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NANO MATERIALS

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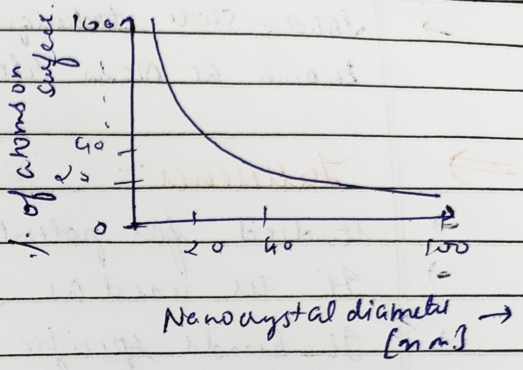
Nanotechnology:

→ The study of controlling of matter on an atomic & molecular scale.

→ They are sized b/w 1 to 100 nm in at least 1 dimensi.

Quantum size effect:-



→ It is dominant when the nanometer size range is reached.

→ mechanical, electrical, optical, etc. properties change when ~~the~~ compared to macroscopic system.

e.g Cu become transparent (Opaque → transparent)
Stable → Combustible (Al)
Insoluble → soluble (Au).

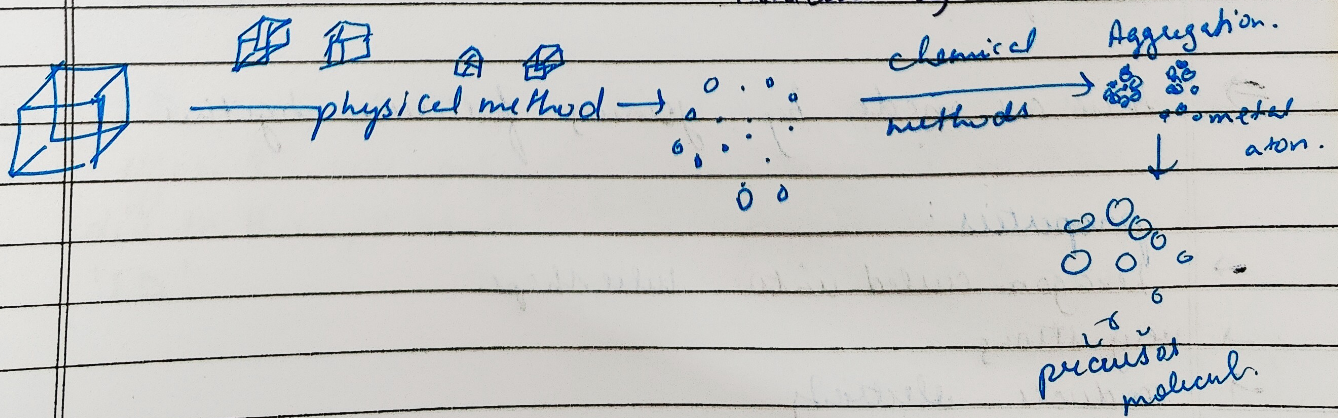
Two different Approaches to Nanofabricatⁿ:

Top-down

Start with the bulk material & cut away material to make the what you want

Bottom-Up:

Building what you want by assembling it from building blocks, atom-by-atom, molecule-by-molecule.



① Top down Approaches :-

→ Milling
→ 10 ~ 1000 nm ; broad size distribution
→ Impurities
→ Solid - state silicon methods for fabricating microprocessors.
→ Solid - State techniques can be used to create devices known as Nano Electro Mechanical System NEMS or MEMS.

⇒ Fullerenes :-

→ studied for potential medical use.
→ It is used as light - activated antimicrobial agents.
→ It binds specific antibiotics to the structure to target resistant bacteria & even target certain cancer cells.
→ They are stable but not totally unreactive
→ sparingly soluble.
→ deep purple colour.
→ C_{70} → reddish brown.

⇒ Carbon Nanotubes : (1-2 nm diameter) (100 mm long).

→ allotropes of 'C'
→ useful applications in nanotechnology, electronics, optics & architectural fields.
→ extraordinary strength & unique electrical properties, conductors of heat.
→ but potential toxic.

⇒ These are made by joining fullerenes together.

properties :
→ hexagon curled into tube shape.
→ very strong
→ conducts electricity

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→ ~~can~~ small with large surface area.

⇒ Uses:
→ Reinforce graphite in tennis racquets
→ Semi conductor
→ Industrial catalysts

① Strength properties :
→ strongest ~~tensts~~ tensile strength
→ highest modulus of elasticity.

② Electrical properties [5,5]
→ If str. is armchair then electrical properties are metallic.
→ If ~~a~~ str. is chiral the either semiconducting otherwise moderate semiconductor. [7,5]
→ can carry electrical current 1000 times greater than metals such as copper.

③ Thermal properties :
→ Stability : stable upto 2800°C in vaccum & 750°C in air.
→ Anisotropy: very good thermal conductors along tube but good insulators laterally tube axis.
→ Conductivity : transmit 6000 W per m per K at rm. temp.

④ 1 D transport :- e^- transport ~~is~~ take place through quatum effects & will only propagate along axis of tube.
due to this, C nanotubes are frequently referred to as '1D'

Advantages of lime soda /

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Applications of ~~At~~ Carbon nanotubes:-

1. Biological: drug delivery, trap dangerous substances, DNA disinfection, immobilization of enzymes.
2. Paints: improve strength & conductivity
3. Actuators: change electrical to mechanical energy, e.g robotics.
4. Electronics: semiconductors, diodes.
5. Chemical industry: catalysts e.g zeolites in HC cracking.

Health Hazards:

→ C nanotubes shorter than 200nm enters into lungs. & increases risk to health.

→ It is an unexplored matter & many of the possible health hazards are still unknown.

Benefits of nanoscale :-

1. Existence of discrete energy levels & quantum tunneling can be made useful in electrical & photonic devices.
2. potential to synthesis any type of desired nanostructure
3. Optical properties, enabling nanoparticles to absorb or emit precise freq. of light.
4. high surface area to mass ratio, enhance ability of nanost. to take part in chemical rxn.

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BATTERY

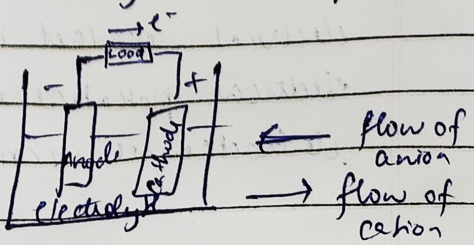
Battery:

→ portable source of electrical power
→ Energy storage / Conversion Devices
→ Converts Chemical Energy into Electrical Energy
→ Works on Electrochemical principles.

⇒ It is a storage device used for storage of chemical energy & for the transformation of chemical energy into electrical energy.

→ It consists of group of two or more electrical cells connected in series.

Chemical	Electrochemical
→ chemical energy → thermal energy	→ chemical → electrochemical.
→ energy producing chemical: fuel & oxidant	→ energy producing chemical: anode material cathode mater
→ fuel & oxidant are brought together. Resultant combust^n rxn produces heat.	→ Anode & cathode materials are kept separately
→ fuel + Oxidant → Heat	→ e^- pass through out side loop.
	→ electrolyte to complete circuit



↳ cationic exchange resin e.g. styrene ...

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⇒ five essential components of a cell

→ The Anode
→ The cathode
→ The ionic conductor (electrolyte)
→ The metallic conductor (electrical connecⁿ)
→ The separator

The Anode: It has lowest potential & is oxidised in the process by loss of e^- :-
Anodic rxn / Oxidatⁿ rxn / e^- generation.

The separator:
Electrical insulator membrane, allowing ionic transfer & solvent wetting.

The cathode:
The cathode has high potential, leading to consumption of e^-.

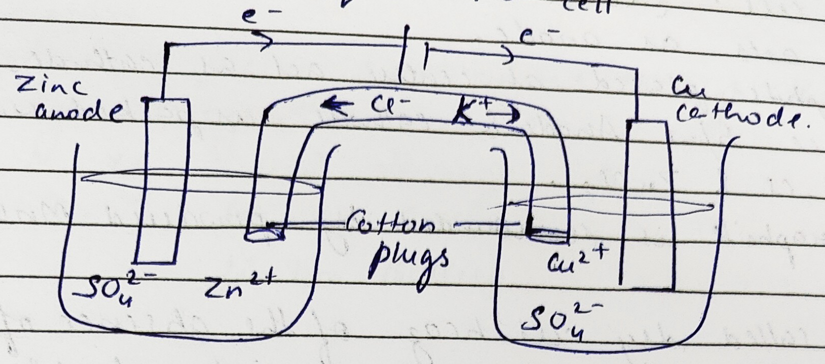
$$MO + ze^- \longrightarrow [MO]^{z-}$$

cathodic rxn, reductⁿ rxn, e^- consumption.

Electrolyte
A solⁿ conducting ions

Electric connections:
The anode & cathode in an electrochemical cell must be in electrical contact in order to generate power & energy. electrical potential which is the driving force for electrochemical rxn.

$$\Delta G^\circ = -RT \ln K_{eq} = -nFE^\circ_{cell}$$



at anode (oxidation)
$Zn(s) \longrightarrow Zn^{2+} + 2e^-$

at cathode (reductⁿ)
$2e^- + Cu^{2+} \longrightarrow Cu$

Types of Batteries:

- Primary batteries (primary cell)
- Secondary Batteries (secondary cells)
- Fuel Cells (flow batteries)

1) Primary Batteries (or) Primary cells :-

→ Those cells in which the chemical rxn occurs only once & the cell becomes dead after sometime & it cannot be used again.

→ These batteries are used as source of DC power

e.g: Dry cell (aka Leclanche Cell) & Mercury cell.

Requirements of Primary cell :- should satisfy

→ convenient to use.

→ cost of discharge should be low.

→ stand by power is desirable.

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Dry cell :- (Leclanche cell)

→ Zn acts as anode.
→ Graphite placed at centre act as cathode.
→ space b/w Anode & cathode is packed with paste of NH_4Cl & $ZnCl_2$.
& graphite is surrounded by powdered MnO_2 & C.

→ It is called dry cell bcoz of the absence of any liq. phase, even the electrolyte consists of NH_4Cl, $ZnCl_2$ & MnO_2 to which starch is added to make a thick paste which prevent leakage.

At Anode: (Oxid^n)

$$Zn(s) \longrightarrow Zn^{+2}(aq) + 2e^-$$

At Cathode (Red)

$$2MnO_2(s) + H_2O + 2e^- \longrightarrow Mn_2O_3(s) + 2OH^-$$

⇒ OH^- reacts with NH_4Cl & NH_3 produced combines with Zn^{2+} & Cl^- ions to form $[Zn(NH_3)_2Cl_2]$

$$2NH_4Cl + 2OH^- \rightarrow 2NH_3 + Cl^- + 2H_2O$$

$$Zn^{2+} + 2NH_3 + 2Cl^- \longrightarrow [Zn(NH_3)_2Cl_2]$$

Advantages:

→ Voltage range 1.25 V to 1.50V
→ used in torches, radio, transistors, watches etc.
→ low price

Disadvantages:

→ short life because the acidic NH_4Cl corrodes the container even when the cell is not in use.

2. Secondary cell (Accumulator Batteries):

→ rechargable
→ recharged by passing an e⁻ current through them & can be used again & again.

eg lead storage battery
Ni-Cd Battery
Li-Ion Battery.

→ Used in cars, trains, motors, e⁻ clocks, power stations, laboratories, emergency lights, telephone exchange, digital cameras, laptops etc.

→ reversible cells (galvanic cell while discharge & electrolytic while charging)

To ~~put~~ improve the performance:

1) Anode & cathode with very small separation to conserve space are used.
2) current discharge should be high at low temp.
3) less variation in voltage
4) high energy efficiency.

$$\% \text{ energy efficiency} = \frac{\text{energy released on discharge}}{\text{energy req. for charge}} \times 100$$

5) should be reliable.
6) should have shock tolerance, temp. etc.
~~7) should have no of~~

1) Lead Acid Battery:

→ no. of cells connected in series, arrangement called Battery
→ most common used in automobiles.
→ 12V LAB is generally used of 6 cell each 2V.

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⇒ Anode → Lead & Lead Oxide → Cathode.

→ alternately separated by wooden piece & suspended in dil H_2SO_4 (38%), which acts as electrolyte.

Anode → Pb Cathode → PbO_2
Electrolyte → dil H_2SO_4 (20.22%) EMF = 2V

To increase the current output of each cell, Cathode & Anode plates are joined together, keeping them in alternate

$$Pb \,|\, PbSO_4(s),\ H_2SO_4(aq) \,|\, PbSO_4(s),\ Pb$$

⇒ At anode

$$Pb \rightarrow Pb^{+2} + 2e^-$$
$$Pb^{+2}(s) + SO_4^{-2}(aq) \rightarrow PbSO_4(s)$$

At Cathode

$$PbO_2(s) + SO_4^{-2}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O$$

Overall ⇒ $Pb(s) + PbO_2 + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O$

⇒ During discharge, H_2SO_4 is consumed & density of H_2SO_4 & when it falls below 1.2 g/cm^3, battery need recharging.

→ In discharge, cell acts as voltaic cell where Oxidⁿ of Pb occurs.

→ In charging, cell act as electrolytic cell.

$$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{-2}(aq)$$
$$PbSO_4(s) + 2H_2O \rightarrow PbO_2(s) + 2H_2SO_4$$
$$PbSO_4(s) + 2H_2O \rightarrow Pb(s) + PbO_2(s) + 2H_2SO_4(aq)$$

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→ During the
lead deposited at cathode
PbO_2 → at anode
H_2SO_4 is regenerated.

Advantages:

→ used for supplying current in (done before).
→ its recharge-ability, portability & its relatively constant potential & low cost.

Disadvantages:

→ Use of H_2SO_4 is dang.
→ Use of lead is toxic

2. Nickel - Aluminium Cell (Ni Cad Cell)

→ rechargable.
→ Anode → Cd   Cathode → $NiO(OH)$
electrolyte → KOH   EMF → 1.4 V

At anode: $Cd(s) + 2OH^-(aq) \rightarrow Cd(OH)_2(s) + 2e^-$
At cathode: $2NiO(OH)(s) + 2H_2O + 2e^- \rightarrow 2Ni(OH)_2 + 2OH^-(aq)$

Overall → $Cd(s) + 2NiO(OH) + 2H_2O \rightarrow Cd(OH)_2(s) + 2Ni(OH)_2(s)$

Advantages

→ has small size & high rate charge/discharge capacity, which makes it very useful.
→ low internal resistance & wide temp. range (upto 70°C).
→ produces potential about 1.4 V & has long life.

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7) Ion - Exchange / deionizat... e.g styrene divinyl benzene
↳ cationic exchange resin

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Uses :-

→ In electronic calculators, electronic flash units, transistors
→ In medical instrumentation & in emergency lighting, toys etc.

③ Fuel cell :-

→ fuel cell is an electrochemical cell which converts chemical energy into electrical energy.

principle :

→ same as electrochemical, the only diff is that the fuel & oxidant are stored outside the cell.

→ fuel & oxidant are supplied continuously & separately to the electrodes at which they undergo redox rxn.

→ They are capable of supplying current as long as reactants are replenished.

fuel + oxidant → Oxidⁿ product + electricity

eg H_2-O_2 fuel cell, propane$-O_2$ fuel cell, CH_3OH-O_2 fuel cell.

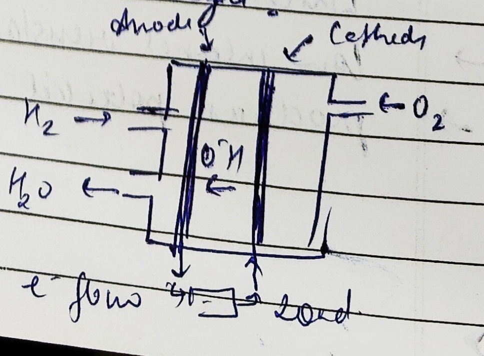
1) H_2-O_2 fuel cell :-

→ most successful.

→ consists of two inert porous electrodes made of graphite impregnated with finely divided 'Pt' or Ni or Pd - Ag alloy & a solⁿ of 2.5% KOH as electrolyte.

at anode

$2H_2(g) + 4OH^- \rightarrow 4H_2O + 4e^-$



at Cathode:

$$O_2(g) + 2H_2O + 4e^- \longrightarrow 4OH^-$$

Net $\Rightarrow$ $2H_2(g) + O_2(g) \longrightarrow 2H_2O$ $\qquad E_{cell} = 1.23V$

→ by products ⇒ heat, CO_2, water (no pollution).

Applications:

→ as auxiliary energy source in space vehicles, submarines & other military vehicles.

→ ~~by~~ by products is a valuable source of ~~fres~~ fresh water for astronauts

→ It is preferred in spacecraft bcoz of lightness

Advantages.

→ high efficiency.

→ efficiency do not depend on size of power plant.

→ low maintenance cost

→ more efficient in producing mechanical power to drive vehicles & require less energy consumption

Disadvantages:

→ Initial cost is high

→ Life time is not known accurately

→ problem of durability & storage of large amount of H_2