDs), solar cells and bioimaging where the color of emitted light can be precisely tuned by controlling particle size. Additionally metallic nanoparticles like gold and silver exhibit surface plasmon resonance, which is also size dependent.

Principle of the HOT-INJECTION Method

The Selenium precursor is rapidly injected into a hot solution of cadmium precursor. The sudden injection causes instant nucleation. Temperature is then reduced or controlled to allow slow growth of nano-crystals. This separates nucleation from growth giving uniform particle size and bright photoluminescence.

Procedure

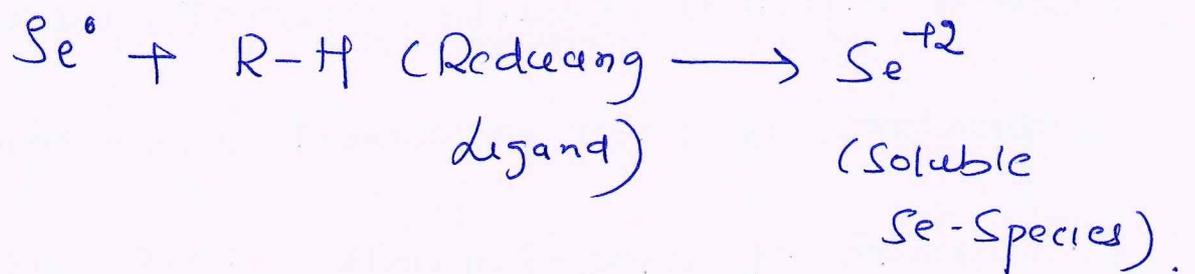
Cd precursor is prepared by combining cadmium salts with high boiling coordinating solvents / ligands such as phosphines / amines organic ~~sol~~ acids



This mixture is heated to a high temperature.

Separately, a reactive selenium precursor is prepared using a suitable coordinating agent such as

trioctyl phosphine (TOP). TOP helps dissolve elemental Selenium and gently reduces it to a reactive Selenium species, that can readily react with Cadmium during the hot injection step.



The Selenium precursor is quickly injected into the hot Cadmium-ligand solution maintained at high temperature (300°C). This sudden addition causes a momentary supersaturation of reactive Se^{+2} ions in the solution. Because the solution is already hot and the Cadmium ions are activated, this supersaturation leads to the simultaneous formation of many small CdSe nuclei.



Q3 5 Discuss synthesis and properties of Chitosan - Carbon quantum dots hydrogel and its applications in next generation flexible and wearable electronics

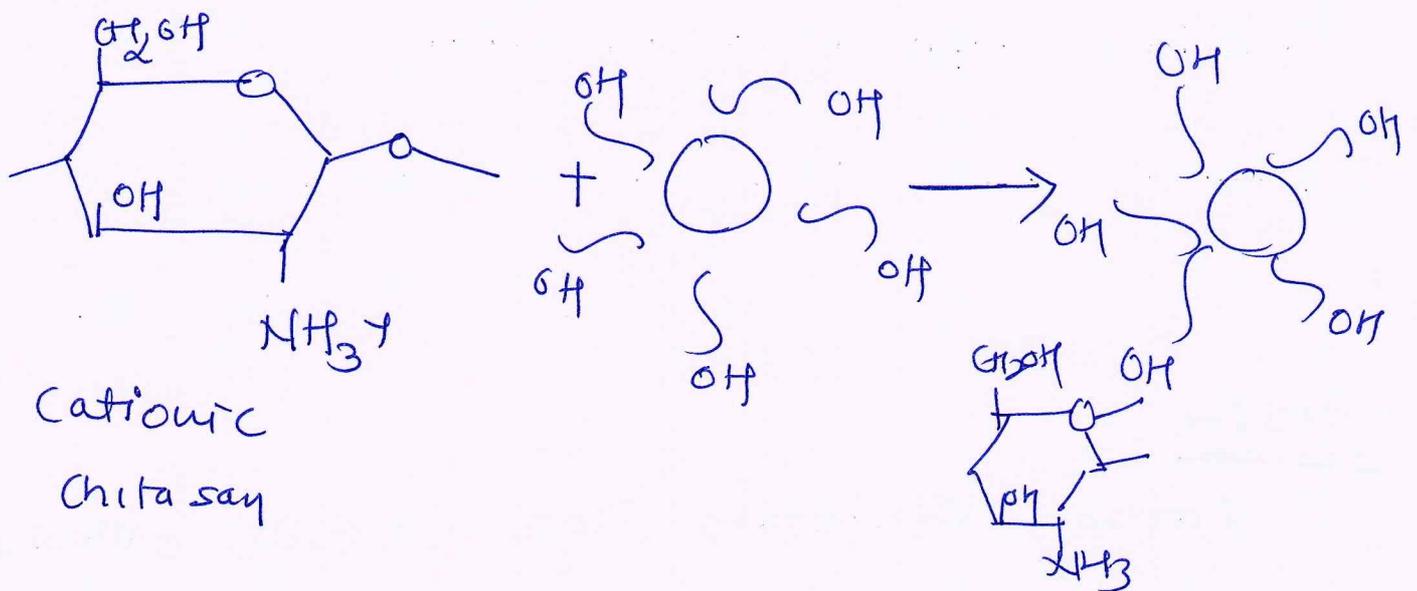
7 marks L2 CO2.

Ans:-

Carbon Quantum Dots (CQDs) Synthesis

Carbon quantum dots are typically synthesized by heating a carbon rich precursor such as glucose or citric acid in water until it carbonize into nanosized fluorescent particles. These CQD usually possess surface functional groups including carboxyl ($-COOH$) & hydroxyl ($-OH$) groups, which makes them water-soluble and highly compatible with biopolymers. After synthesis the mixture is purified - commonly through filtration & dialysis to remove larger impurities giving

a clear CO₂D solution enriched with these functional groups,



Applications :

1. Chitosan-CO₂D hydrogels serve as highly stretchable strain sensors, capable of tracking human motion, joint bending and gestures with excellent mechanical durability.
2. Their intrinsic pH-responsiveness enables wearable biochemical monitors. Such as sweat analysis patches for real-time health tracking.

3. The (QD) fluorescence within the hydrogel enables optical or light responsive wearable devices. including photo activated switches and optoelectronic skins.

4. Chitosan - QD hydrogels can act as chemical or ion sensors. detecting analytes like heavy metals through (QD) fluorescence quenching for environmental or on skin monitoring.

Q4a What are Quantum dots (QDs)? Explain optical and electronic properties of quantum dots. (QDs) 6 marks L2 CO2.

Quantum dots can be categorized by their structure, composition and application

Optical properties :-

Size tunable emission :- The most prominent property is that the colour of light a QD emits

can be precisely controlled by changing its size
smaller dots emit shorter wavelengths (blue-green)
and larger dots emit longer wavelengths (orange-red)

High brightness and quantum yield. :-

QDs are known for their high brightness and fluorescence quantum yield, meaning they are very efficient at emitting light after being excited.

Photo stability

Unlike organic dyes, QDs are highly resistant to photobleaching, meaning their fluorescence does not degrade quickly when exposed to light.

Broad absorption and narrow emission

QDs absorb light over a broad range of wavelengths but emit it in a very narrow, specific band which makes them useful for precise applications like imaging and displays.

Smaller QD's. have a smaller band gap

emitting longer wavelengths of light (orange to red)

Broad absorption : Quantum dots can absorb a wide range of incoming light frequencies from UV to visible light

Narrow emission : When excited QD's emit light at a very specific and narrow range of wavelengths leading to vibrant and pure colors.

4 D. Explain Synthesis of TiO_2 nano particles by sol-gel method and its uses in sensor applications (7 marks) L2 CO2.

Ans:- The sol-gel method is one of the most widely used approaches for preparing titanium dioxide (TiO_2) nanoparticles because it offers excellent control over purity, composition and particle size.

Electronic Properties

Quantum Confinement :- Electrons and holes are confined in all three dimensions, leading to quantized energy levels (similar to an electron in a box).

Discrete Energy levels :- The density of states is made of discrete, delta like functions rather than a continuous range found in bulk materials,

Size dependent band gap :- As the size of the quantum dot decreases, the band gap increases. This is because the confinement effect is stronger in smaller particles, requiring more energy for an electron to jump from the valence band to the conduction band.

Size dependent emission :- The colour of the light emitted by a QD is determined by the band gap which is set by its size.

It is a chemical process based on the gradual transformation of a liquid solution (sol) into a solid network (gel). TiO_2 nanoparticles produced through this technique are commonly used in photocatalysts, sensors, pigments and solar energy applications.

Preparation of the Sol & Hydrolysis

A titanium precursor such as a titanium alkoxide is dissolved in ethanol. Controlled addition of water initiates hydrolysis which breaks the metal-alkoxide bonds. This step must be well regulated because fast hydrolysis can cause large, uncontrolled particles, while slow hydrolysis helps to form nanosized TiO_2 particles.



Condensation

After hydrolysis condensation reaction takes place. They link the hydrolyzed molecules through $Ti-O-Ti$ bridges, forming small polymeric clusters. These clusters are evenly distributed within the sol, giving the material its uniformity.



3) Gel Formation

As condensation reactions progress small clusters of TiO_2 join together, forming a continuous solid network dispersed in liquid. This semi-solid structure is known as a gel. The gel contains partially polymerized $Ti-O-Ti$ structures and trapped solvents.

4) Drying of the Gel

4C7 Discuss synthesis and properties of Graphene Quantum Dots using citric acid method and its applications in emerging electronics. (7 marks) d_2 CO_2

Ans:-

Synthesis

Melting and Carbonization

A small quantity of citric acid is placed in a clean beaker and gradually heated to around $180-200^\circ C$. At this temperature, citric acid first melts into a transparent liquid and then slowly changes colour from yellow to orange and finally brown. Indicating the onset of carbonization. This transformation represents the formation of small carbon rich clusters. which ultimately develop into graphene quantum dots.

The gel is dried to remove the solvent and volatile compounds. Drying leads to the formation of a porous, brittle solid called a xerogel, which contains the titanium oxide precursor in a non-crystalline form.

Heat Treatment (Calcination)

The Xerogel is then heated (calined) to convert the amorphous precursor into crystalline TiO_2 . The step converts the amorphous material into crystalline TiO_2 nanoparticles.

Applications

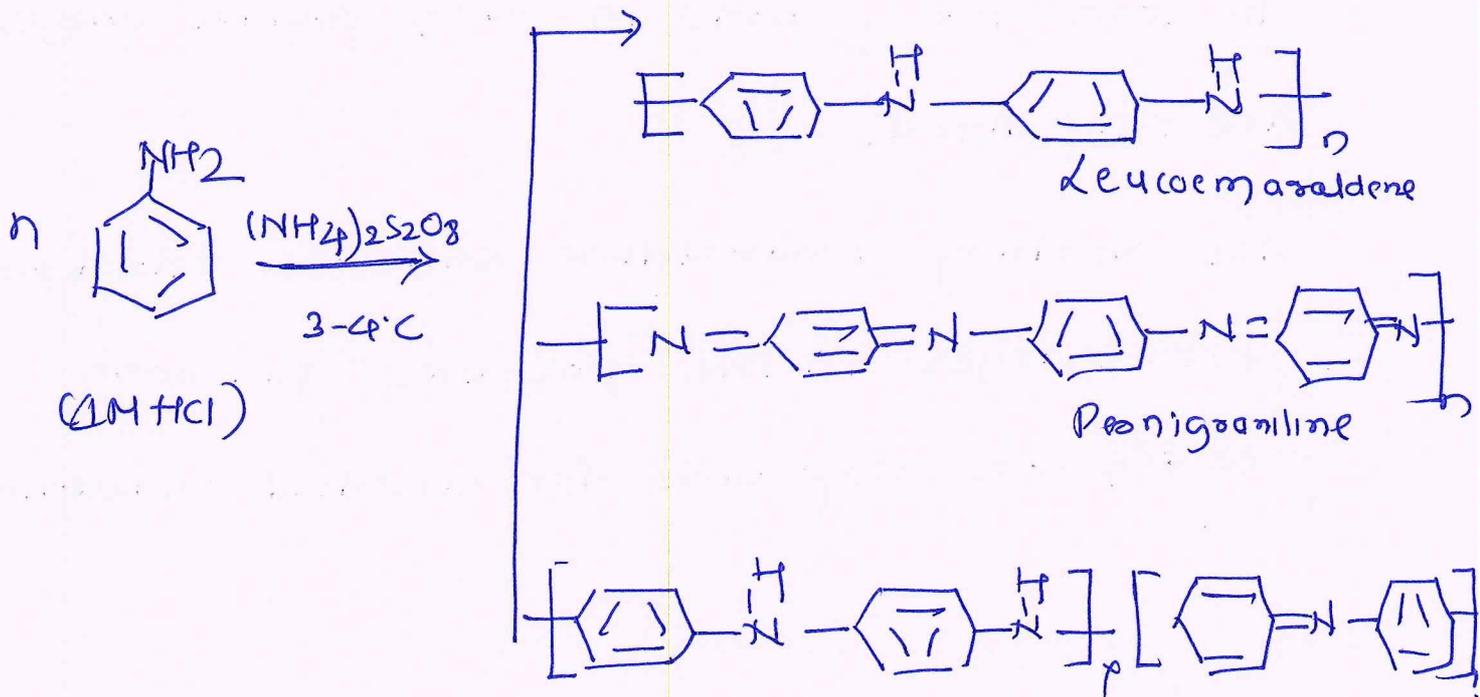
- (1) Used in gas sensors
- (2) Applied in humidity sensors
- (3) Used in Biosensors
- (4) Used in UV sensors
- (5) Integrated into chemical sensors
- (6) Employed in electrochemical sensors.

Module-3.

Q5a) Explain Synthesis and Conduction

mechanism of polyaniline G marks 12 CO_3 .

Ans:- Polyaniline is obtained by polymerisation of aniline dissolved in 1M HCl at $3-4^\circ C$ in the presence of ammonium ~~sulfate~~ persulfate as an initiator. The product consist reduced form of polyaniline which is called leucoemeraldine, oxidized form of polyaniline which is called pernigraniline and an emeraldine base consisting of both forms



Mechanism of conduction in polyaniline

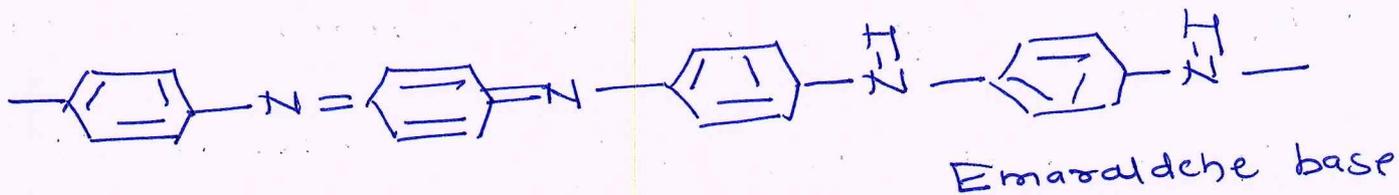
Conducting form of polyaniline is obtained from emeraldine base consisting of equal proportions of amine ($-NH$) and imine ($=N-$) sites.

Protonation of each imine group introduces one +ve charge into polymeric backbone.

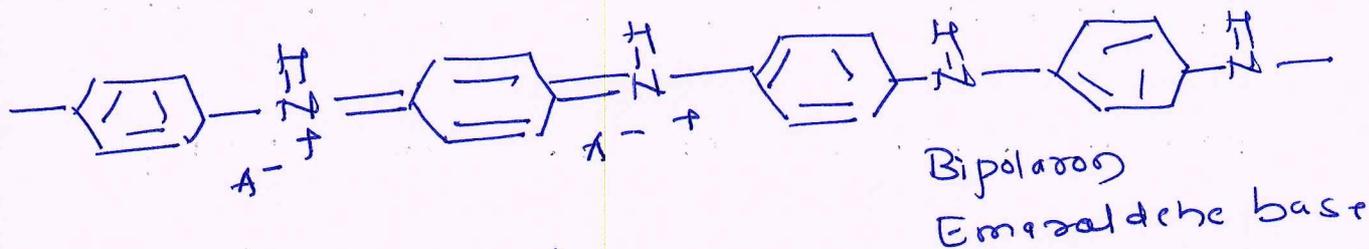
Therefore, when this base is treated with aqueous HCl two nearby imine sites are protonated to form a bipolaron.

The bipolaron then undergoes a further rearrangement to form two polarons in which positive charges are delocalized.

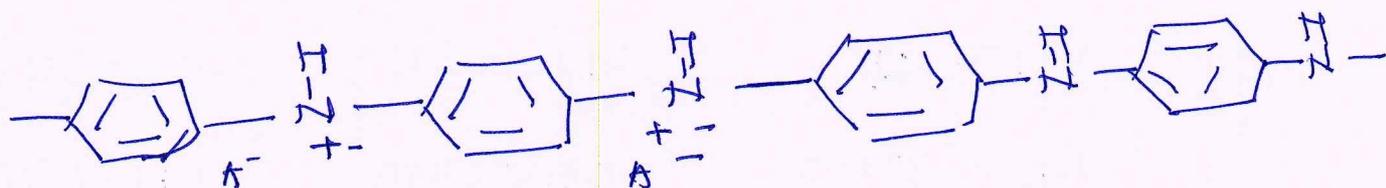
The resulting emeraldine salt has delocalized +ve charges in the polymeric backbone which are responsible for electrical conductivity.



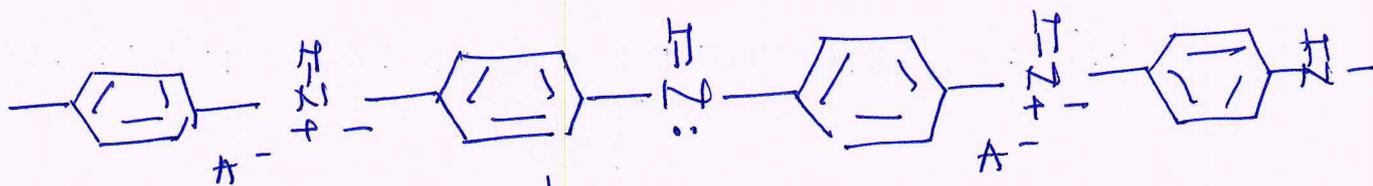
H^+A^- ↓ Protonation



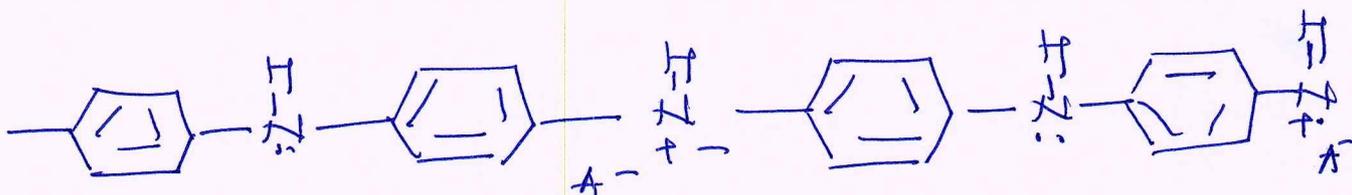
↓ Dissociating of Bipolaron to form
two polarons with two positive
charges on ~~the~~ its backbone.



↓ Delocalization of Polarons



↓ Resonance form of
delocalized polaron lattice



5 b) A Sample of polymer contains 20 molecules of molecular mass 3000, 30 molecules of molecular mass 5000 and remaining molecules of molecular mass 7000. Calculate number average weight average molecular mass and polydispersity index. (7 marks) L₂ CO₃

Ans:-

~~Number~~

$$n_1 = 20$$

$$n_2 = 30$$

$$n_3 = 50$$

$$M_1 = 3000$$

$$M_2 = 5000$$

$$M_3 = 7000.$$

$$\sum n_i = n_1 + n_2 + n_3 = 20 + 30 + 50 = 100.$$

$$\bar{M}_n = \frac{[(20 \times 3000) + (30 \times 5000) + (50 \times 7000)]}{100}$$

$$= \underline{\underline{5600}}$$

=

$$\bar{M}_w = \frac{\sum N_i M_i^2}{\sum N_i M_i}$$

$$= \frac{n_1 M_1^2 + n_2 M_2^2 + n_3 M_3^2}{N_1 M_1 + N_2 M_2 + N_3 M_3}$$

$$= \frac{[20 \times (3000)^2] + [30 \times (5000)^2] + [50 \times (7000)^2]}{[20 \times 3000] + [30 \times 5000] + [50 \times 7000]}$$

$$= \underline{\underline{5600}}$$

=

$$DDI = \frac{\bar{M}_w}{\bar{M}_n} = \frac{5600}{5600} = \underline{\underline{1}}$$

Q50 Discuss working principle of lithography for micro-patterned copper depositing

(mask) Li_2CO_3

Ans:

Principle :-

The basic principle relies on using light sensitive material called photoresist to selectively expose certain regions of the surface.

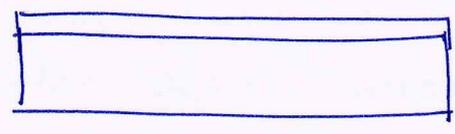
When UV light passes through the ~~transparent~~ transparent areas of the mask, it modifies the solubility of the photoresist. After development this results in well defined openings or protected areas that guide where copper will either be deposited. (in additive processes) or removed (in subtractive processes) thus, lithography enables highly precise copper patterning on the micro scale.

Etching

The process begins by coating the copper covered substrate with a thin, uniform layer of photoresist. A common example for positive photoresist is a mixture of a diazoquinone (DQ) and Norolac resin and for negative photoresist is mixture of cyclopentanone and epoxy based resin.

In positive resist the regions exposed to UV light become more soluble and are removed during development. The choice of resist depends on the required feature size and process method. After coating the substrate is aligned with a photomask that contains the desired copper pattern. UV light is then shone through the mask exposing selected parts of the resist. This exposure changes the chemical structure of the resist according to whether it is positive or negative. The substrate is subsequently placed in a developer solution, which removes either the exposed or unexposed portions of the resist. This step creates the micron scale openings or protective regions that form the template for copper patterning.

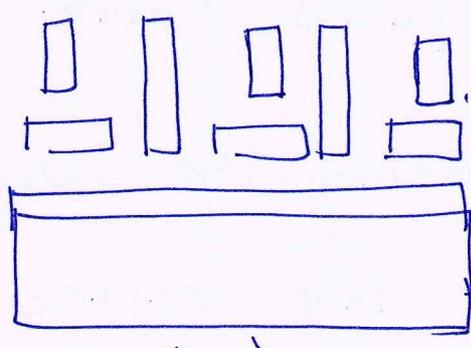
1. Deposition
of photoresist



Resist
layer

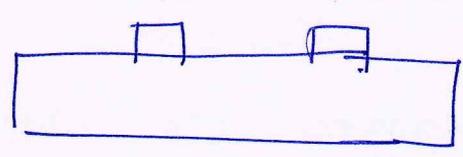
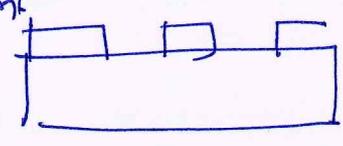
2 Exposure of
Photoresist

Photon



Mask

3 Development



Positive
Photoresist

Negative
Photoresist

6a. What are polymer composites? Explain the synthesis & properties of epoxy resin magnetite (Fe_3O_4) composite from ultra-sonication method.

→ Two or more distinct components which combine to form a new class of material suitable for structural applications are referred to as composite materials. A composite containing polymer matrix is known as fiber reinforced polymer composite synthesis.

Fe_3O_4 nanoparticles are commonly synthesized by the co-precipitation method, where ferrous & ferric salts such as $FeCl_2$ & $FeCl_3$ are mixed in an aq. soln under alkaline conditions (NH_4OH or $NaOH$) at elevated temp ($60-80^\circ C$) with constant stirring. The reaction leads to the formation of Fe_3O_4 nanoparticles.



To prepare the epoxy resin- Fe_3O_4 composite, Fe_3O_4 nanoparticles are first dispersed in a suitable solvent

Such as Ethanol & sonicated for 30-60 min. using an ultrasonic probe to break agglomerates.

The epoxy resin is added & the mixture is sonicated briefly (10-15 min) to ensure uniform incorporation of nanoparticles.

A curing agent, commonly (TETA) or (DETA) is then mixed & composite is allowed to cure at room temp. to form nanocomposite.

6b. Discuss the synthesis & properties of Kevlar Fiber Reinforced polymer (KFRP) for smart electronic devices applications.

→ Synthesis

① In the beginning Kevlar fibers & polymer resin such as epoxy resin followed by surface treatment of the fibers to improve adhesion

* The treated fibers are arranged in the desired orientations such as unidirectional, woven, or layered

* The polymer resin is thoroughly impregnated into the fibers using techniques like hand lay-up, vacuum-assisted resin infusion, resin transfer molding & composite

is cured under controlled temp & pressure to solidify the material.

- * Optional post-processing like ~~mach~~ machining or surface finishing can be done, & the resulting CFRP exhibit high tensile strength, low density & chemical stability suitable for aerospace engineering

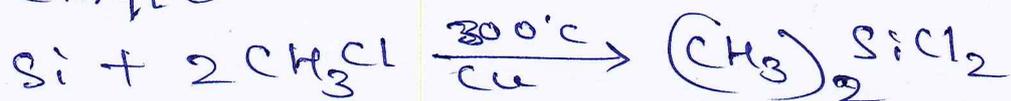
Properties

- * High tensile strength
- * Lightweight
- * Thermal stability
- * Chemical Resistance
- * Flexibility & Repairability

Q.C. Explain the synthesis, properties of PDMS & its uses in E-shims

→ Synthesis

- * Elemental silicon reacts with methyl chloride at elevated temp to form dimethyl dichloro silane



- * The prod is purified by distillation then dimethyl silane undergoes hydrolysis to produce silanol-



* These silanol groups subsequently undergo condensation polymerisation to form the siloxane backbone & generating linear PDMS.



Properties

- * very flexible due to the Si-O backbone
- * Low glass transition temp
- * High optical transparency
- * High gas permeability
- * Resistance to water.
- * Hydrophobic surface

Uses in e-skin →

PDMS-based e-skin works by combining PDMS with conductive or functional materials such as graphene, carbon nanotubes or silver nanowires.

For pressure sensing when the PDMS layer is stretched or compressed, the spacing between conductive elements changes, altering resistance or capacitance, which can then be measured electrically.

Q7 Discuss types of electrodes with example

→ i) Metal - Metal ion electrode

An electrode of this type consists of a metal dipped in a solⁿ containing its own ions

Potential of this electrode is due to oxdⁿ of metal to metal ion & reduction of metal ion to metal

ii) Metal - insoluble salt Electrode →

In this electrode a metal is in contact with its insoluble salt which is further in contact with a solⁿ containing the anion same as the anion of insoluble salt. Potential arises in this electrode due to oxdⁿ of metal to its insoluble salt & reduction of insoluble salt to metal.

Ex → Calomel electrode

iii) Gas Electrode: In this electrode

an inert metal like platinum is in contact with gas molecules & also with the ionic solⁿ of the same gas molecules. Potential arises in this electrode due to oxdⁿ of gas molecules to its ion

of redⁿ of ion into gas molecules.
Ex → SHE

(v) Amalgam electrode → Amalgam is the alloy of any metal with mercury. In this electrode, amalgamated electrode is in contact with ionic solⁿ of the metal. Potential of this electrode is due to oxⁿ of metal to its ion of redⁿ of metal ion to metal.
An inert metal like Pt is used to pick the potential.
Ex → $Zn(Hg) | Zn^{2+} (xM)$

(vi) Redox electrode → In this electrode potential arises due to presence of ions of a chemical species in two different oxⁿ states.
Ex → $Pt, | Fe^{2+}, Fe^{3+}$

(vii) Ion selective electrode → In this electrode, a suitable membrane separates two solⁿs, containing similar ions of different concⁿ & acts as an electrochemical membrane. A potential called boundary potential develops across the membrane due to difference in the concⁿ of ions.
Ex → Glass electrode

Q.7
Discuss instrumentation & application of potentiometric sensor for the estimation of iron in steel.

- A potentiometric instrument consist of
- * An indicator electrode
Ex Pd electrode in red-ox reactions
glass electrodes in acid-base reactions
 - * A standard reference electrode
Ex - Calomel or Ag-AgCl electrode
 - * A meter to measure the variation in potential

Applications of potentiometry - Estimation of Fe

pipette out 25 ml of Fe solⁿ into a clean beaker. Add 1 test tube of sulphuric acid. Immerse the calomel-platinum electrode assembly into the solⁿ & measure the initial potential. Add $K_2Cr_2O_7$ from the micro burette in the increments of 0.5 ml. The following changes take place.



Apply Nernst's eqⁿ for the above

$$E = E^0 + \frac{0.0591}{n} \log \frac{[Fe^{3+}]}{[Fe^{2+}]}$$

Reaction

The potential of the indicator electrode increases gradually as the conc of Fe^{3+} increases after each addⁿ of $K_2Cr_2O_7$. There will be rapid jump at the equivalence point as the pt electrode changes from $Pt/Fe^{3+}/Fe^{2+}$ to $Pt/Cr^{6+}/Cr^{3+}$.

To identify the exact equivalence point plot a graph of $\Delta E/\Delta V$ against the vol^m of $K_2Cr_2O_7$.

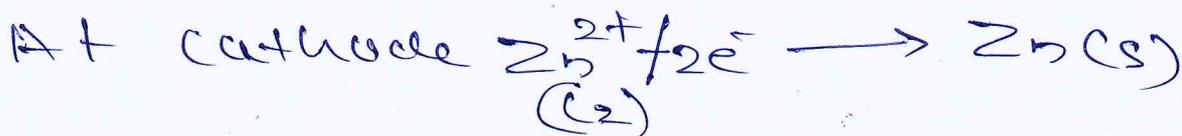
What is concⁿ cell?

IE Concentration cells are the galvanic cells in which both half cells will have same electrode & electrolyte material but emf will be generated due to difference in the concⁿ of electrolyte.

cell represents



Cell Reaction



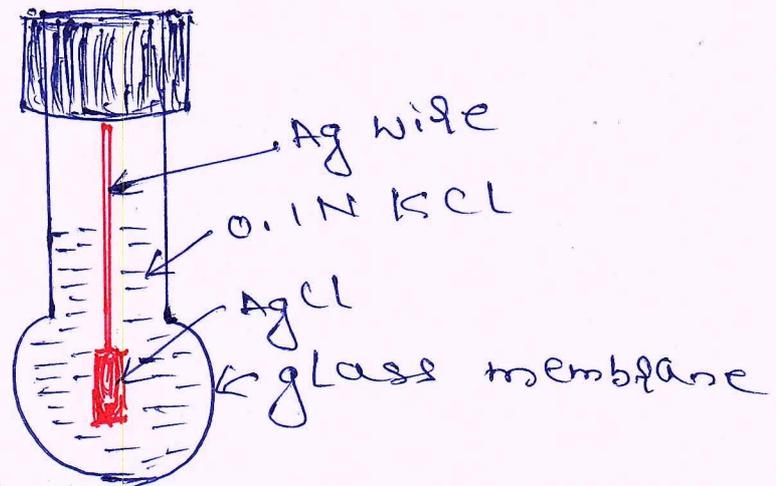
$$E_{cell} = \frac{0.0591}{n} \log \left(\frac{C_2}{C_1} \right) \text{ at } 298K$$

$$E_{\text{cell}} = \frac{0.0591}{2} \log \left(\frac{0.4}{0.02} \right)$$

$$= \underline{\underline{8.89 \times 10^{-3} \text{ V}}}$$

Q.8 Discuss construction & working of glass electrode

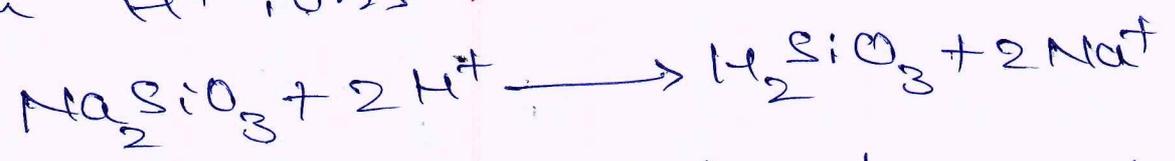
→



construction →

The glass electrode consists a very fragile glass bulb made up of corning glass. The composition of corning glass is 72% SiO_2 , 22% Na_2O , 6% CaO . The glass bulb is filled with 0.1N HCl which acts as internal reference solⁿ. A silver wire fused with silver chloride is dipped in HCl solⁿ. It acts as internal reference electrode & provides electrical contact.

Working → Silica gel membrane used in glass electrode constructs is made by fusing Na_2CO_3 with SiO_2 . When the membrane comes in contact with 0.1 N HCl (Internal reference soln) the Na^+ ions present in the internal layer of the membrane are replaced with H^+ ions.



Similar reaction will take place at the outer layer of the membrane when glass electrode is dipped in an unknown sample containing H^+ ions (or H^+). Therefore either sides the membrane will be hydrated. Due to the difference in the conc of H^+ ions on both sides a potential called boundary potential is developed across the membrane. The developed boundary potential is measured using Ag-AgCl wire. The measure of this potential gives the conc of H^+ ions in unknown sample.

8b This 'Describe instrumentats & application of colorimetric sensor in the estimats of copper in PCB with diagram.

→ Instrumentats

- i) Light source: Tungsten bulb is used as a light source
- ii) Filter or grating: To get a mono chromatic light
- iii) Sample Holder: To keep the sample in the path of light
- iv) photocell/detector: To detect the intensity of transmitted light
- v) Amplifier: For increasing the power of a signal
- vi) Display Unit: To read out absorbance / transmittance

Application of colorimetry - Estimation of copper

Principle:- Copper forms intense blue colour complex with ammonia. The intensity of blue colour is proportional to the amount of copper.

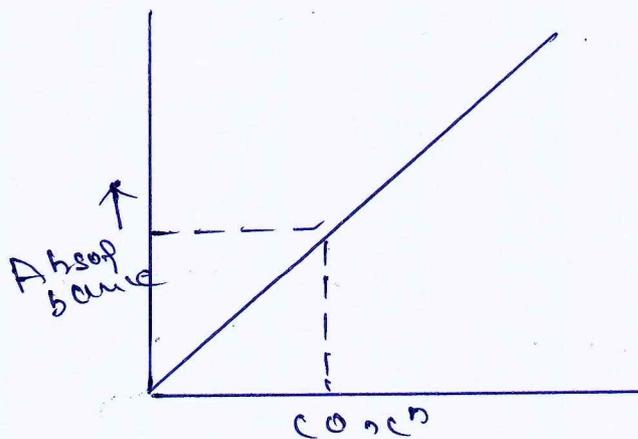


The resulting blue complex exhibits maximum absorbance at 620nm.

Procedure →

Fill the burette with given CuSO_4 soln. Draw out 4, 8, 12, 16, 20 ml of CuSO_4 into five separate 50 ml volumetric flasks from the burette. Add 5 ml of NH_3 soln to each one of them including the blank & test solns. Make up all the soln exactly up to the mark with distilled water. Mix well for uniform concn. The absorbance of all these solns is measured at 620 nm against blank soln using colorimeter.

Plot the graph of absorbance against volm of CuSO_4 to get calibration curve. Finally by knowing the absorbance of test soln, the volm of CuSO_4 in the test soln can be determined.



8c Explain the principle & instruments of conductometric sensor & its application in the estimation of acid mixture.

→ Principle →

The conductometric sensor functions based on the fact that many chemical reactions in solutions produce changes in the electrical conductance due to changes in ionic compounds. The change in conductivity is measured & correlated with the concⁿ of analyte in the sample.

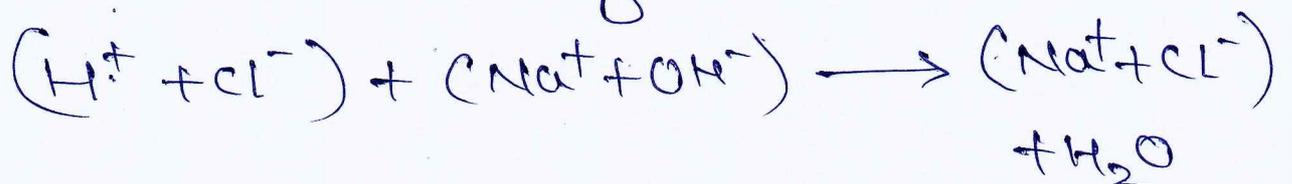
Instruments →

The basic unit used in measuring the conductivity of a solution is called conductivity cell. It consists of two Pt foils coated with Pt black, separated by unit distance l cm & area of cross section equal to A sq cm.

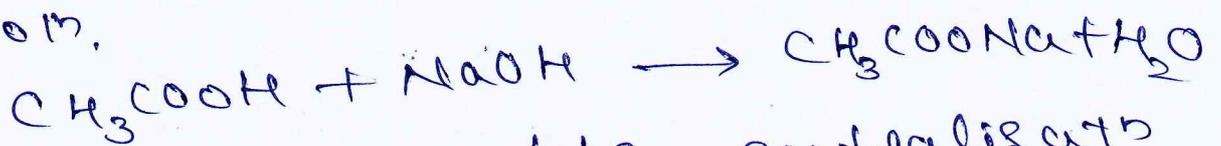
The foils are sealed to glass so that the distance betⁿ them remains const. For a given cell, l & A are const. & the quantity (l/A) is called the cell const (k) $k_{cell} = l/A$

Application in estimation of acid mixture

pipette out known vol^m of acid mixture into a cleaned beaker. Fill the burette with std NaOH. Due to common ion effect the weak acid remains un-dissociated. Upon adding the alkali to acid mixture the conductance decreases due to highly mobile H⁺ ions of HCl are replaced by slow moving Na⁺ ions.



The trend will continue till all HCl is neutralised. Once the strong acid is neutralised the weak acid begins to dissociate & gets neutralised. This results to increase the conductance of solⁿ.



After the complete neutralisation of CH₃COOH addition of NaOH will result in addition of the fast moving OH⁻ ions. Hence conductivity increases rapidly.

9a What is e-waste? Explain the need for e-waste management.

→ The Electronic waste also called e-waste is various forms of electric & electronic equipment that have no longer satisfy their original purpose

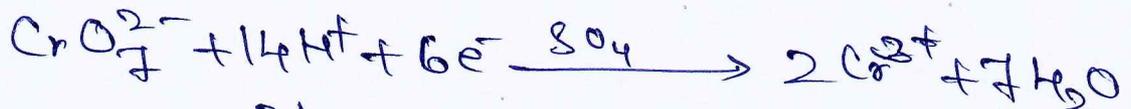
Need for E-waste Management

- * Cause Harm to Environment & Human Health.
- * Decrease Raw Material Demand
- * Energy efficiency
- * Reduce Greenhouse gas Emissions
- * ~~The social benefits of e-waste~~

9b Apply the principles of electroplating to explain the process of Cr plating used for Hard & Decorative coating.

Bath condn	Decorative Cr	Hard Cr
Bath compositn	250-300 g/l Chromic acid + 2.5-3.0 g/l con. H_2SO_4	250-300 g/l Chromic acid + 2.5-3.0 g/l con. H_2SO_4
Operating Temp	45-55°C	45-55°C
Current density	100-200 mA/cm ²	215-430 mA/cm ²
Current efficiency	10-15 %	17-21 %

Anode:	In soluble anode : Pb-Sn of Pb-Sb coated with PbO ₂	In soluble anode : Pb-Sn of Pb-Sb coated with PbO ₂
Cathode:	Article to be plated	Article to be plated



90. What is CPR? A thick steel sheet of area 80 inch² is exposed to moist air. After 6 months it was found to experience a weight loss of 340 g due to corrosion. If the density of steel is 7.9 g/cm³. Calculate the corrosion penetration rate in mpy & mmpy (PS = 534 in mpy & 87.6 mmpy)

→ Is the speed at which any metal or alloy deteriorates in specific corrosive environment through chemical or electrochemical reaction.

$$CPR = \frac{L \times W}{D \times A \times T}$$

mmpy

$$CPR = \frac{534 \times 340 \times 1000}{7.9 \times 80 \times 6.45 \times 6 \times 30 \times 24}$$

$$= 10.310 \quad \text{mmpy}$$

mmpy

$$CPR = \frac{87.6 \times 340 \times 1000}{7.9 \times 80 \times 6 \times 30 \times 24}$$

$$= 10.908 \quad \text{mmpy}$$

10a What is metal finishing? Explain technological importance of metal finishing.

→ Metal finishing is the name given to wide range of processes carried out to modify the surface properties.

Technological importance

- * Offer corrosion resistance
- * Impact abrasion & wear resistance
- * Impact thermal & impact resistance
- * Provide electrical or thermal conductors
- * Manufacture of PCB's

106. Discuss the Electrochemical theory of corrosion taking iron as an example.

→ According to this theory the corrosion of metals under corrosive environment is due to formation of large number of galvanic cells i.e. anode & cathodic regions on the same metal.

* Under corrosive environment if two dissimilar metals are in contact or when metal is under stress or defects are present on the surface of the metal anodic & cathodic regions are formed.

* During the corrosion, oxides of the metal at anode & reduction of the species present at cathode will take place.

The metal acts as electronic conductor & the moisture acts as medium for ionic conduction.

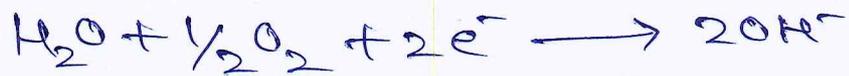
Corrosion reactions are



At cathode During O_2 absorption
a) If medium is acidic



ii) In the medium is basic of neutral



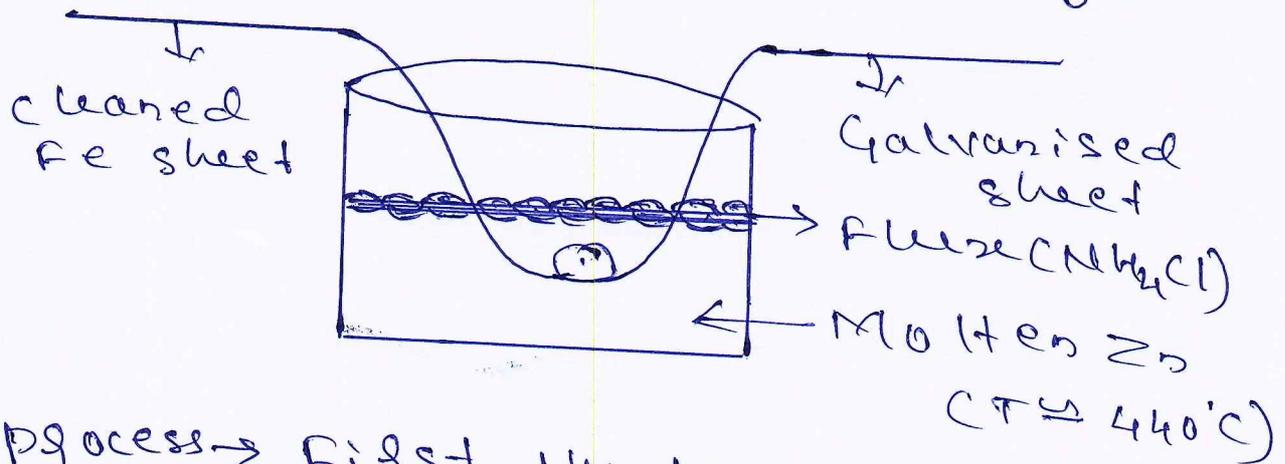
iii) corrosion of iron produces Fe^{2+} & OH^- ions at anode & cathode respectively

Therefore overall rxn can be written as



10c. Apply the concept of galvanisation to prevent corrosion in steel structures exposed to marine environments. Justify your choice with appropriate chemical reasoning.

→ Galvanisation → It is a process of coating a base metal (iron) with Zn metal. This process is usually carried out by Hot dipping method.



Process → First the base metal surface is washed properly with organic solvents to remove any organic matter. (like oil, grease etc) on the surface afterwards it is washed with dil H_2SO_4 to remove

any inorganic matter (like rust). Finally the base metal is well washed with water & air dried. The base metal then dipped in a bath of molten zinc maintained at $425-430^{\circ}\text{C}$ & covered with a flux of NH_4Cl to prevent the oxides of molten Zn. Then excess Zn on the surface is removed by passing through a pair of hot rollers, so that a proper thin coating is obtained.

Prepared by

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(Do V. + ex lab)

~~By~~
(G.S. Khandelwal)

Sure