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Review paper on Electrical Vehicle (EV) Batteries

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Abstract – Battery is a device that stores electric charge. As per renewable energy sources the Electrical Vehicle is option to Bikes, Vehicles as an alternative of petrol & Diesel.it helps to reduce Carbon Monoxide & other toxics gases emission form the Vehicles. It is better option as Green energy with zero emission.in worldwide the EV Vehicles use in increases, Batteries are comprised of two distinct sections: the negatively charged anode and the positively charged cathode. The anode is negatively charged as a result of an excessive buildup of electrons which inherently possess a negative charge. Conversely, the cathode is positively charged as a result of a deficit of electrons. The electric potential energy defined by the magnitude of this charge difference is commonly referred to as Voltage, and electricity is what happens when electrons move to balance out the charge imbalance.

Key Words: Battery, Anode & cathode, Electrical Charges, Electrical Potential, Lithium-ion Batteries, Nickel-Metal Hydride Batteries, Lead-Acid Batteries, Ultra capacitors Energy storages.

1.INTRODUCTION

This advantages of electric vehicle (EV) batteries over traditional fossil fuel-powered vehicles. It highlights key attributes of EV batteries that make them a compelling choice for sustainable transportation solutions

- **Energy Storage and Environmental Impact**: EV batteries are seen as crucial for replacing fossil fuels because of their ability to store energy efficiently and their positive environmental impact.
- **Higher Voltage and Specific Capacity**: This enables longer driving ranges per charge
- **High Energy Density**: This results in lighter, more compact battery packs, improving vehicle efficiency and range.
- **No Memory Loss**: Unlike some older battery technologies, EV batteries maintain their performance without degradation due to partial discharges.
- **Superior Cycling Performance**: EV batteries can withstand many charge and discharge cycles before experiencing significant capacity loss.
- **High Efficiency**: EV batteries convert more stored energy into usable propulsion energy.
- **Minimal Self-Discharge**: This allows batteries to retain their charge over long periods without significant energy loss.
- **Wide Operating Temperature Range**: EV batteries function effectively across various environmental conditions.
- **Diverse Metal Components**: The performance of EV batteries is influenced by the metals used in their construction, including nickel, manganese, cobalt, iron, aluminium, and titanate. These materials play a crucial role in the efficiency and longevity of the batteries.

2. TYPES OF EV BATTRIES:

2.1.1 lithium-ion battery cell:

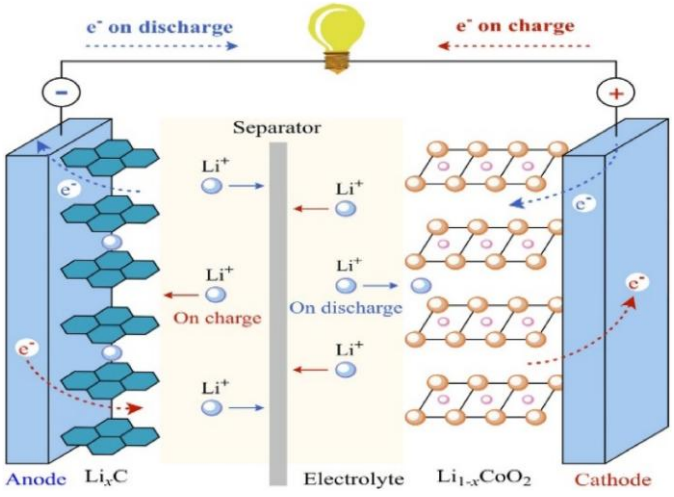

Fig -1: Lithium -ion cell

- **Positive Electrode (Cathode)**: This is where lithium ions are stored during charging and released during discharging. It is typically made of lithium metal oxide (e.g., lithium cobalt oxide).

- **Negative Electrode (Anode)**: This is the electrode where lithium ions are stored during discharging and released during charging. The anode is typically made from graphite.
- **Separator**: This thin, porous membrane allows lithium ions to pass between the anode and cathode while preventing direct contact between them to avoid short circuits.
- **Electrolyte:** The electrolyte is a lithium salt dissolved in an organic solvent that facilitates the movement of lithium ions between the anode and cathode during charge and discharge cycles.

Advantages:

1. **Long Lifespan**: Can handle hundreds to thousands of charge-discharge cycles.
2. **No Memory Effect**: Can be recharged without fully discharging.
3. **Fast Charging**: Many Li-ion batteries support rapid charging technologies.

Disadvantages:

1. **Cost**: Relatively expensive compared to other battery types like lead-acid or NiMH.
2. **Thermal Runaway**: Overcharging or damage can lead to overheating and potential fire hazards.
3. **Limited Raw Materials**: Relies on scarce and often ethically contentious resources like cobalt and lithium.

2.1.2 Nickel-Metal Hydride (NiMH) battery cell:

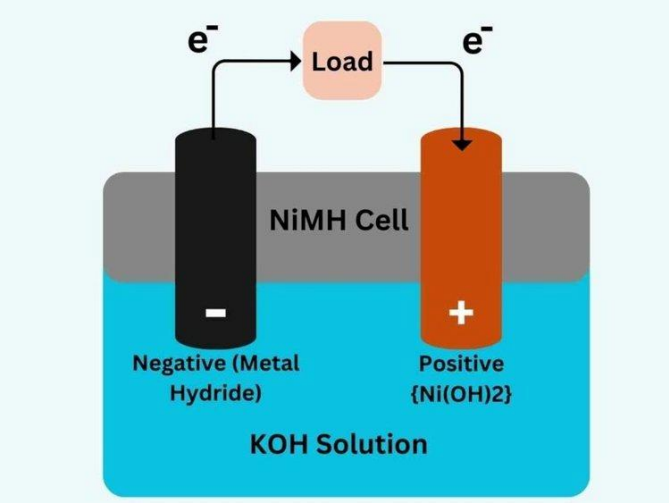

Fig -2: NiMH Cell

Nickel-Metal Hydride (NiMH) batteries are rechargeable batteries that use a chemical reaction between nickel oxide hydroxide (NiOOH) and a hydrogen-absorbing alloy to store and release electrical energy.

Structure of NiMH Batteries:

- **Anode (Negative Electrode)**:

Made of a hydrogen-absorbing alloy (e.g., AB5 or AB2, where A is a rare earth metal and B is a transition metal like nickel, cobalt, or manganese).

- **Cathode (Positive Electrode)**:

Composed of nickel oxide hydroxide (NiOOH).

- **Electrolyte**:

Usually an alkaline solution of potassium hydroxide (KOH) that facilitates the movement of ions.

- **Separator**:

A non-conductive porous material that prevents the electrodes from directly contacting each other while allowing the flow of ions.

- **Casing**:

A sealed metal container that houses the electrodes and electrolyte.

Charging Reaction:

- **A) Negative electrode**:

Alloy + H2O + e- → Alloy (H) + OH-

- **B) Positive electrode**:
- Ni(OH)2 + OH- → NiOOH + H2O + e-
-
- **Discharging Reaction:**

A) Negative electrode:

Alloy (H) + OH- → Alloy + H2O + e-

- **B) Positive electrode**:
- NiOOH + H2O + e- → Ni(OH)2 + OH-

Advantages:

1. **High Energy Density**: NiMH batteries have higher energy capacity compared to older NiCd (Nickel-Cadmium) batteries.
2. **Environmentally Friendly**: They do not contain toxic heavy metals like cadmium.
3. **Rechargeable**: Can be recharged hundreds of times.
4. **Wide Applications**: Used in hybrid vehicles, electronics, and cordless tools.

Disadvantages:

1.Self-Discharge: NiMH batteries lose charge over time even when not in use.
2.Lower Cycle Life: Fewer charge/discharge cycles compared to lithium-ion batteries.
3.**Temperature Sensitivity**: Performance drops in extreme heat or cold.

2.1.3 Lead –Acid Batteries:

Lead-acid batteries are the most common type of rechargeable batteries and are widely used in automobiles, uninterruptible power supplies (UPS), and industrial applications. They store electrical energy through a chemical reaction between lead (Pb) and lead dioxide (PbO_2) electrodes immersed in a sulfuric acid (H_2SO_4) electrolyte.

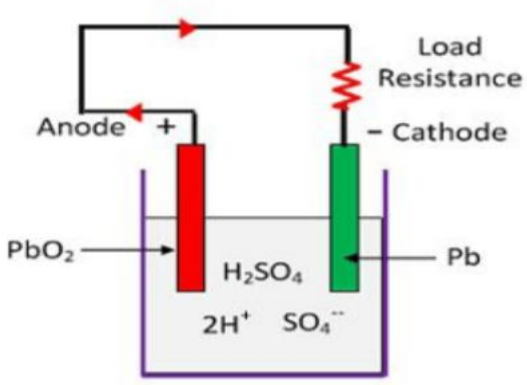

Fig -3: Lead Acid Cell

The overall chemical reaction is:

$$PbO_2 + Pb + 2H_2SO_4 \underset{charge}{\overset{discharge}{\Longleftrightarrow}} 2PbSO_4 + 2H_2O$$

Advantages:

1. **Low Cost**: Economical compared to other rechargeable batteries.
2. **High Reliability**: Proven technology with stable performance.
3. **High Surge Current**: Ideal for applications requiring high initial current (e.g., car starters).
4. **Recyclable**: Components can be recycled efficiently.

Disadvantages:

1. **Heavy Weight**: High energy density but low energy-to-weight ratio.
2. **Limited Cycle Life**: Repeated deep discharges can shorten lifespan.
3. **Maintenance**: Requires regular checking of electrolyte levels (in non-sealed models).
4. **Environment Impact**: Contains lead, which is toxic if improperly disposed of.

2.1.4 Ultra Capacitors Batteries:

Ultra capacitors, also known as super capacitors or electrochemical capacitors, are energy storage devices that store energy through electrostatic charge separation rather than through chemical reactions like traditional batteries. They are valued for their high power density, fast charge/discharge capabilities, and long cycle life.

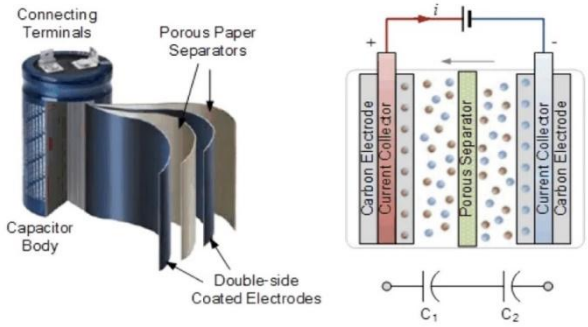

Fig -4: Ultra-capacitor Cells

Energy Storage Process

When a voltage is applied across the electrodes the Positive ions in the electrolyte move toward the negatively charged electrode. Negative ions in the electrolyte move toward the positively charged electrode. This creates a double layer of charges at the interface between each electrode and the electrolyte (known as the electric double layer). No electron transfer occurs across the electrolyte; energy is stored as an electric field.

Energy Discharge Process

When the ultra-capacitor is connected to a load, The stored charge flows back through the external circuit as an electric current. The ions in the electrolyte return to their original positions.

Advantages:

1. **Durability**: Extremely long cycle life compared to batteries.
2. **Rapid Charging**: Fully charges in seconds to minutes.
3. **High Power Output**: Excellent for applications requiring quick bursts of energy.
4. **Environmentally Friendly**: No toxic chemicals or heavy metals.
5. **Low Maintenance**: Minimal degradation over time.

Disadvantages:

1. **Low Energy Density**: Ultra capacitors store less energy per unit weight compared to batteries, making them unsuitable for applications requiring extended energy delivery.
2. **Higher Cost**: More expensive per watt-hour than traditional batteries.
3. **Voltage Limitation**: Operates at lower voltages, often requiring multiple units in series for higher-voltage applications.

3. COMPARISON OF DIFFERENT EV BATTERIES:

Parameter	Lithium-Ion	NiMH	Lead-Acid	Ultra-capacitors

Cost	High	Medium	Low	High
Charging Time	Fast	Moderate	Slow	Extremely Fast
Life span	Long	Medium	Short	Very Long
Weight	Light weight	Heavy	very Heavy	Lightweight
Power Density	High	Medium	Low	Very High
Applications	EVs	Hybrids	Low Speed EVs	Hybrids Systems

Table 1- Comparison of Batteries

4. CONCLUSIONS:

Depending on use various parameters the probable conclusion is as given below

- For full EVs: Lithium-Ion batteries are the best choice due to their high energy density, long range, and fast charging capabilities. They are standard in most modern EVs like Tesla, BYD, and Hyundai.
- For hybrids: NiMH batteries are better suited because they are durable and safer for frequent cycling in hybrid drivetrains.
- For cost-sensitive EVs: Lead-acid batteries may work, but they are outdated for high-performance vehicles.
- For specific use cases: Ultra-capacitors are ideal for applications requiring rapid energy bursts, such as regenerative braking systems.

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