COMPUTER SCIENCE ENGINEERING BRANCH
25CC102
MODULE 3:Energy System

Energy Systems: Introduction to batteries, construction, working, and applications of Lithium-ion and Sodium-ion batteries. Quantum Dot Sensitized Solar Cells (QDSSCs)-Principle, Properties and Applications.

ENERGY SYSTEM

A battery is a device consists of two or more galvanic cells arranged in series or parallel or both that can convert chemical energy into electrical energy.

Classification of batteries

i).Primary (single-discharge) Batteries:

These are the batteries in which net cell reaction is not completely reversible, therefore these are not rechargeable. The primary battery contains a finite quantity of the reactant materials participating in the reaction; once this quantity is consumed (on completion of discharge), it cannot be used again.

Example: Leclanche cell (Zn-MnO_2), Magnesium cell (Mg-MnO_2), Zn-air cell (Zn-O_2), Lithium primary cell etc.

ii).Secondary Batteries (Storage or Rechargeable Batteries):

These are the batteries in which net cell reaction is completely reversible and therefore these are rechargeable. On the completion of discharge, a storage battery can be recharged by forcing an electric current through it in the opposite direction; this will regenerate the original reactants from the reaction (or discharge) products.

Example: Lead-acid, Nickel- cadmium, Nickel-metal hydride, Lithium-ion batteries.

iii).Reserve Batteries: In this battery, one of the key components is separated from the remainder of the cell until activation. The electrolyte is the component that is usually isolated, activation of the reserve battery is accomplished by adding the electrolyte just prior to use.

Example: Zinc/Silver Oxide, Mg-AgCl, lithium-thionyl chloride batteries, etc,

Construction and working of Li-Ion battery

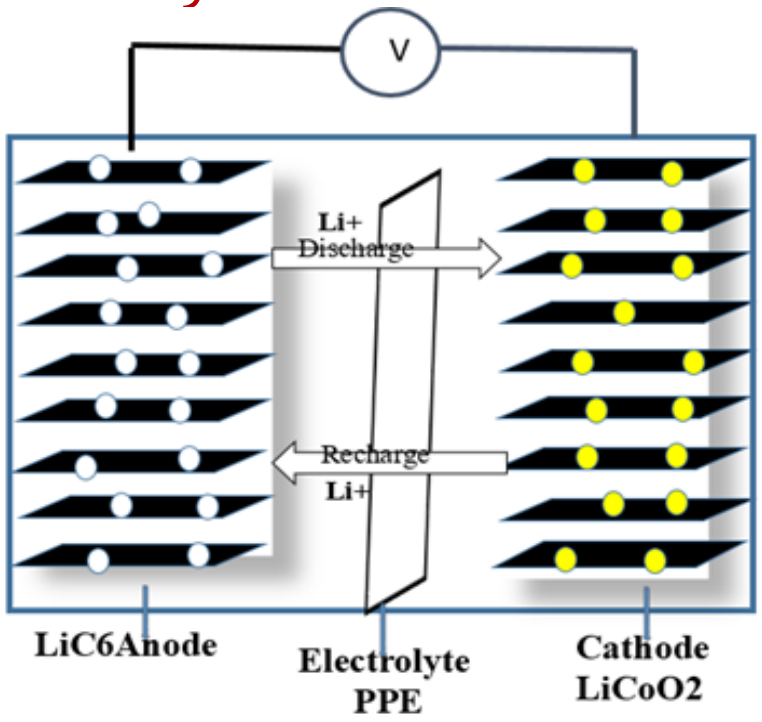


Fig: 1.20 Li-ion battery

Anode: Lithiated carbon or graphite and a binder coated on a copper foil.

Cathode: Lithiated transition metal oxide like $LiCoO_2$ mixed with a conductor and binder and coated in an Aluminium foil.

Electrolyte: Lithium salt in ethylene carbonate propylene carbonate

Separator: micro porous polythene film

Binder: poly vinylidene fluoride

Battery Representation:

Li_xC_6 | LiX, Polypropylene | $Li_{(1-x)}CoO_2$

Simply, the Li-ion is transfers between anode and cathode through lithium Electrolyte. Since, neither the anode nor the cathode materials essentially change, the operation is safer than that of a Lithium metal battery.

Advantages	Disadvantages
High Energy Density	They require protection from being over charged and discharged too far.(integrated circuit technology is required to monitor)
High Voltage compared to other batteries	LCO battery or cell needs to be stored it should be partially charged - around 40% to 50% and kept in a cool storage area. (-15˚C)
Low self-discharge (long shelf life)	A major lithium ion battery disadvantage is their cost.(40% more than Ni-MH batteries)
Low maintenance	

Uses

Cellular phones, Portable CD player, Note PC, DVC/DSC/DVD/ Portable LCD TV etc. MD player, Semiconductor-driven audio etc and Portable electric vehicles.

Sodium Ion Battery

Anode: Sodium metal intercalated on graphite is used as anode

Cathode: Chalcogenides, fluorides, polyanion compounds and chromium cathodes have been used as cathode material.

Electrolytes: Commonly used electrolytes are PEC, PPC

The electrode reactions in a Na-ion battery utilizing hard-carbon (C_6) anode and a layered transition metal oxide, $NaMO_2$, cathode are depicted in equation below.

The discharged electrodes are on the right-hand side of eq

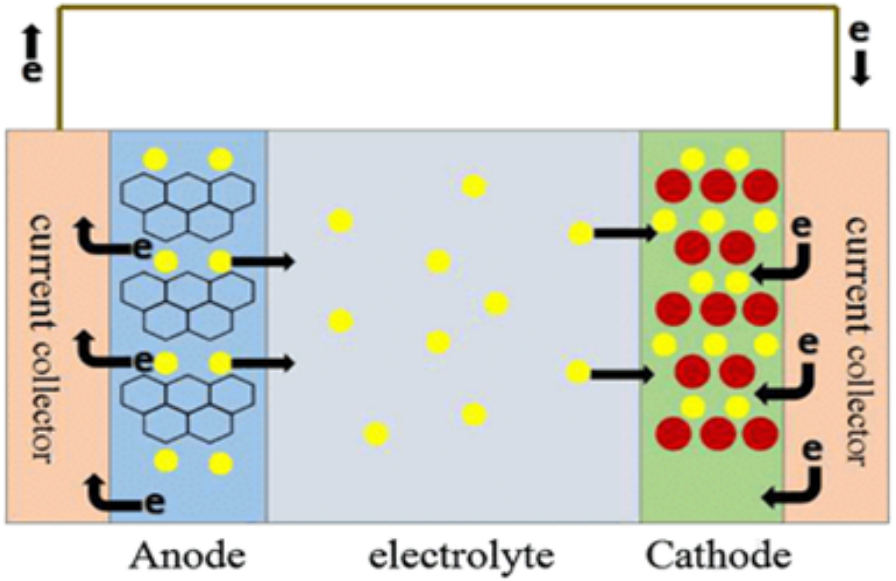


Fig:1.20 Sodium ion battery

Sodium Ion Battery

It stores energy in the chemical bonds of anode.

When battery is recharging sodium ions moves from cathode to the anode.

Meanwhile charge balancing electrons pass from the cathode through the external circuit containing the charger and into the anode.

During discharge process electrons move from and anode to external circuit, it can be used for various applications.

Meanwhile, Na+ ions move from anode to the cathode. Voltage obtained from every sodium ion cell is 3.6V.

Working:

Discharge reactions

At anode: $Na_xC_6 \longrightarrow xNa^{+} + xe^{-} + 6C$

At cathode: $Na_{(1-x)}CoO_2 + xNa^{+} + xe^{-} \longrightarrow NaCoO_2$

Net Cell : $Na_xC_6 + Na_{(1-x)}CoO_2 \longrightarrow NaCoO_2 + 6C$

Recharging reactions

At Cathode: $xNa^{+} + xe^{-} + 6C \longrightarrow Na_xC_6$

At Anode: $NaCoO_2 \longrightarrow Na_{(1-x)}CoO_2 + xNa^{+} + xe^{-}$

Net Cell: $NaCoO_2 + 6C \longrightarrow Na_xC_6 + Na_{(1-x)}CoO_2$

Advantages

Sodium resources are more abundant,

The cost of sodium-ion batteries is about 30% lower than that of lithium batteries,

Sodium-ion batteries are safer and are not easy to produce lithium dendrites.

Disadvantages of sodium ion batteries:

Lower energy density of sodium ion batteries;

short cycle life;

the industrial chain is still incomplete.

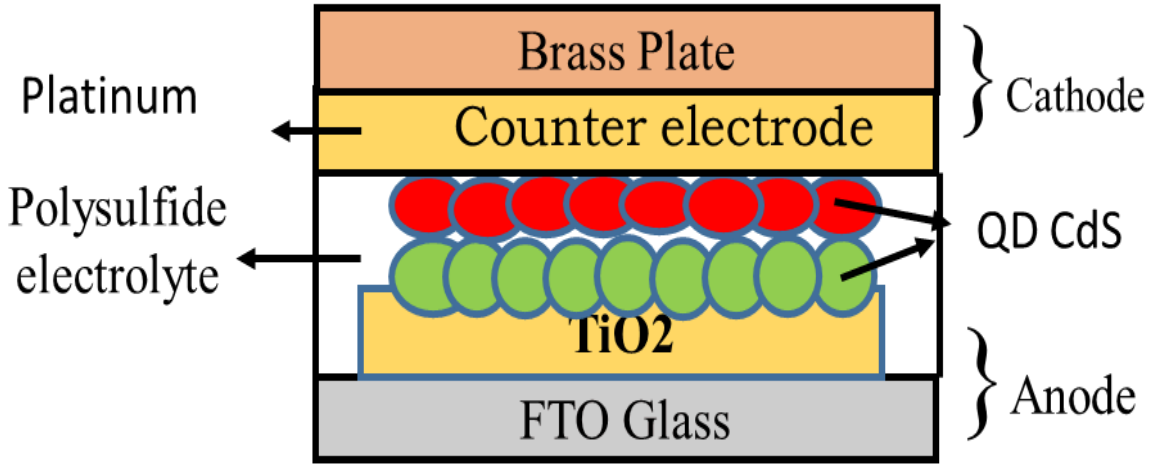
Quantum dot-sensitized solar cells (QDSCs)

A semiconductor device which convert sunlight into direct current is called solar cell or PV cell.

A quantum dot solar cell (QDSC) is a solar cell design that **uses quantum dots as the absorbing photovoltaic material**.

Construction of QDSSC- Quantum Dot Sensitized Solar Cell

Working Electrode: Fluorinated Tin Oxide substrate is taken and coated with mesoporous wide band gap semiconducting TiO_2. TiO_2 is coated with quantum dots such as CdS by CBD method. TiO_2 act as electron conductors (or acceptors) and transport layers. CdS facilitates the charge separation

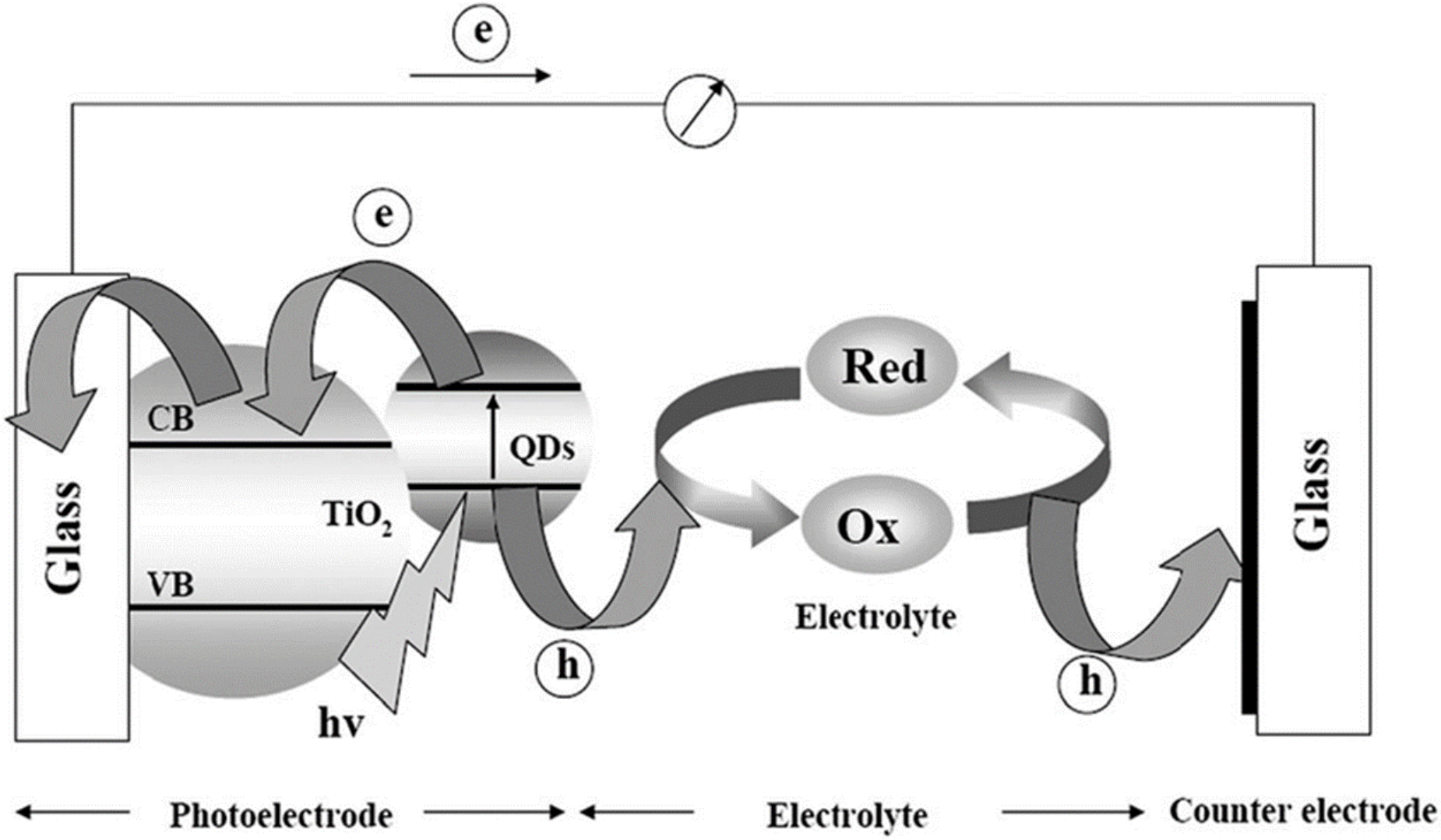


Counter Electrode: A platinum and carbon based materials are coated on a brass substrate. Counter electrode is acting as cathode and it transfers electrons from external circuit to electrolyte and catalyze the reduction reaction of the oxidised electrolyte at the electrolyte/ counter electrode interface.

Electrolyte: Polysulfide is used as electrolyte((S2-/Sx 2-) It is a redox electrolyte or hole conductor. Redox electrolyte significantly influence both stability and efficiency of QDSSC. It is a medium which transfer charges between counter electrode and photo anode for the regeneration of oxidized quantum dots.

Sensitizer: CdS is a sensitizer, it is a Quantum dot nanocrystal made of semiconductor materials.

Working of QDSSC



Working of QDSSC

1. Upon light irradiation the photosensitizer is photo excited.
2. The excited electron of QD are injected into the conduction band of TiO2.
3. The electrons penetrate through nano crystalline TiO2 film to the back contact of the conducting substrate and flow through an external circuit to the counter electrode.
4. At the counter electrode the oxidized(S^{2-}/Sx^{2-} component of the redox couple in the electrolyte is reduced.
5. The oxidized form of the sensitizer(QD) are finally regenerated by the reduced component of the redox couple in the electrolyte.

1. The quantum dots absorb light and gets excited

2. The electron-hole pairs are created only if the photon energy is greater than the binding energy

3. The excited electrons are injected into TiO_2

4. The electrons are extracted to anode , passes through the external circuit towards counter electrode to produce electrical energy

5. Regeneration of CdS

6. Regeneration of electrolyte at counter electrode

Properties of QDs

1. Quantum dots has narrow bandgap.
2. It exhibits tunable bandgap.
3. Strong light absorption and
4. High multiple electron generation.

Application

1. QDSSC is mainly used to harness solar energy.