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ADVANCEMENT IN ELECTRIC VEHICLE BATTERY

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ABSTRACT

We see the huge development in the automobile sector. The Electric vehicles are growing presto and the demand for them is adding each around the world day- by- day. The main component of Electric vehicles is Battery for driving all types of electric vehicles. So the development in the battery took place in a different manner. The various types of batteries are used for various applications. The sizing of the battery varies as per the load requirements and its application. For better performance of the Electric vehicle we need to find the right battery for the right application. Engineers find various types of the batteries. In starting the lead acid battery was the important battery for the purpose of auxiliary supply required in automobiles. Later on, the Lithium Ion battery is used in Electric vehicles. The battery used in the vehicles needs to be further explored to harness outside energy with a compact design. Electric vehicles should soon be suitable to contend with combustion machine vehicles in every aspect. Also, this paper reviews indispensable accouterments for electrodes and batteries to make charging briskly and dependable than ever. It includes the standard charging biographies and revision of the standard pattern which affects battery performance and working life, is presented. The results show a conspicuous enhancement in battery life by reducing capacity declination and lowering the rate of increase of the internal resistance of the battery (therefore perfecting battery power capacity). The lithium ion battery is a commonly usable battery pack in electric vehicles. It has a higher storage capacity than other battery packs. The paper also discusses research gaps in various batteries.

Keywords: Electric Vehicle, Lithium-Ion Battery, Battery Power, Plug-In Vehicle.

I. INTRODUCTION

The effects of fossil fuel depletion on the ecosystem have increased the urgency to transition to renewable energy sources and alternative transportation technologies. The excessive extraction and utilization of fossil fuels result in the generation of significant quantities of CO2 and other greenhouse gas emissions (GHGE). Utilizing renewable energy sources and electrifying the transportation sector, as shown in Fig.1, can reduce the GHGE by up to 40%. Renewable energy, such as solar, wind, wave, and tidal power provides a greener, more sustainable alternative to fossil fuels [13]. However, the intermittent nature of these energy sources poses a challenge to maintaining a consistent and reliable power supply. To tackle this challenge, energy storage systems (ESSs) are utilized to store surplus energy generated from renewable sources during peak production periods and release it to the grid during high demand or when renewable energy generation is low. The ESSs play a crucial part in boosting the viability and stabilizing the power grid of the widespread adoption of renewable energy sources.

EVs and HEVs are powered by batteries, which offer features including high energy density, low environmental impact, and durable performance. The wider adoption of EVs depends on advancements in battery technology. Efforts are being made to enhance energy storage capacity, reduce charging times, and lower costs. Currently, Lithium-ion (Li-ion) batteries are the most prevalent type used in EVs due to their favorable characteristics, but researchers are also exploring other battery chemistries as shown in Fig. 1.

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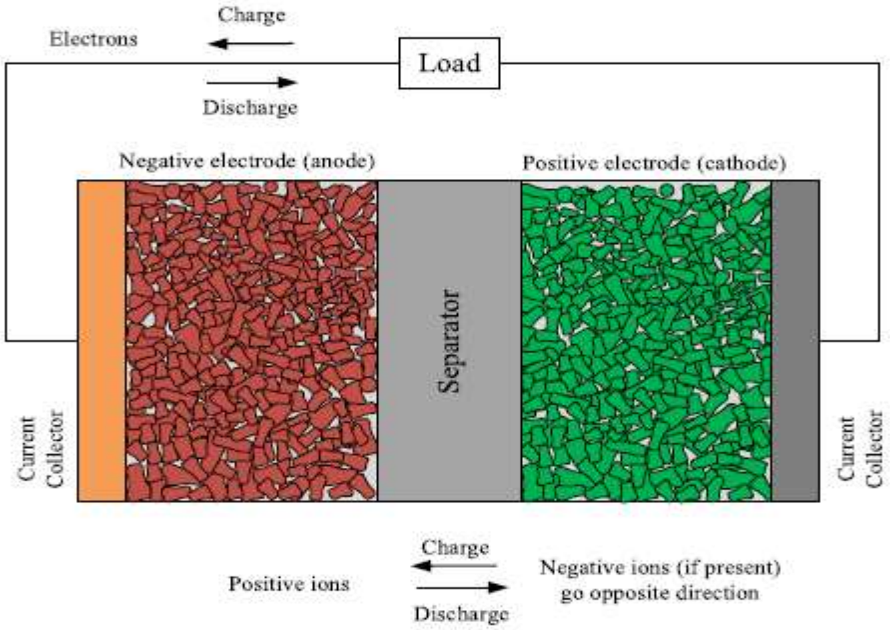

Figure 1: Schematic diagram of Li-ion cell.

II. BATTERY TYPES IN EV

Various types of batteries can be utilized as the power EV applications as given in Fig. 2 The BMS consists of multiple functional modules. In this study, popular battery types and key BMS technologies are analysed and condensed. According to their capacity for charging, batteries can be divided into two general categories: primary batteries and secondary batteries. Secondary batteries can be recharged following the discharge process, however primary batteries can only be used once after being entirely depleted. Secondary batteries with a high cycle life, a low power density, a low energy loss, and sufficient safety levels are required for EV and HEV applications. Some commonly used battery types in EVs include Li-ion, lead acid, nickel-cadmium (NiCd), and NiMH, among others and the evolution of the batteries with respect to its timeline is shown in Fig. 3. Key details for these well-liked battery types are presented in Table 1. This clearly demonstrates that Li-ion batteries exhibit significant advantages over other types, in terms of their longer cycle life, which is essential for ensuring long service life in EVs (typically 6-10 years) [1]. Additionally, Li-ion batteries are made of environmentally acceptable components, don't emit any hazardous gasses, and provide a high level of safety.

As a result, Li-ion batteries are now the most widely used kind of EV power. Lithium-based batteries have the highest cell potential and the lowest reduction potential when compared to other elements as given Table 2. Lithium is one of the single-charged ions with one of the smallest ionic radii, making it the third-lightest element in terms of mass. These qualities allow Li-based batteries to attain high power density, gravimetric capacity, and volumetric capacity [2]. The Li-ion battery exhibits an energy density range of 200-250 Wh/kg and boasts a high coulombic efficiency of nearly 100% [3]. It is also free from memory effects. Due to its superior energy and power density compared to lead-acid and Ni-Cd batteries, lithium-ion batteries are now the preferred

choice. It is widely used in many different products, such as electric automobiles, power equipment, and portable gadgets [4], [5], [6]. Li-ion battery development is ongoing with the goal of increasing their cycle life and safety in both normal and abusive situations [7], and overall performance characteristics. In the pursuit of higher energy density for electric vehicles, researchers have explored alternative electrochemical energy storage systems. One such technology is the lithium-sulfur (Li-S) battery, which offers advantages for instance, increased energy density, enhanced security, a larger operational temperature range, and maybe lower prices due to the abundance of sulfur. These factors make Li-S batteries a promising option for EV applications [8]. Energy density and specific energy of various batteries at cell level is shown in Fig. 4. However, widespread commercialization of lithium-sulfur technology has not yet been achieved due to certain limitations. These

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excessive discharge current, self-discharge, poor cycle life and capacity decline brought on by cycling, low coulombic efficiency, uncontrolled dendrite development, and other factors.

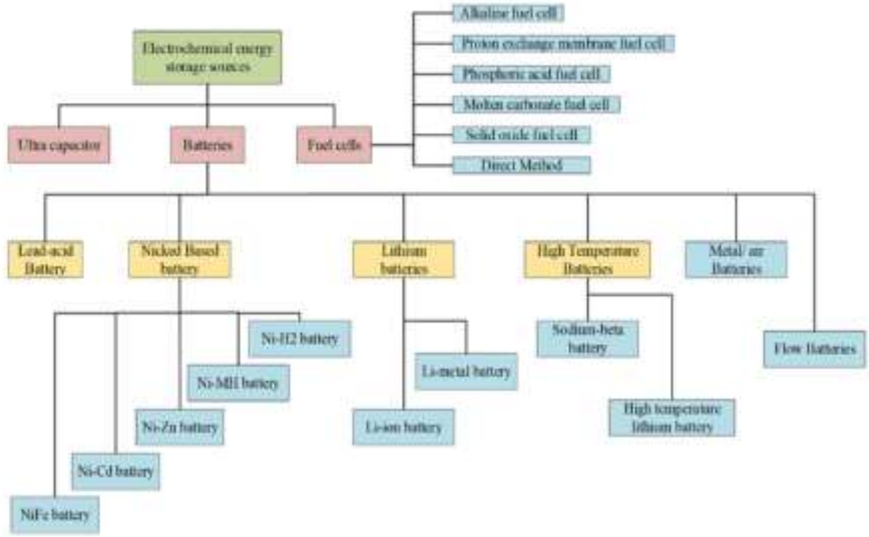

Figure 2: Classification of electromechanical energy storage sources.

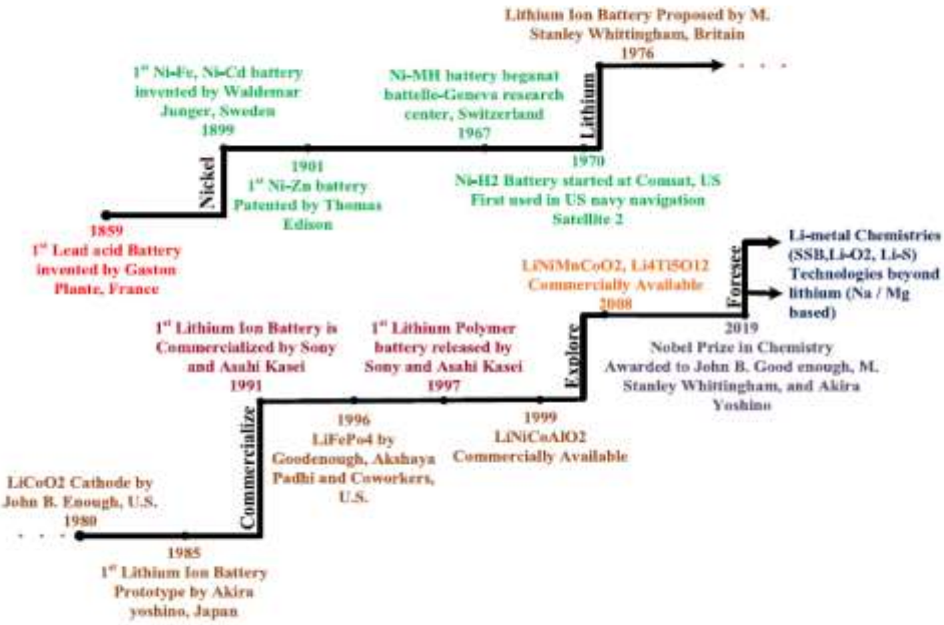

Figure 3: Milestones and foresight of battery Technologies.

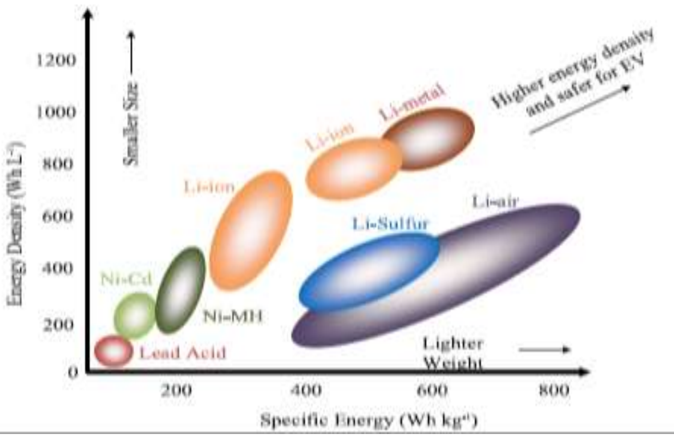

Figure 4: Energy density and specific energy of various batteries at cell level.

III. BATTERY TECHNOLOGIES BEYOND LITHIUM

Extensive research has been done on battery technologies other than lithium as LIBs get close to their natural limits in terms of specific energy and energy density. Three different battery types have developed as alternative technologies in recent decades:

1) METAL/AIR BATTERIES

Anodes made of metal and cathodes made of air are used in metal/air batteries. The energy capacities of these batteries are primarily determined by the anode capacity and the handling process. Despite this limitation, they offer exceptionally high energy density and specific energy, with maximum values of 400 and 600 Wh/L, respectively. Zinc/air, aluminum/air, iron/air, magnesium/air, calcium/air, and lithium/air batteries are only a few examples of the several kinds of metal/air batteries that are available. These batteries can be classified as primary (non-rechargeable), electrically rechargeable, or mechanically rechargeable. Among them, mechanically rechargeable batteries provide the convenience of refueling and recycling.

2) SODIUM-BETA BATTERIES

High energy density is a well-known characteristic of sodium-beta batteries, although researchers have successfully developed only two technologies in this field. These include sodium/sulfur (Na/S) batteries and sodium/metal chloride (Na/MCl2) batteries. These batteries must function at high temperatures between 270 and 350 ◦C in order to achieve the necessary ionic conductivity.

3) SODIUM/METAL CHLORIDE (NA/MCL2) BATTERY

Na/MCl2 batteries use transition metal chloride as the cathode material. In particular, Na/FeCl2 and Na/NiCl2 batteries are made using iron chloride and nickel chloride, respectively. Among these, the Na/FeCl2 battery has undergone more significant development compared to the Na/NiCl2 battery. The Na/NiCl2 battery offers several advantages, including increased power density, a wider working temperature range, and less corrosion of metallic elements.

4) SODIUM/SULFUR BATTERY

The Na/S battery uses beta-alumina ceramic electrolyte, sodium anode, and sulphur cathode. However, the performance of Na/S batteries tends to decline as the internal resistance increases, which is further exacerbated by deeper discharges. In recent research, there has been exploration into room-temperature Na/S batteries that demonstrate robust and consistent cycling performance [9], [10].

Table 1: Key details in battery used in EV [11]

Battery Type	Nominal Voltage (V)	Power Density ($W.kg^{-1}$)	Energy Density ($W.h.kg^{-1}$)	Charging Efficiency (%)	life cycle	Self-Discharge rate ($\%.month^{-1}$)	Charging Temperature (°C)	Discharging Temperature (°C)
Li-ion	3.2-3.7	250-680	100-270	80-90	600-3000	3-10	0 to 45	-20 to 60
NiCd	1.2	150	50-80	70-90	1000	20	0 to 45	-20 to 65
Lead Acid	2.0	180	30-50	50-95	200-300	5	-20 to 50	-20 to 50
NiMH	1.2	250-1000	60-120	65	300-600	30	0 to 45	-20 to 65

Table 2: Li-ion battery types [12].

Battery Types	Cathode Material	Anode Material	Nominal Voltage (V)	Life Cycle	Energy Density ($Wh.L^{-1}$)	Cost	Safety
Lithium Iron Phosphate (LiFePo4)	LiFePo4	Graphite	3.2	High	Low	High	Safest Li-ion cell Chemistry
Lithium Cobalt oxide (LiCoO2)	LiCoO2	Graphite	3.6	Medium	High	Low	Highest safety concern
Lithium Nickel Manganese Cobalt oxide (LiNiMnCoO2)	LiNiMnCoO2	Graphite	3.6	Medium	High	Medium	Good Safety
Lithium Manganese oxide (LiMnO2)	LiMnO2	Graphite	3.7	Low	Low	Medium	Good Safety
Lithium Nickel Cobalt Aluminum oxide (LiNiCoAlO2)	LiNiCoAlO2	Graphite	3.6	Medium	High	Medium	Safety Concern Required

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Batteries are the most essential element for a vehicle that runs on electricity. Also, the vehicles have the advantage of recharging overnight due to the presence of an electric grid. Recently, due to environmental and security reasons, countries like the U.S., India, China, and European Union are taking a several interest in promoting electric vehicles through schemes, incentives, etc, the drive range is directly proportional to battery capacity. Due to the lack of charging stations everywhere, customers fear getting stuck somewhere causing delay, inconvenience, and anxiety in a journey. The term describing this is called "range anxiety", fear of insufficient power in the vehicle to reach the destination or to any nearby charging infrastructure. OEMs are constantly working towards increasing the driving range by increasing battery capacity that impacts the size, chemistry, and battery management system

The battery makes up a significant portion of the cost and environmental impact of an electric vehicle. Growth in the industry has generated interest in securing ethical battery supply chains, which presents many challenges and has become an important geopolitical issue.

IV. ADVANCEMENT IN BATTERY

A. Advance Li-ion batteries are made up of several components:

- Anode: The anode is the negative electrode of the battery. It is typically made from graphite or lithium metal.
- Cathode: The cathode is the positive electrode of the battery. It is typically made from a lithium metal oxide, such as lithium cobalt oxide ($LiCoO2$) or lithium iron phosphate ($LiFePO4$).
- Electrolyte: The electrolyte is a solution that allows lithium ions to flow between the anode and cathode. It is typically made from a lithium salt dissolved in a solvent.
- Separator: The separator is a porous membrane that prevents the anode and cathode from coming into physical contact with each other. It allows lithium ions to flow through but blocks the flow of electrons.
- Current collectors: Current collectors are conductive materials that collect electrons from the anode and cathode and deliver them to the external circuit.

When the battery is charged, lithium ions are removed from the anode and inserted into the cathode. This creates a flow of electrons through the external circuit, which powers the device. When the battery is discharged, the lithium ions flow back from the cathode to the anode, reversing the flow of electrons and providing power to the device.

Lithium-ion batteries are mainly used in portable electronic devices, such as laptops, smartphones, tablets, and digital cameras as well as it becoming increasingly important for electric vehicles and grid-scale energy storage.

B. Some challenges

1] Cost of the battery: as per the increasing demand of E-Vehicle the price of batteries is also increasing. Also, it can be increased due to the advancement in battery.

2] Charging capacity: the battery should have a high charging capacity which can charge in minimum time.

3] Structure: If the structure of batteries are large it becomes heavy; due to this it takes a large space in the vehicle.

4] Temperature: If the load is increased in the vehicle the motor consumes more power due this the battery gets heated a lot.

C. Some advancement in Battery system

- **Aluminium-ion Batteries**: The Lithium-ion batteries are commonly used in EVs for a long time. The disadvantages of li-ion batteries made alternative research on chemicals to maximize the efficiency of batteries Aluminium-ion batteries are promising alternatives to li-ion batteries. Aluminium-ion batteries are good for energy storage offering potential advantages like lower cost,higher abundance of aluminium and potentially higher energy density. Aluminium is more abundant than lithium. Al-ion batteries provide four times more energy than Li-ion batteries at a low cost. In Al-ion batteries, Aluminium is used as a negative electrode and graphite as a positive electrode when graphitic materials are used.
- **Foldable Batteries**: These batteries support fast charging and can be used to power up small components in EVs. It is stable even with bending fatigue and has a high energy density.These batteries would be

flexible,durable,and capable of maintaining their performance even after repeated bending and flexing. Foldable batteries have an operating temperature from -20C to 60C which makes them suitable for any climatic condition.

- **Lithium-Air Battery**:The lithium-air battery (LiO2B) is yet another lithium battery that needs to be explored more due to its high capability in producing energy. In the cell, the anode is lithium metal, the cathode is porous carbon and the electrolyte used .The energy density of aqueous lithium-air batteries is lower than that of non-aqueous lithium-air batteries but higher than that of the traditional gasoline engine .
- **Material selection of electrodes for Fast charging**: The efficiency of the battery is determined by the material used for electrodes. Li-ion batteries are capable of fully charging in less time. In a Li-ion battery due to its high conductivity and stability, graphite is used as one electrode. Materials should be selected in such a way that it decreases the time of charging. Red phosphorus can be used for its high-energy-density fast charging of Li-ion batteries.
- **Solar Panel**: By using solar panels for producing power for EVs .Solar panel module can be used to energize the battery packs automatically which reduces the driver's anxiety, unnecessary stops and helps to increase the range of the EV. Production of batteries by using renewable energy sources will reduce the toxic wastes caused by vehicles. This concept is perfectly environmentally friendly. The solar panel modules are installed on the roof of the EVs. The output from the battery depends on the solar light it absorbs. Electrical energy is generated when the sun's rays are captured by panels.
- **Solid-State Battery** : A solid-State battery (SSB) is an emerging technology that uses solid electrolytes instead of the liquid and gel electrolytes which are commonly found in other batteries . A solid-state battery has higher energy when compared to the Li-ion battery which uses liquid as the electrolyte solution. SSB are safer than current battery systems. Since it is made up of solids, it is less risky, non-flammable, and there is no worry of electrolyte leaks. The flame-resistant electrolyte is used in SSBs. Solid states batteries are also used in improving other types of batteries.A solid-State battery is perfect to make an EV battery system. Car manufacturers are working on Solid-State batteries to improve vehicle's efficiency.
- **Supercapacitor**: Supercapacitors are an innovation built to store chemical energy but follow a completely different principle than that of a battery. Supercapacitors, also called electric double-layer capacitors (EDLC), have gained more importance lately due to their applications in the EV industry. They have more than half a million life cycles by storing their energy in an electrostatic field .The batteries have a shorter life cycle as compared to supercapacitors. EDLCs also have the potential to work under a wider temperature range of -40to 70 C while batteries tend to cause problems in colder temperatures.

V. CONCLUSION

This paper overlooks the major challenges faced by electric vehicles such as lack of charging infrastructure, drive range and thermal management of batteries. Possible solutions to solve this kind of issue are also discussed in the paper. The advancements in battery technology to improve the quality of electric vehicles are put forward. It also discusses a few concepts that may not be possible currently but will aid with future technology improving electric vehicles. New battery technology such as graphene even though has already revealed great potential, but it is still in this stage and it will not be suitable for mass production in the near future. So far, Lithium-ion batteries still have the highest power density of all batteries on the commercial market on a per-unit of volume and weight basis. This advantage along with its characteristics of fast response, low power capacity cost, and good scalability make Lithium Ion batteries remain the most promising batteries for electric vehicles and a competitive technology for energy storage applications.

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