

Module 3: Materials for Energy Systems

Nanomaterials: Introduction, Synthesis of TiO₂ nanoparticles by the sol-gel method and their uses in catalytic converters. Size-dependent properties of nanomaterial: surface area, catalytic, electrical and thermal conductivity. Graphene - Synthesis by chemical vapour deposition (CVD) method, properties and engineering applications. Role of carbon nanotubes (CNTs) in energy devices.

Energy Systems: Batteries – Introduction, classification of batteries, characteristics (capacity, power density, shelf life and cycle life). Construction, working and applications of Li-ion battery. Fuel cells - Introduction, Construction and working of solid oxide fuel cells (SOFCs) and its uses in auxiliary power units (APUs). Differences between fuel cell and battery. Solar photovoltaic cells (PV cells) - construction, working, advantages and limitations.

Nanomaterials:

The term nano originated from the Greek nanos which means ‘dwarf’. It is one billionth of a meter. The size of the materials at least in any one of its dimension ranges between 1 to 100 nm is called nanomaterial.

Size-dependent properties

Surface area to volume ratio:

The total surface area (or) the number of surface atoms increases with the reduction in size of the particles. The physical and chemical properties of nanomaterials are size-dependent because, at the nanoscale, more surface area is exposed than in bulk materials. If bulk materials are subdivided into nanomaterials, the collective surface area increases significantly, as shown in the figure.

The change in surface-to-volume ratio when breaking down molecules invariably affects physical, chemical, mechanical, and other properties.

1. **Surface-to-Volume Ratio:** Nanomaterials have a high surface-to-volume ratio, which means a larger fraction of atoms are on the surface compared to bulk materials. This increases the surface energy and reactivity.
2. **Chemical Reactivity:** The increased surface area enhances the chemical reactivity of nanomaterials. This is beneficial in applications like catalysis, where nanoparticles can provide more active sites for chemical reactions.

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

3. **Adsorption Properties:** High surface area makes nanomaterials excellent for adsorption applications. They can effectively adsorb gases, liquids, or other substances, making them useful in sensors, environmental remediation, and filtration.
4. **Surface Functionalization:** Nanomaterials can be easily functionalized with various chemical groups due to their high surface area. This allows for tailoring their properties for specific applications, such as targeted drug delivery or improved compatibility in composite materials.
5. **Surface Energy:** High surface energy can lead to agglomeration of nanoparticles to minimize the energy. This needs to be controlled or utilized depending on the desired application, such as in the stabilization of emulsions.

Catalytic properties

The catalytic activity of the catalyst increases with an increase in surface area, hence the nanomaterial exhibits better catalytic activity. Better catalytic activity can be achieved only by precisely controlling the size, shape, spatial distribution and surface composition of the individual nanocomponents. Since nanoparticles have a large surface-to-volume ratio compared to bulk materials, they are attractive candidates for use as catalysts.

High Reactivity: The high surface-to-volume ratio makes nanomaterials highly reactive, which is advantageous in catalytic applications.

Surface Functionalization: Nanomaterials can be easily functionalized with various chemical groups, enhancing their reactivity and specificity for targeted applications.

Example,

- Gold in macro medium is an inert catalyst, whereas on the Nano scale it acts as a good catalyst.
- Hydrogen production by steam reforming ethanol over nanostructured indium oxide catalysts

Electrical property

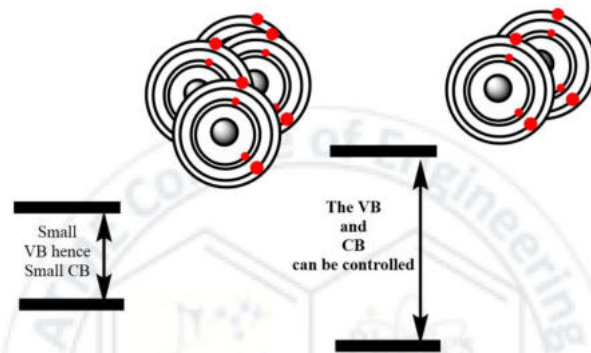
The properties like conductivity or resistivity come under category of electrical properties. These properties are observed to change at the nanoscale level, like optical properties.

When several atoms are brought together into a molecule, their atomic orbitals split and produces several molecular orbitals proportional to the number of atoms.

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

In solids, there are so many atoms that the difference in energy between them becomes minimal, so that they form bands of energy rather than discrete energy levels form nearly continuous bands of states.

Each band has a width that reflects the interaction between atoms, with a bandgap between the conduction and the valence bands that reflects the original separation of the bonding and antibonding states.



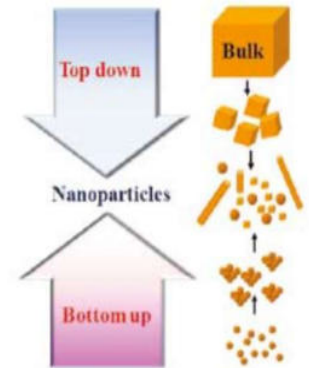
Thermal Properties

- **Thermal Conductivity:** - Nanomaterials can exhibit different thermal conductivity compared to their bulk forms. For instance, carbon nanotubes have very high thermal conductivity due to their one-dimensional structure and strong covalent bonding along the tube axis. - The reduction in size to the nanoscale can lead to an increase or decrease in thermal conductivity depending on the material and its structure. Quantum effects and increased phonon surface scattering play a significant role.
- **Heat Capacity:** - The specific heat capacity of nanomaterials can be different due to the increased surface-to-volume ratio. At the nanoscale, the proportion of atoms at or near the surface is significant, altering the overall heat capacity. - Nanoparticles often exhibit a higher specific heat capacity compared to their bulk counterparts due to the presence of surface states that can store additional thermal energy.
- **Thermal Expansion:** - Nanomaterials often show reduced thermal expansion coefficients. The presence of many surface atoms with different bonding environments compared to the bulk material can result in different thermal expansion behavior. - This property is particularly important in applications requiring high-dimensional stability under temperature variations.

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

Synthesis of Nanomaterials:

- 1 **Top-down process:** Bulk materials are broken into nano-sized particles, e.g., Ball milling. As the name suggests, the top-down approach means moving from top (larger) to bottom (smaller). In the top-down approach, a bulk piece of material is taken. Then, carving and cutting are done until the desired shape is achieved. Example: Different kinds of lithographic techniques, such as electron beam, photo ion beam or X-ray lithography cutting, etching, grinding, ball milling and sol gel technique.



- 2 **Bottom-up process:** Nano materials are produced by building atom by atom. Eg., CVD, As the name suggests, the bottom-up approach means from bottom (smaller) to top or up(larger).

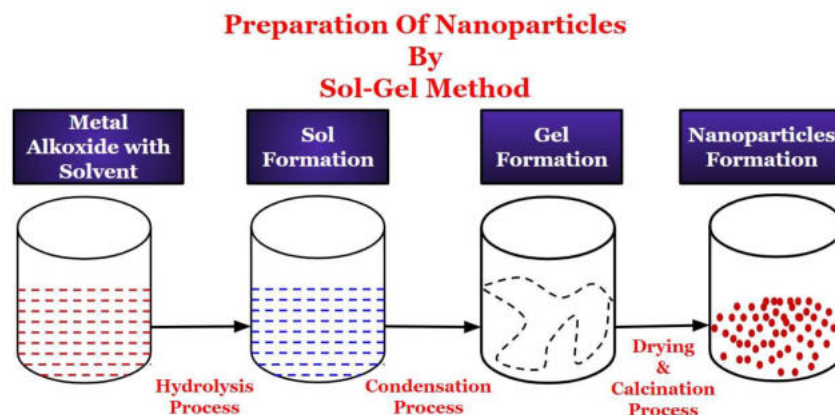
Example: all cell use enzymes to create DNA by taking constituent molecules and binding them together to make the final component.

TiO₂ Nanoparticles:

TiO₂ is chemically stable, non-toxic, abundant, and inexpensive. It also has unique electronic and optical properties that change when it is converted into nanomaterials. Titanium dioxide (TiO₂) nanomaterials exhibit excellent properties, making them suitable for a range of applications. At the nanoscale, TiO₂ shows enhanced surface area, improved charge transport, and size-dependent properties. These features make TiO₂ nanomaterials excellent for sensor applications.

Synthesis of TiO₂ Nanoparticles by sol-gel method:

The sol-gel technique is an essential bottom-up approach for synthesising nanomaterials. The process has mainly been used for the synthesis of monodispersed metal oxide nanoparticles and temperature-sensitive organic-inorganic hybrid materials.



DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

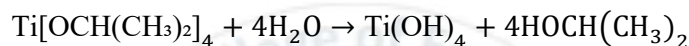
a. Preparation of sol (colloidal suspension of small solid particles in a solvent)

A sol is prepared by mixing titanium isopropoxide with ethanol in a beaker; a required volume of HCl is added to control hydrolysis. Stir the mixture at room temperature for 2 hours.

b. Conversion of sol to gel:

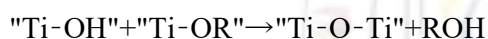
Sol further undergoes hydrolysis and condensation reactions, forming a gel. A simple hydrolysis and condensation reaction is given below.

Hydrolysis: In the presence of water, the alkoxide groups of TTIP hydrolyse to form titanium hydroxide intermediates.

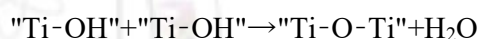


Condensation: The hydroxyl groups on $\text{Ti}(\text{OH})_4$ undergo condensation to form Ti–O–Ti bonds, releasing water or alcohol. These reactions form a three-dimensional Ti–O–Ti network, giving a gel (sol $\rightarrow$ gel transition).

i) Alcohol condensation:



ii) Water condensation:



c. Aging of a gel:

Gel on ageing, condenses to nanoscale clusters of Mesoporous Titanium hydroxides.

d. Removal of solvent:

The encapsulated solvent is removed from the gel by evaporative drying.

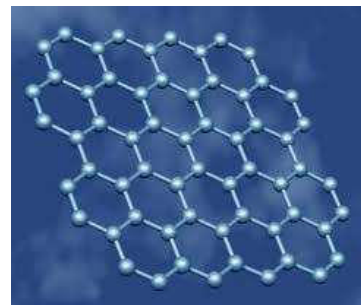
e. Heat treatment:

The sample thus obtained is heat-treated (calcined at high temperature) to obtain nanoparticles. Particle size, morphology and microstructure of the nanoparticles can be tailored by controlling the concentration of precursor, rate of hydrolysis and condensation reactions, and aging time.

Nanoparticles formed by sol-gel processes range from 1 to 100 nm. The synthesised TiO_2 powder is characterised using techniques such as XRD, SEM and TEM.

Graphene

Graphene is defined as a one atom thin sheet of carbon atoms arranged in a Hexagonal format or a flat monolayer of carbon atoms that are tightly packed into a 2D honeycomb lattice. Graphene is a one-atom-thick sheet of carbon whose **strength**, **flexibility**, and **electrical conductivity** have opened up new horizons for **high-energy particle physics research** and **electronic, optical, and energy applications**.



DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

Synthesis of Graphene by CVD

Graphene films can be produced by varying methods, which include mechanical and thermal exfoliation, chemical reduction and epitaxial growth; but the most common method used in production today is by chemical vapor deposition (CVD).

CVD creates the graphene film in two steps. The first involves pyrolyzing a precursor material to form carbon atoms on a substrate.

Core components and setup

Reactor: A horizontal tube furnace, often using a quartz tube, is common for its ability to withstand high temperatures and allow for visual monitoring.

Catalyst substrate: A metal foil, such as copper or nickel, acts as the catalyst for breaking down the precursor and a substrate for graphene to grow on.

Carbon precursor: A carbon-containing gas is used; methane (CH_4) is a widely used option.

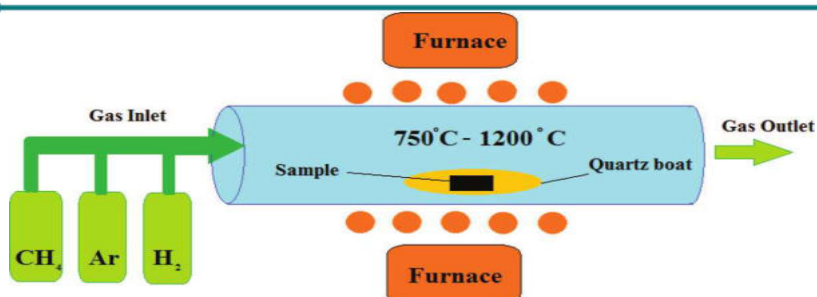
Carrier/reducing gas:

An inert gas like argon (Ar) or a reducing gas like hydrogen H_2 is used to provide a clean atmosphere and influence growth behavior.

The copper metal foil substrate is placed in the center of the furnace's reaction chamber. The chamber is evacuated, and the temperature is raised to above 1000°C under low pressure and a flow of hydrogen gas. Hydrogen plays a dual role as a reducing agent to clean the catalyst surface during annealing and as an etching agent during growth. This cleans the substrate and prepares it for growth. The choice of carbon precursors, such as methane, acetylene, or ethylene, helps the temperature needed and the growth rate. A lower precursor flow rate generally reduces the nucleation density and allows for the growth of larger graphene domains.

These carbon-containing precursor gases are introduced into the furnace at a slow flow rate along with carrier gas, such as Hydrogen, and inert gases, such as argon. The high temperature causes the precursor to decompose, and the carbon atoms migrate to the metal surface, forming graphene. The gases are turned off, and the system is cooled, often under inert gas flow to prevent oxidation. The graphene-coated copper disk is removed by treating it with PMMA. The copper deposited on the lower surface is removed by immersing it in acid. PMMA can be removed by wiping it with acetone.

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES



Graphene Properties

Electronic Properties: Graphene has a delocalized π -electron system across its entire surface, and electron movement is highly fluid. It exhibits no band gap, due to overlapped pi-electrons, allowing for an easy movement of electrons without the need to input energy into the system

Thermal Properties: The repeating structure of graphene makes it an ideal material for in-plane heat conduction, allowing phonons to move through the material without impediment at any point along the surface.

Mechanical Properties: Graphene is one of the strongest materials ever discovered, with a tensile strength of 1.3×10^{11} Pa. It is also very lightweight (0.77 mgm^{-2}). The mechanical strength of graphene is unmatched and & can enhance strength in many composite materials.

Flexibility/Elasticity: The repeating sp^2 -hybridised backbone of graphene molecules allows for flexibility, as rotation occurs around some bonds, whilst still providing enough rigidity and stability for the molecule to withstand changes in conformation and support other ions.

Graphene Applications

Sensors: Because of the flat and consistent arrangement of atoms in a graphene sheet, each atom is exposed to the surrounding environment. This enables graphene to detect changes in its surroundings at micrometer resolution, resulting in a high level of sensitivity. Graphene can also detect specific events at the molecular level.

Batteries: The strong electrical conductivity, surface area, and dispersibility of graphene augment the favourable features seen in many classic inorganic-based electrodes while also alleviating the electrodes of their constraints.

Graphene can be used as an anode or cathode in a variety of battery systems to improve battery efficiency and charge/discharge cycle rates.

Catalyst Supports: Graphene's surface is planar and uniform, although it, like any other material, is prone to intrinsic flaws. Metal ions can act as catalysts in these cavities, providing support. In addition

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

to mechanical support, graphene's outstanding charge carrier ability facilitates charge transfer reactions involving the catalyst. Graphene is also inert, therefore it does not interfere (negatively) with the interaction of the catalyst and substrate materials. Graphene also provides a uniform dispersion of catalyst particles, ensuring that the catalyst-substrate reaction occurs consistently across the entire support.

Electron Emission Displays: The graphene surface's linear dispersion yields massless Dirac Fermions. When subjected to an electric field, the field-emitted electrons avoid all backscattering because their escape velocity is independent of their energy. Graphene is a good material for electron emission displays due to its high aspect ratio and the dangling bonds at each end of the sheet, which allow for effective electron tunneling.

Polymer Masterbatches: Because many polymeric materials suffer from strength issues, the addition of graphene can aid to boost the tensile strength of the polymers, extending their shelf life in commercial applications. Graphene can be combined with polymeric materials to create graphene-polymer composite composites. Incorporating graphene into polymers can also enhance their electrical conductivity.

Structural Composites: Graphene is used in numerous composites for applications where strength and weight are limited, such as in the aerospace sector. Graphene is being used in a variety of materials to make them stronger and lighter. For the aviation industry, composite material that is significantly lighter than steel while yet providing the essential strength will save a lot of money on fuel usage, which is why graphene is beginning to be included into such materials. Graphene-based structural composites have the potential to become a popular alternative to many materials utilized today.

Functional Inks: Graphene can be employed in functional inks for electrical, heat-resistant, and anticorrosion applications. By introducing graphene into ink formulations, the conductivity qualities of graphene affect the ink, leading it to become conductive. The inks can then be utilized to coat electrical components. Graphene is a non-toxic, environmentally friendly, cost-effective, quick-drying, and recyclable alternative to existing conducting inks. Graphene is also very thermally stable, making it perfect for heat-resistant ink coating in electronic applications that generate a lot of heat. It is also an ideal ink for high-temperature processing since the graphene does not degrade during the production process. Graphene has great chemical stability and is inert. For applications where environmental factors are an issue, graphene inks can provide a stable barrier to protect materials from chemicals and corrosion.

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

Carbon Nanotubes

Carbon Nanotubes are formed from essentially a graphite sheet, and the graphite layer appears somewhat like a rolled-up, continuous, unbroken hexagonal mesh with carbon molecules at the apexes of the hexagons. A Carbon Nanotube is a tube-shaped material, made of carbon, having a diameter measured on the nanometre scale. They can be single-walled (SWCNT) with a diameter of less than 1 nanometer (nm) or multi-walled (MWCNT), consisting of several concentrically interlinked nanotubes, with diameters reaching more than 100 nm. Their length can reach several micrometres or even millimetres.

Carbon nanotubes in batteries

Carbon nanotubes are graphene sheets rolled up into hollow one-dimensional tubes. Made only of carbon atoms, they have a range of properties that make them ideal for applications in batteries and energy storage:

- **High electrical conductivity:** CNTs can increase the rate of charge transport in a battery, reducing internal resistance.
- **High thermal conductivity:** CNTs can improve composite electrode safety by increasing the rate at which heat dissipates throughout the device, avoiding issues like thermal runaway.
- **Tunable electrochemical properties:** CNTs can be tuned based on their morphology (number of defects, lengths, and diameters)
- **High mechanical strength:** CNTs can protect battery from structural degradation that results from charge-discharge cycles leading to safer batteries with a longer lifespan.
- **High surface area and ability to conduct electrons efficiently:** CNTs allow for faster charge transfer, resulting in better energy retention and higher battery capacity.
- **Lightweight:** Carbon nanotubes are incredibly light compared to other conductive materials, which can contribute to reducing the overall weight of energy storage devices.

Advantages of CNTs in energy devices

- **High Li storage capacity** without damaging the electrode.
- **Faster charge/discharge rates** due to shorter ion travel distance.
- **Improved electrical conductivity** for better performance.
- **Larger surface area** for better contact with the electrolyte.
- **Less volume change** during charging and discharging, improving stability.

Disadvantages of CNTs in energy devices

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

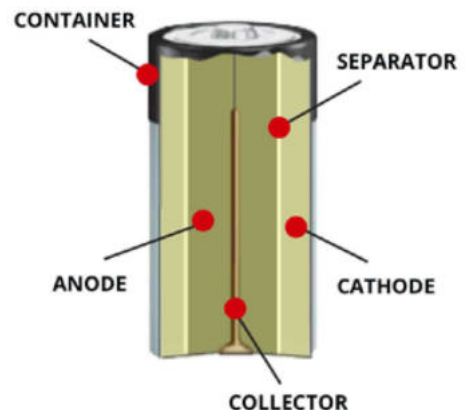
- **Price** - Carbon nanotubes are currently expensive to produce on a scale, which limits their commercial viability. Manufacturing high-quality CNTs involves complex, energy-intensive processes such as CVD or arc-discharge methods. This high production cost translates into expensive battery components, making it challenging for CNT-enhanced batteries to compete with traditional lithium-ion batteries on cost.
- **Processing** - CNTs tend to agglomerate, which can make uniform dispersion difficult during manufacturing. Achieving a homogeneous distribution of CNTs in the anode or cathode is crucial to ensuring consistent battery performance. Furthermore, carbon nanotubes have specific structural and electronic properties that must be carefully controlled during processing.
- **Impurities** - Impurities from the CNT manufacture such as residual catalyst particles can significantly degrade battery performance. Even small amounts of impurities can negatively affect the electrical conductivity and stability of CNTs. This reduces the battery's overall energy storage capacity and lifespan. Removing these impurities requires additional steps in the production process, adding to both time and cost!

Batteries

A battery is an electrochemical device that converts stored chemical energy into electrical energy.

Components of Battery:

1. **The anode (Negative electrode):** the electrode at which oxidation takes place by liberation of electrons.
2. **The Cathode (Positive electrode):** the electrode at which reduction takes place by accepting electrons.
3. **Electrolyte:** The electrolytes act as a medium for transfer of ions. The electrolyte must have good ionic conductivity.
4. **Containers:** This holds the components and must be corrosion resistant.
5. **Separator:** it separates anode and cathode materials to prevent internal short circuit.



DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

Classification of Batteries:

1. Batteries are classified as primary (non-rechargeable)
2. Secondary (rechargeable)
3. Reserve (inactive until activated)

Primary batteries	Secondary batteries	Reserve batteries
→Primary batteries are those which cannot be recharged. →The net cell reaction is not reversible. →Primary batteries are relatively inexpensive. →Example: Dry cell.	→Secondary batteries are those which can be recharged. →Net cell reaction is reversible. →Example: Lead acid, Li-Ion batteries etc →Used in cell phones, laptops etc	→Reserve batteries are special purpose primary batteries designed for emergency use and for long term storage. →The vital part of the battery is stored separately. →The battery is only activated when it is needed. →Self-Discharge is eliminated. →Example: Magnesium-AgCl batteries, zinc-silver oxide batteries, etc. →Used in Missiles, spaceships, etc.

Battery Characteristics

A few important characteristics of batteries are,

1. Capacity

“It is the quantity of electrical charge which may be obtained by the battery during battery discharge”.

Quantity of electrical charge is measured in Ampere hour (Ah). The capacity of a battery depends on its size, which is determined by Faraday’s relation.

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

Where, W is the mass of active material, M is the molar mass of the active material; 1A-h is the ability to supply 1A current for 1hr.

Thus the amount of active materials consumed during discharge is the capacity of the battery.

- #### 2. Power density:
- It is defined as the energy available from a cell to its weight.

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

$$\text{Energy density} = \frac{\text{Energy available from the cell}}{\text{Weight of the cell}}$$

3. Shelf life: The period of time a battery can be stored without significant deterioration. A good cell have longer shelf life, the reason for shorter shelf life is due to the self-discharge. i.e. lower is the self-discharge longer is the self-life.

Primary batteries have a shelf-life up to 10 years, lithium based batteries are good for 2-3 years etc. Batteries should have high energy efficiency. Higher is the efficiency better is the battery.

4. Cycle life: is the number of charge and discharge cycles that are possible before failure occurs. It is applied only for secondary cells. A good battery has high cycle life. Some of the factors which cause the failure are

- Loss of electro active material from the electrode due to rapid charging.
- Corrosion of the contact wires due to rapid charging.

1.11 Lithium Batteries:

Lithium metal is an attractive anode material because of its lightweight, high voltage, very low electrode potential, high electrical equivalence, and good conductivity. A lithium cell can produce voltage from 1.5 V to 3.5 V based on the types of materials used. There are two types of lithium-based batteries available. A schematic diagram of the Lithium Metal Battery is shown in Figure and Lithium-ion Battery

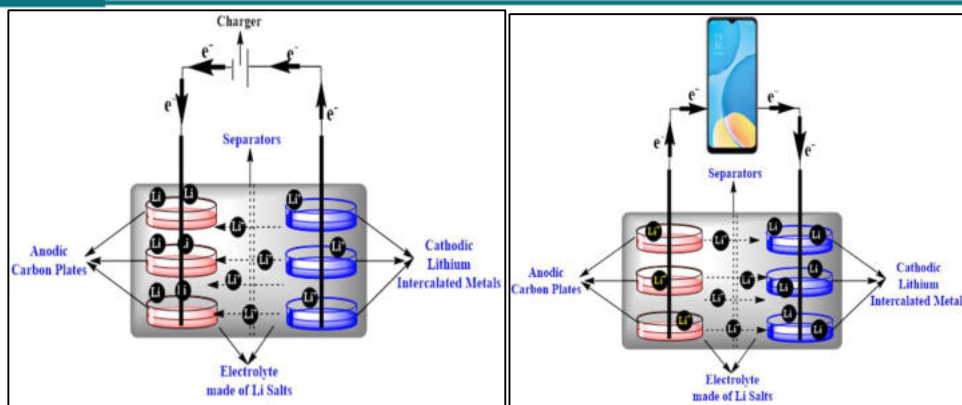
Construction and working of Li-Ion Batteries:

The cell is represented as, $\text{C, Li}^+ \mid \text{Li}^+ \mid \text{LiMn}_2\text{O}_4$

It consists of

- **Anode:** is made of graphite (C_6)
- **Cathode:** The cathode material is made of intercalated lithium compound, such as multi layered lithium cobalt oxide (LiCoO_2), lithium iron phosphate (LiFePO_4), lithium manganese oxide (LiMn_2O_4) etc.
- **Electrolyte:** A non-coordinating electrolyte salt such as LiPF_6 or lithium hexafluoroarsenate monohydrate (LiAsF_6) or lithium tetrafluoroborate (LiBF_4) is dissolved in an organic solvent like ethylene carbonate or diethyl carbonate etc. Since lithium reacts violently with water, a non-aqueous electrolyte must be used.
- **Separator:** Polypropylene soaked with electrolyte.

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

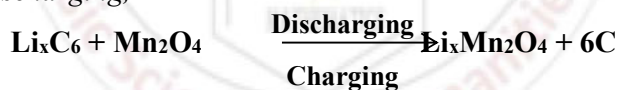


Working:

During charging; an external load forces the Li^+ ions to travel from cathode (lithium compound of LiMn_2O_4) to anode and accumulates on the surface of graphite. During discharge, Li^+ spontaneously starts migrating back to lithium compound (LiMn_2O_4) at cathode and electrons flow through the external circuit. The probable cell reactions are given below,

Anode	$\text{Li}_x\text{C}_6 \rightarrow x\text{Li}^+ + 6\text{C} + x\text{e}^-$
Cathode	$\text{Mn}_2\text{O}_4 + x\text{Li}^+ + x\text{e}^- \longrightarrow \text{Li}_x\text{Mn}_2\text{O}_4$
Overall reaction	$\text{Li}_x\text{C}_6 + \text{Mn}_2\text{O}_4 \rightarrow \text{Li}_x\text{Mn}_2\text{O}_4 + 6\text{C}$

Overall charging and discharging,



Advantages

1. They have high energy density than other rechargeable batteries
2. They are less weight
3. They produce high voltage out about 4 V as compared with other batteries.
4. They have improved safety, i.e., more resistance to overcharge.
5. No liquid electrolyte means they are immune from leaking.
6. Fast charge and discharge rate

Applications:

- Light weight and compact, low maintenance
- High voltage and high energy density
- Used in mobile phones, tabs, laptops, wireless communication devices etc.
- Used in medical devices, electric cars, auto mobiles etc.

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

Fuel Cells

“Fuel cell is a galvanic cell in which chemical energy of a fuel is converted into electrical energy by means of redox reactions involved with oxidants”.

Difference between battery and fuel cell: The fuel cell differs from a battery in the following aspects.

Fuel Cell	Batteries
Reactants are fed from outside	Reactants are kept inside
Fuel cells does not store chemical energy, it is an energy conversion device.	Batteries are Energy storage device
Electrical energy is continuous process till the reactants are supplied constantly.	Electrical energy is generated until reaction is complete.
The products are constantly removed from the cell.	The products are not removed from the cell.

Advantages of Fuel cells

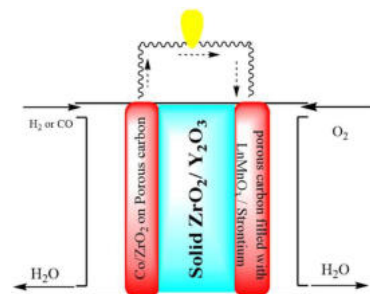
- Savings in fossil fuels due to the high efficiency of electrochemical energy conversion.
- Low pollution level, no noxious exhaust gases formed.
- Low maintenance, exchangeable parts.

Disadvantages:

- High initial cost of the system (catalyst, membranes etc).
- Large weight and volume of gas fuel storage systems.
- High price of clean hydrogen.

Solid Oxide Fuel Cell (SOFC)

Anode is made up of porous carbon electrode coated with Co and ZrO₂. Cathode contains LaMnO₃ doped with strontium filled in carbon electrode. A non-porous solid oxide Zirconia (ZrO₂) is used as an electrolyte doped with yttria (Y₂O₃). Solid fuel helps in migrating the O²⁻. H₂ or CO is used as fuel in fuel compartment. Oxygen used as oxidant is allowed to pass at oxidant compartment. Water is the byproduct obtained at both compartments



Anode	$\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$
Cathode	$2\text{H}^+ + 1/2\text{O}_2 + 2\text{e}^- \rightarrow \text{H}_2\text{O}$
Overall	$\text{H}_2 + 1/2\text{O}_2 \rightarrow \text{H}_2\text{O}$

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

Solar Energy

Introduction: The radiation reaching the earth from the sun and converting it into different useful forms of energy is called solar energy.

Photovoltaic cell: “These are the semiconductor device, which converts light energy directly to electrical energy”.

The most common material used for solar cells is crystalline silicon, the second member in group IV A in the periodic table. It never occurs free in nature but occurs as oxides and silicates. Silicon is the second abundant element found in world.

Construction and working of photovoltaic cell

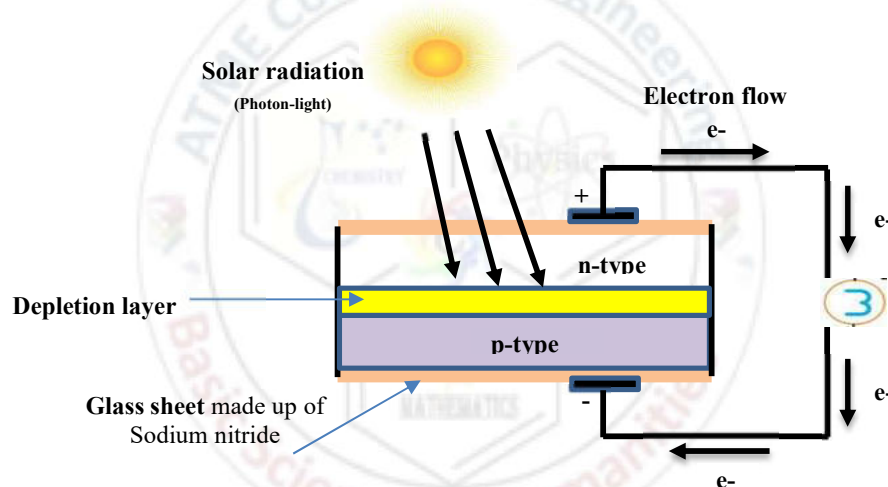


Figure: Schematic diagram of the construction of PVC

Construction: PV cells mainly consist of a p-n junction diode made up of Si semiconductor, as shown in fig. Two electrical contacts construct it; one is a metallic grid over n-type and the second layer of sodium nitride or silver metal at the back of the p-type semiconductor. An anti-reflective layer (silver nitride) or TiO_2 is coated between the metal grids to prevent the reflection of solar light.

Working: when sunlight with (photon of energy $E=h\nu$) required energy falls on p-n junction, electrons are ejected from the electron-hole pair in the p-n junction. The ejected electrons move to n-type since the movement in n- type is one way, these ejected electrons must flow through external circuit to combine with holes. These movements of electrons

DEPARTMENT OF BASIC SCIENCES AND HUMANITIES

from n side to the p side generate an electric current. Electrical energy is directly proportional to areas of cell exposed to light radiation and intensity.

Applications: Telecommunication repeater stations/tower • Water pumps • Navigational aids • Laptop computers • Cottages and remote residences • Parks in remote regions • Supplying occasional power • Satellites • Toys, watches

Advantages: Environmentally friendly, no need for recharging, Does not corrode, Operate at low temperature, No emission, no combustion, High public acceptance and excellent record, Low operating cost, No moving parts, and so no wear and tear.

Disadvantages: High Installation cost, Energy can be produced only during daytime, Sun light is a diffuse source.

