Review of Recent Research in Batteries

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***Abstract* - In this paper we present the different kinds of research and development in batteries and another sources, Now a days in automotive technology is shifted from conventional fuel to electrical sources to drive a automotive devices (EV), so for that battery is a primary part for this technology, but there are some limitation because of batteries Amp-Hours capacity consequences it will not give a reliability as well as time consuming because of every batteries has a different charging time, So now researches tires to make battery that will give a reliability and less time consume with good Amp-Hours capacity and energy density, Also the battery are used in many of small and medium size devices like " Cell phone, watch, home appliances etc. In this paper we shows that some small and medium research are done in real world,**

***keywords* - Introduction, Literature Review, Configuration of battery, Improvement in LI-ion BATTERY, paper BATTERY, Lithium Sulfur Battery, Different battery technologies for various grid use cases, Conclusion**

I. INTRODUCTION:

Over the past 10 years, a global ecosystem has emerging to provide a foundation for rapid innovation and scaling of these new technologies. This ecosystem includes following points like

1. Large and private Investment
2. Ambitious government support
3. Strategic Alliances
4. Diversifying Global Manufacturing Investment.

Investment in research and development will continue to unlock better performance, while faster adoption in both mobile and stationary applications will create self-reinforcing feedback loops for demand growth and price decreases. Continuing investments in Li-ion technologies are leading to batteries that perform better against multiple attributes, especially energy density and cycle life. [8].

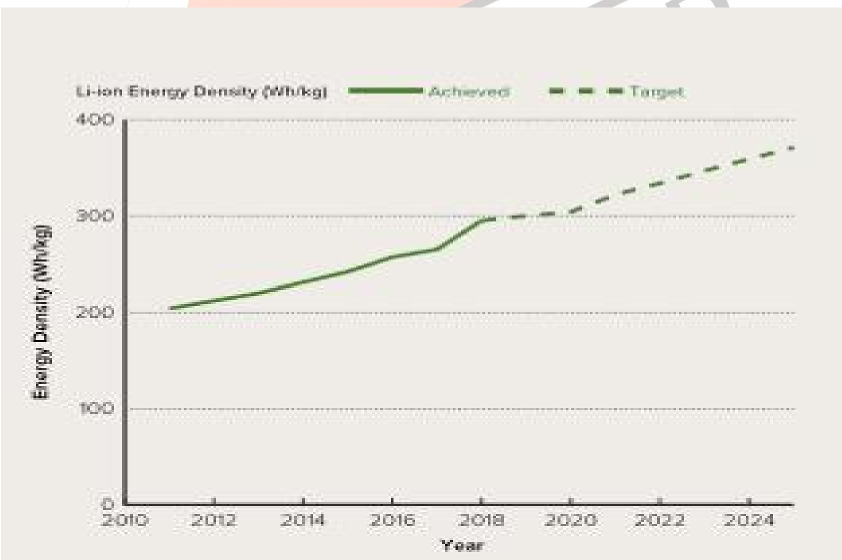

Figure 1. Graph of Energy Density and future requirement

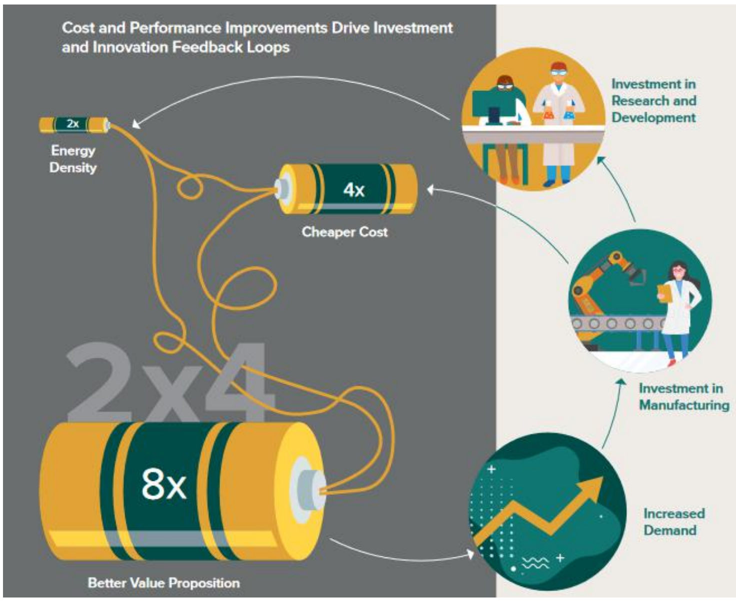

Figure 2. Targeted Cost and performance improvement in battery

In figure 2. Shows such improvements have multiplicative and self-reinforcing effects as the prices decrease, batteries are simultaneously becoming longer lasting, lighter, and safer, leading to rapid increases in value for customers. As early adoption shifts to exponential growth, additional investment and enabling policies reinforce the cycle of innovation. Newer innovations approaching commercialization, such as solid-state technology, could unlock even more dramatic cost reductions and step changes in performance. Here some challenges are faced when any kinds of research & development in battery like, [1]

1. Metals such as Cadmium, Mercury, Lead, Lithium and Zinc have been identified as highly toxic metals
2. Batteries may be harmful or fatal if swallowed. Small button/disk batteries can be swallowed by young children.
3. Hydrogen-based fuel cells are still extremely costly for general consumer use,
4. Liquid Hydrogen and Hydrogen Peroxide are essential ingredients that make them costly.
5. Also Solar cells cannot be used under all situations, like Emergency Power-Backup, Emergency Energy Purge
6. Solar cells cannot be used in all battery-powered equipment.
7. They are not at all portable or robust & need of an Auxiliary back-up battery, The solar cells need an auxiliary back-up battery during failures.

II. Literature Review:

In this paper we have used different kinds of papers that we can applied for new technology for battery, we have cover a various topics for research in battery. First we explain the concept of battery, its structure, and material that used to make a good energy densities battery like Li-ion, new batteries that will used in future devices. A new technology to make a new kinds of battery like paper battery. Also we discuss about how to reduce a Li-ion material used for Li-ion battery. At last we discuss a new era of power sources like Nano-generator & Tribo-Electric generator exist in different form Flexible Tribo-electric generator.

III. Configuration of battery:

According to basics principle of battery, it require following five major components: [4]

1. Anode
2. Cathode
3. Current Collector
4. Electrolyte
5. Separator

The purpose of the anode is to hold the active ions in a high energy state. The higher the energy state, the higher the eventual voltage of the cell. In principle, pure metal is the best anode material, due to the metal being the highest possible energy state to hold the metal in, as well as holding the largest amount of metal atoms in the smallest amount of space. However, dendrite formation often hampers the use of pure metal. Hence, other solutions, which can prevent this dendrite formation, are often used instead, such as inserting the ions into the interlayer spacing's in graphite.

Conversely, when the metal is oxidized and the resultant ion moves over to the cathode during discharge, the ion inserted cathode needs to be in a much lower energy state than when it was at the anode. It is this difference in energy that gives the thermodynamic push for electrons to move through a circuit and do work. The larger the difference, the higher the voltage, and the battery will store more energy.

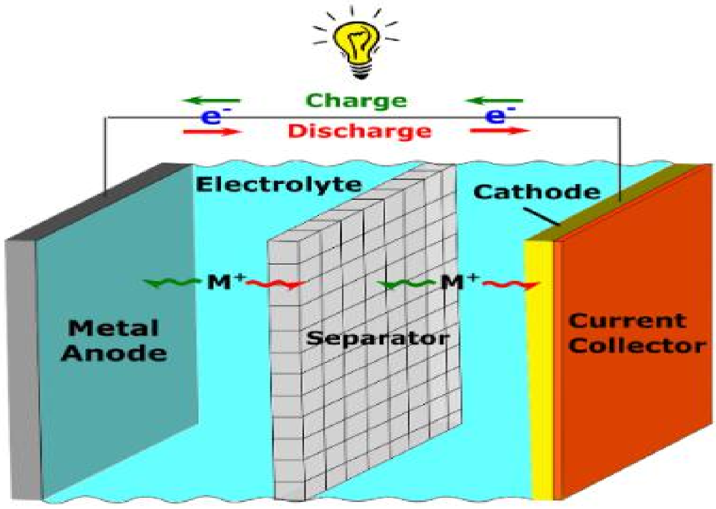

Figure 3. Battery with its components

An ion-battery operates by transferring charge using freely moving ions shuttling back and forth between the two electrodes. This charge transfer occurs via different mechanisms depending on how the active ion interacts with an electrode material. The amount of charge that a battery can store depends on the potential difference of the electrochemical reactions of the active ion that occur at the two electrodes and the number of electrons involved in each of these reactions. One can either increase the potential difference between the two electrode processes or use ions involving multiple electrons to increase the amount of charge stored or the capacity of the system. Both these factors are governed by the mechanism with which charge is transferred. Now a days Li-ion battery is more demanding battery in various section, as investment in Li-ion grows, companies are pursuing different battery chemistry compositions with widely varying performance attributes,

IV. IMPROVEMENT IN LI-ION BATTERY: [5]

There are various improvements are done for Li-ion battery, here some improvements are shown on base of various factors,

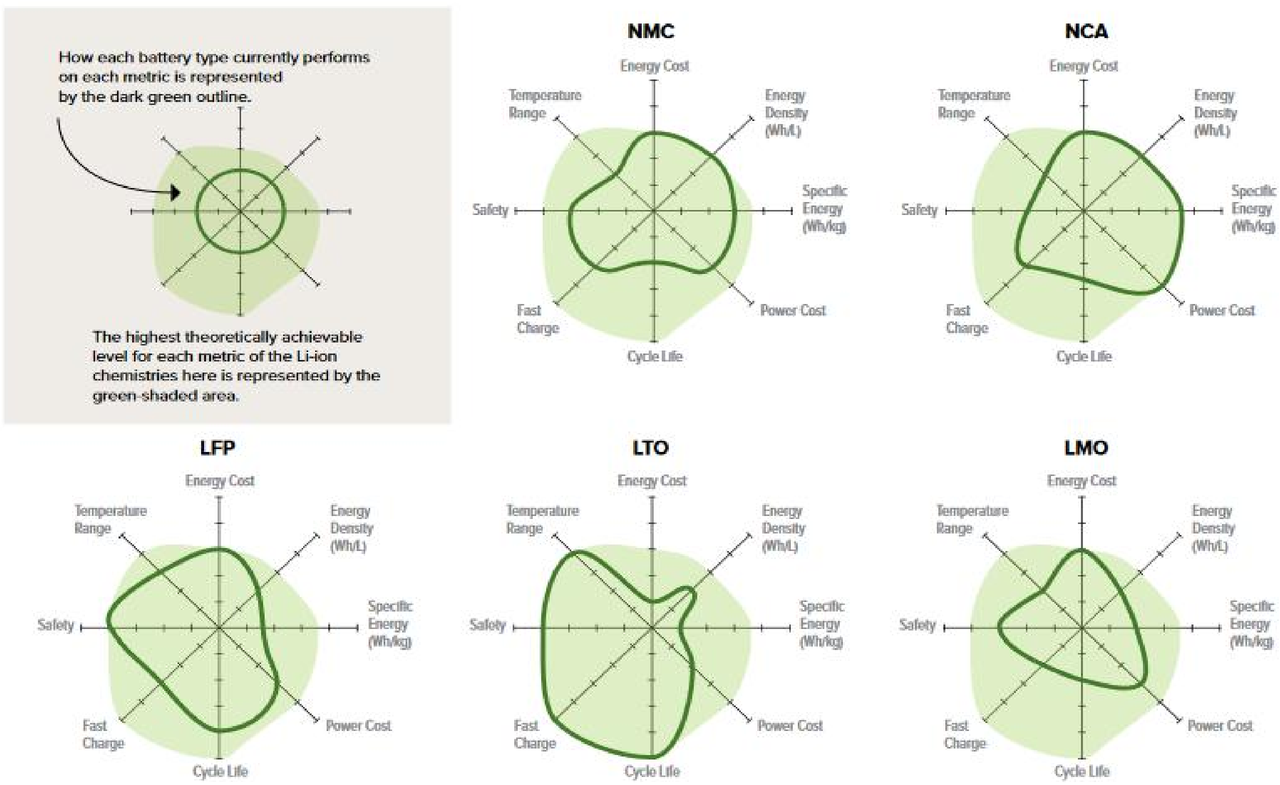

Figure 4 Selected performance of various Li-ion battery

- *Specific Energy*. EV manufacturers will continue to fuel the search for more space- and weight-efficient batteries. **Li-nickel manganese cobalt oxide (NMC) and Li-nickel cobalt aluminum (NCA)** chemistries have the most effort directed toward increasing energy density at an affordable cost.

- *Cycle Life*: Fast charging and temperature strain have big impacts on Li-ion battery cycle life. **Li-iron phosphate (LFP) and Li-titanate (LTO)** have good cycle life but are not the main focus of current manufacturing additions, as this cycle life comes at the expense of specific energy and cost.

- *Safety:* Todays Li-ion batteries are vulnerable to cooling and controls failures due to their use of highly flammable electrolytes. The required thermal management systems and controls add around 1%–5% to total pack costs, and decrease round trip efficiency. Project developers, investors, policymakers, and regulators should gain familiarity with differences in manufacturer quality to minimize risk.

- *Cost :* Continual manufacturing improvements are expected to reduce packaging costs by 10%–15%.15 Cathode improvements represent one key area for cost reduction, especially decreasing cobalt content (e.g., moving from NMC 111 to NMC 811.This requires significant R&D and carries similar technological risks to other new battery chemistries.

Here some application where the above batteries are used.

Sr no	Name of Battery	Application
1	**Li-nickel manganese cobalt oxide (NMC)**	Power tools & Electrical vehicles
2	**Li-nickel cobalt aluminum (NCA)**	Electric Vehicle
3	**Li-iron phosphate(LPF)**	Electrical buses, Grid Storage
4	**Li-titanate (LTO)**	Personal electronics, UPS, some electric vehicles
5	**LMO(Li-manganese oxide)**	Power tools, some electric vehicles (often combined with NMC)

Table 1. Batteries and its Application

V. PAPER BATTERY:

As we know about the structure of batteries and its chemical content used for it, every battery has its own merits and de-merits on that based its characteristics, using its characteristics an application is decided, here some common limitations are shown for present electro-chemical battery.[1]

1. *Limited life*: There are two types in battery (1) **Primary cell** which are irreversible, although it cannot recharge (2) **Secondary cell** which will reversible and it can charge, but the life cycle of primary cell is more limited then secondary cell although if it will charge then it will cause to physical danger on other side the secondary cell is costlier then primary cell for its own chemical composition.
2. *Leakage*: In primary cell "**zinc**" is often used, if leakage occur may any other reason or accidently then it release the chemical which will dangerous, If this kind of battery is run all the way down, or if it is recharged after running down too far, the reagents can emerge through the cardboard and plastic that forms the remainder of the container.
3. *Environment:* Metals such as Cadmium, Mercury, Lead, Lithium and Zinc have been identified as highly toxic metals. Also, batteries may be harmful or fatal if swallowed. Small button/disk batteries can be swallowed by young children. While in the digestive tract the battery's electrical discharge can burn the tissues and can be serious enough to lead to death.

- **Basics of paper battery**: [1] [3]

It is a flexible, ultra-thin energy storage and production device formed by combining carbon nanotubes with a conventional sheet of cellulose based paper. A paper battery acts as both a high-energy battery and super capacitor, combining two discrete components that are separate in traditional electronics. In paper "Cellulose" which is complex organic substance found in paper and pulp. A Carbon Nanotube (CNT) is a very tiny cylinder formed from a single sheet of carbon atoms rolled into a tiny cylinder. These are stronger than steel and more conducting than the best semiconductors. They can be Single-walled or Multi-walled

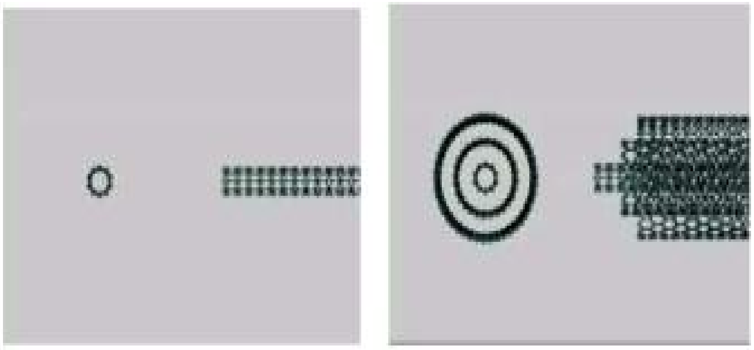

Figure 5: Carbon Nano Tubes

- Properties of Paper Battery : A paper battery is a combination of Cellulous and Carbon Nano tubes and both having a separate properties so the paper batteries properties is same as its content.

1. High Tensile strength; Low Shear Strength
2. Biodegradable
3. Biocompatible
4. Excellent Porosity & Absorption Capacity
5. Easily Reusable and Recyclable
6. Non –Toxic
7. Low Mass density & High Packing Density.
8. Very Light and Very Flexible.
9. Very Good Electrical Conductivity
10. Low resistance **"33 ohm"** per sq. inch
11. Output Open Circuit Voltage(O.C.V): 1.5-2.5 V
12. No heavy metals
13. No safety limitations for shipment, packaging storage and disposal.
14. Temperature operating range: -75°C to +150°C.

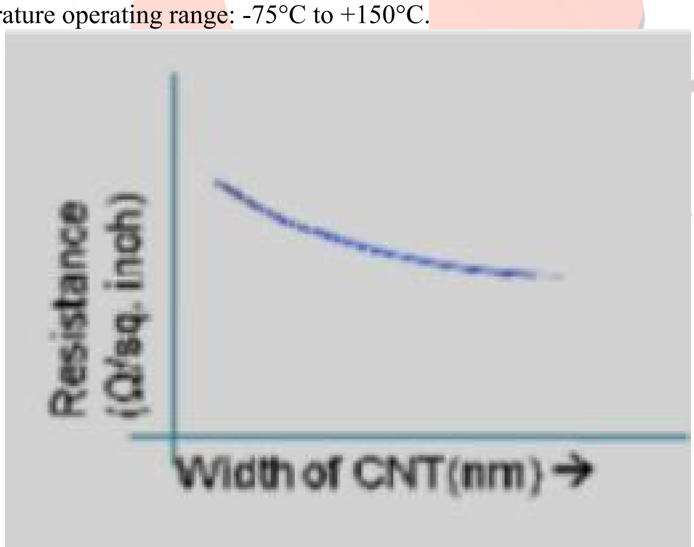

Figure 6: Variation of Resistance with Width of CNT

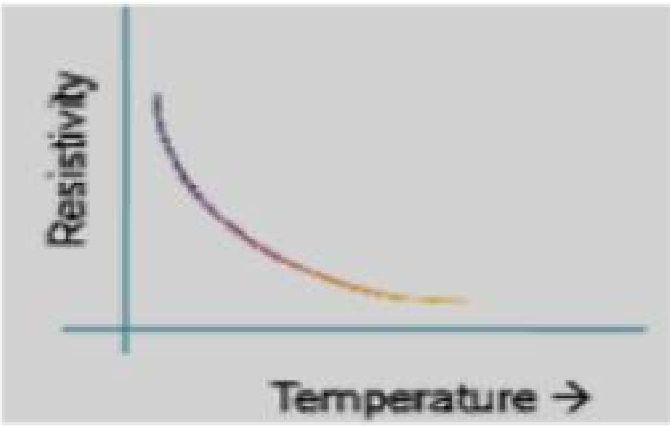

Figure 7: Variation of Resistivity with Temperature

❖ Construction and working :

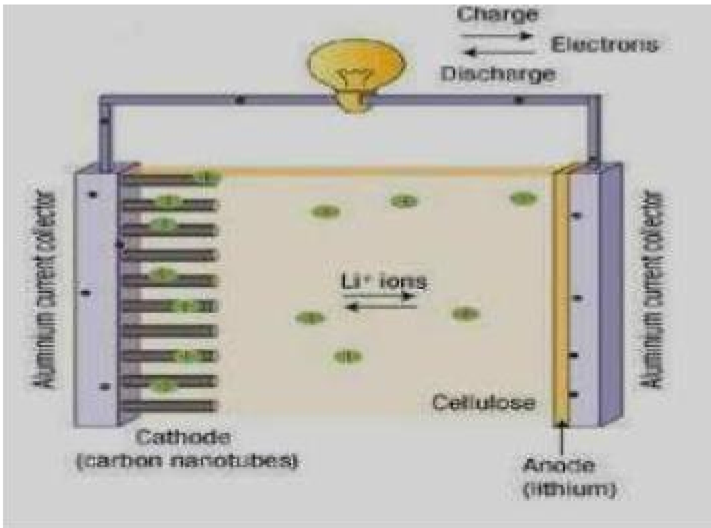

Figure 7 Construction of Paper Battery

The component of battery is as follow:

1. Cathode: Carbon Nanotube (CNT)
2. Anode: Lithium metal (Li+)
3. Electrolyte: All electrolytes (incl. bio electrolytes like blood, sweat and urine)
4. Separator: Paper (Cellulose)

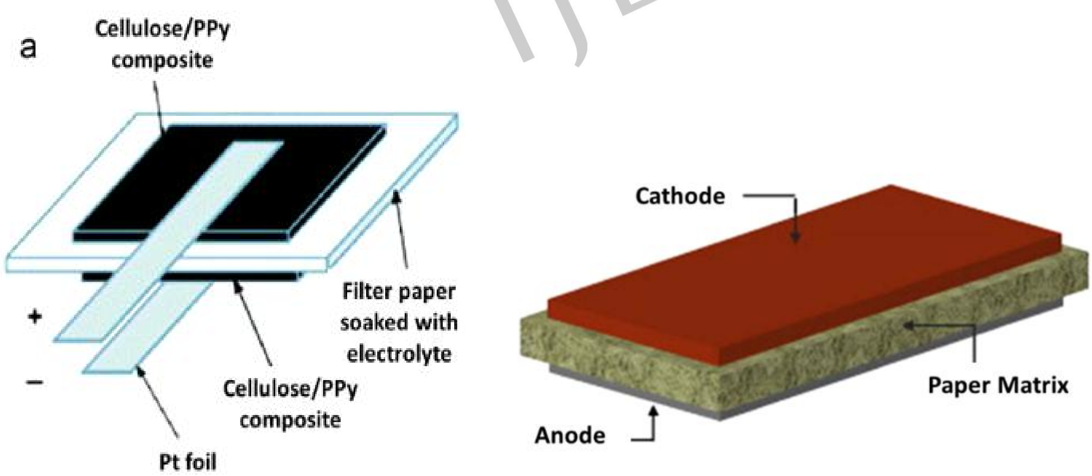

Figure 8 Schematic Diagram of paper battery

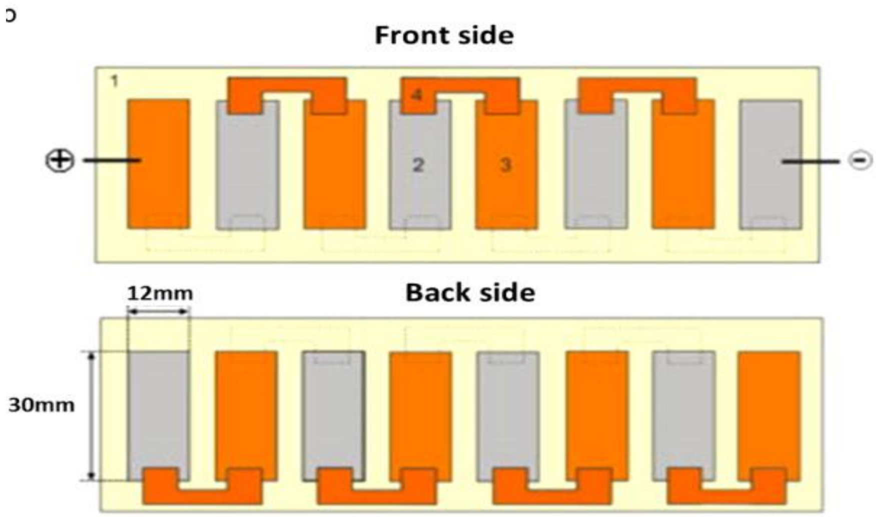

Figure 9. Series integration of cell elements 1) Vegetal-paper, (2) Al anode, (3) Cu cathode, (4) connection

- The Process of construction of paper battery:
  1. Firstly, a common Xerox paper of desired shape and size is taken.
  2. Next, by conformal coating using a simple Mayer rod method, the specially formulated ink with suitable substrates (known as CNT ink henceforth) is spread over the paper sample.
  3. The strong capillary force in paper enables high contacting surface area between the paper and nanotubes after the solvent is absorbed and dried out in an oven.
  4. A thin lithium film is laminated over the exposed cellulose surface which completes our paper battery. This paper battery is then connected to the aluminum current collectors which connect it to the external load.
  5. The working of a paper battery is similar to an electrochemical battery except with the constructional differences mentioned before the procedure.
- Advantages of paper battery :

  1. Biodegradable & Non Toxic: Since its major ingredients are of organic origin, it is a biodegradable and nontoxic product.
     Biocompatible: They are not easily rejected by our body's immune system if implanted into human body.
  2. Easily Reusable & Recyclable: Being cellulose based product it is easily recyclable and reusable, even with the existing paper recycling techniques.
  3. Durable: It has a shelf life of three years (at room temperature). Under extreme conditions it can operate within -75° to +150°C.
  4. Rechargeable: It can be recharged up-to 300 times using almost all electrolytes, including bio-salts such as sweat, urine and blood.
  5. No Leakage & Overheating: Owing to low resistance, it does not get overheated even under extreme conditions. Since there are no leaky fluids, so even under spontaneous or accidental damage, there is no leakage problem.
- Application :
  1. In Electronics: In laptop batteries, mobile phones, handheld digital cameras in calculators, wrist watch and other low drain devices. Wireless communication devices like speakers, mouse, keyboard, Bluetooth headsets etc.
  2. In Medical Sciences: Pacemakers for the heart Artificial tissues
  3. In Automobiles and Aircrafts

VI. Lithium Sulfur Battery : [4]

Lithium–sulfur (Li–S) batteries have been considered as one of the most promising energy storage devices Due to their high theoretical energy density and cost-effectiveness, Li–S batteries have received great attention and have made great progress in the last few years.

- **Principle :**

  A typical Li–S cell is composed of a lithium metal anode, a separator, electrolyte, and a sulfur-based cathode. A schematic illustration of a typical Li–S cell configuration and the two types of charge/discharge voltage profiles are shown in Fig. 10. During the discharge process, lithium metal is oxidized to lithium ions, which travel to the sulfur cathode through the electrolyte where Li forms conversion-type Li–S compounds. Figure 10 b (left) demonstrates the typical discharge–charge pro-files of a solid–liquid dual-phase Li–S electrochemical reaction. At the first plateau around 2.3 V, S_8 is reduced to Li_2S_4, which delivers 1/4 of the theoretical capacity (418 mA h g−1) due to 1/2 electron transfer per sulfur atom. Then, Li2S4will further obtain 3/2 electron per sulfur atom and reduce to Li2S at the plateau around 2.1 V, achieving a capacity of 1254 mA h g−1.

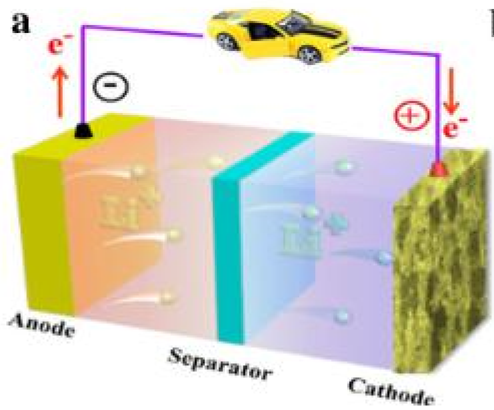

Figure 10. Schematic Diagram of Li-Sulfur Cell

- **Challenges of Li-Sulfur Battery:**

1. The "Shuttle effect" results from the dissolution of soluble polysulfides into the electrolyte (solid–liquid dual-phase reaction system). During the charge process, the solid Li2S/Li2S2 particles are oxidized into long-chain polysulfide. When the charge state deepens, the con-centration of long-chain polysulfides increases significantly. At the end of charge process, the diffusion force is stronger than the electric field force, which results in long-chain polysulfides diffusing to the anode side. Li metal, leading to the loss of active material, Li metal anode corrosion, and low Columbic efficiency.
2. Low conductivity of S and Li2S. The natural electrical conductivities of S and Li2S at room temperature are only 5×10^{-30} and 3.6×10^{-7} S cm−1, respectively.
3. Large volumetric expansion during lithiation.
4. Growth of lithium dendrites. Lithium dendrites can penetrate the solid–electrolyte interphase (SEI) film, resulting in continuous consumption of electrolyte to reform the SEI film during continued cycling and decreased Columbic efficiency along with increased interfacial resistance.
5. Side reactions between lithium and electrolyte.

- **RESEARCH PROGRESS OF HIGH ENERGY LI-S BATTERY:**

About research progress for Li-S battery there are various work done which are given as follow:

1. Sulfur Cathode
2. Sulfurized Polymers
3. Alucone-Coated Porous Carbon–Sulfur Electrodes

- **Sulfur Cathode: [4]**

In this section, we will briefly introduce the fundamentals of the sulfur cathode in terms of different Li–S redox reactions. The strategies for achieving high loading sulfur cathodes will then be summarized in detail with the synthetic method, structure design, and electrochemical characterizations. The insulating nature of sulfur, dissolution of polysulfide, and volume expansion of sulfur are the three main issues of sulfur cathodes. The design of multi-architectural and multi-functional cathode materials has the potential to overcome these challenges and has been one of the most researched strategies in recent years,

Currently, physical routes including capillary force absorption shell coating and chemical routes containing heteroatom-doped carbons and metal-based additives are proposed to obtain high discharge capacities and excellent cycling stability. These strategies can improve performance by providing intimate electrical contact for insulating active materials, limiting the free shuttle of soluble polysulfide and buffering volumetric expansion during sulfur litigation which is shown in figure 11.

Many reported literatures have developed different types of sulfur cathodes for carbonate Li–S batteries. According to the chemical structure of the sulfur molecules in the carbon hosts, we categorize sulfur cathodes into three main types: (1) confined sulfur in microporous structures; (2) polymeric sulfur, and (3) molecular layer deposition (MLD) alucone-coated carbon–sulfur electrodes. The next section will introduce the three sulfur cathodes in detail with their development, advantages and challenges, as well as electrochemical performance and provide insight into their working mechanisms

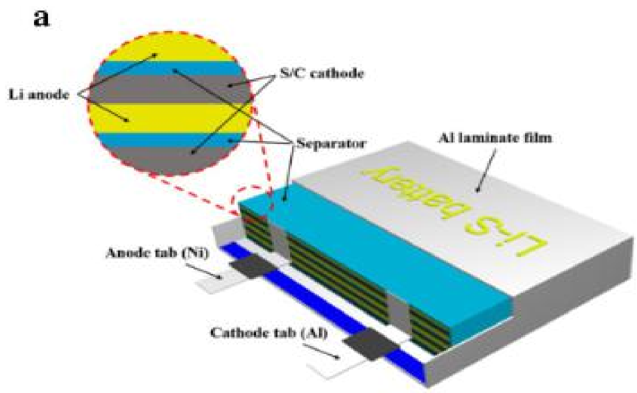

Figure 11 capillary force absorption shell coating and chemical routes containing heteroatom-doped carbons and metal-based

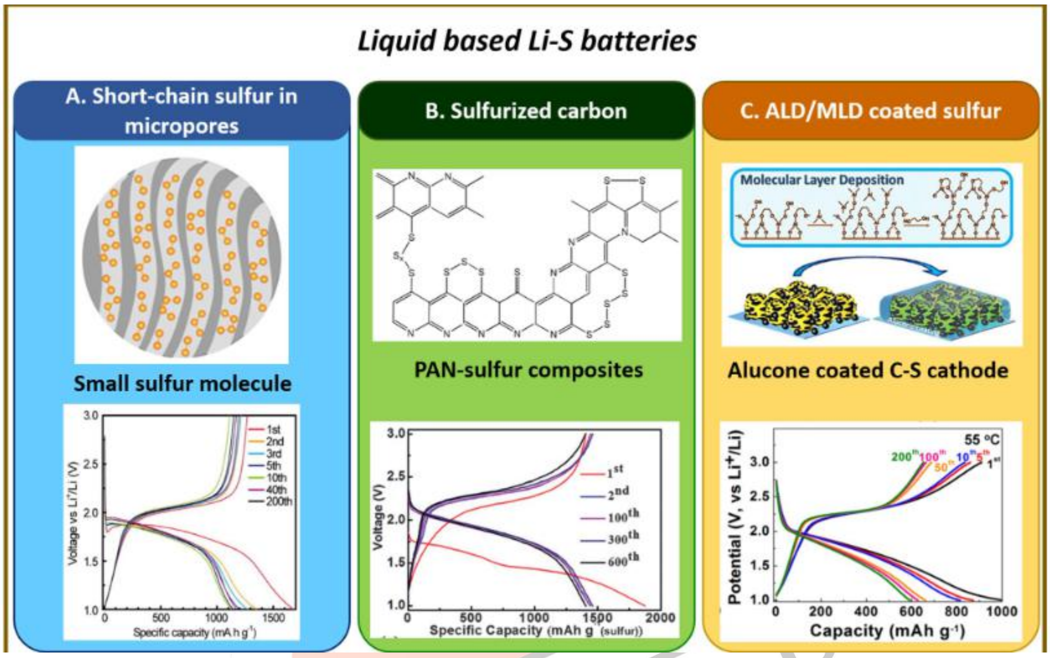

Figure 12 Different sulfur cathodes delivering solid-phase Li–S electrochemical reaction.

❖ **Sulfurized Polymers:**

Sulfurized polymers are another facile approach to anchoring short-chain sulfur on polymer matrices, the synthetic process employed a one-pot reaction of the mixture of polyacrylonitrile (PAN) and sulfur with a heating treatment of around 300 °C. The as-prepared PAN-S demonstrated a highly reversible electrochemical performance with a specific capacity above 600 mA h g−1 after 50 cycles. The developed PAN-S composites demonstrate very stable electrochemical performances in carbonate electrolyte and therefore it is important to investigate the novel electrochemical behavior to further improve the safety and performance of Li–S batteries.

❖ **Alucone-Coated Porous Carbon–Sulfur Electrodes**

The two aforementioned sulfur-based cathodes demonstrate excellent cycling performance in Li–S batteries and both of them present a single pair of discharge charge plateaus during the discharge–charge process. It was found that both of the confined short-chain sulfur molecules and sulfurized polymers are not conventional cyclo-S8 molecules. Therefore, it is critical to limit the sulfur content to maintain their unique chemical structure. The low sulfur con-tent (mostly < 50 wt %) of the cathodes, even with excellent cycling performance, is not sufficient enough to achieve high-energy Li–S batteries. Furthermore, the delicate synthesis of confined sulfur cathodes decreases the feasibility of carbonate Li–S batteries in practical application.

The alucone-coated C–S electrode demonstrates a single pair of discharge–charge plateaus, which indicates that conventional commercial carbon–sulfur cathodes can be operated in carbonate electrolyte. Furthermore, this study demonstrates safe and high-temperature Li–S batteries with the use of carbonate electrolyte for the first time. Firstly, the cycling performance and Columbic efficiency of alucone coated C–S electrodes at room temperature is relatively low, which should be further improved. Secondly, the underlying mechanism of alucone-coated C–S electrode is still unclear. The study did not reveal why the use of alucone coating could enable cyclo-S8 molecule cathodes to operate in carbonate electrolyte and the reason behind this unique electrochemical behavior. Thirdly, despite the high content of the sulfur cathodes employed in this study, the areal loading of the developed sulfur cathodes is still not sufficient. The high content and areal loading sulfur cathodes applied in carbonate electrolytes will be an important direction for practical application.

VII. Different battery technologies for various grid use cases:[5]

Figure 13 summarize of new technology of battery

These technologies vary widely in their leveled cost to provide different grid services, due largely to their respective depth of discharge capabilities, degradation rates, and lifetimes. Battery technologies that offer lower degradation rates (e.g., flow, high temperature, or Li-ion LFP) could be less risky options for value-stacking use cases. Figure 13 shows modeled LCOS outputs for Li-ion and flow batteries under an assumed set of stacked value grid-support applications.

VIII. Conclusion : From the above discussion we observe that there are many of technologies are doing for battery and at future many of devices are run or operate by battery because it will help for green technology and battery is a vital part, Also we concluded that in future we have a cost effective battery with high power density and take a less time for charging

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