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Solid State Batteries for EV'S

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ABSTRACT
Solid-state batteries have become a major area of research interest in recent years because of their clear benefits over conventional batteries. Solid-state batteries provide a higher energy and power density, better safety characteristics, as well as a longer lifespan due to their solid electrolytes. Thus, they are ideal for meeting the necessity of energy storage in smart grid and electric car applications. In order to determine whether different kinds of solid-state batteries are viable for use in electric vehicle applications, this research will examine their characteristics, benefits, and drawbacks. In addition to conducting a comprehensive examination of the anode and cathode elements of among the solid-state batteries in both their fresh and damaged states using scanning electron microscopy (SEM), the goal is to determine and suggest the most efficient solid-state battery that fits the unique requirements and operating conditions of electric vehicles.

Keywords:- *Electrical vehicle, Battery management*

INTRODUCTION

These days, electric cars (EVs) are growing in popularity due to the fact that they a sustainable substitute for conventional fuel-powered automobiles. Developments in energy storage technologies, such as batteries, have made electric vehicles (EVs) fierce rivals to traditional batteries. With lithium-ion batteries powering a resounding majority of today's sustainable transportation options, EV technology has become indispensable.

According to statistics, Li-ion batteries one of the well-known liquid electrolyte batteries power about 90 Despite these benefits, there are significant safety issues with the liquid electrolytes, which are often utilized in commercial LiBs. High temperature, corrosion, short circuit, and charging decomposition, leaking and other conditions liable to cause fire or explosion. Lithium dendrite formation is a key issue, especially when subjected to severe temperatures or poor charging procedures, which leads to short circuits and thermal runaway due to exothermic interactions between the liquid electrolyte and the electrode.

All of these problems eventually lead EV performance and efficiency to decline. Numerous studies have been focused on creating electrochemical energy storage systems that satisfy performance, energy density, safety, and cost goals for upcoming applications in order to solve these safety concerns. Solid-state batteries are showing promise as a way to get around many these issues with lithium- ion technology in electric cars.

Solid electrolyte is used in solid-state batteries rather than a liquid one, in contrast to lithium-ion batteries that are conventional. This crucial distinction greatly improves their safety profile by reducing the likelihood of thermal runaway and almost eliminating the potential of leaks. This solves a serious safety issue by making solid-state batteries much less likely to catch fire or explode under pressure.[1]

Furthermore, among the biggest advantages of solid-state batteries is their simpler design. It also makes the production procedure simpler. ASSBs are capable of attain greater energy density. Improved energy storage capacity results from the use of various electrode materials and designs that are not compatible with liquid electrolytes because of the presence of solid electrolytes. EVs can go farther because to this increase in energy density and portable electronics operate more effectively.

Solid-state batteries have the ability to completely transform the EV market, notwithstanding the obstacles. Ongoing studies and funding in this field, however, show promise that solid-state technology may soon emerge as a practical and sustainable substitute, driving the development of the upcoming generation of electric vehicles.[3]

LITERATURE REVIEW

Yihan Xiao, Yan Wang, Shou-Hang Bo, Jae Chul Kim, Lincoln J. Miara, and Gerbrand Ceder Nature Reviews Materials 5 (2), 105-126, 2020 Solid-state batteries (SSBs) with a solid electrolyte have the potential to achieve higher energy and power density and better safety than traditional Li-ion batteries.

Nevertheless, there remain two significant challenges to address: first, the creation of solid electrolytes that exhibit ionic conductivities comparable to or surpassing those of conventional liquid electrolytes; and second, the formation of stable interfaces among the components of all-solid-state batteries, including the solid electrolyte, active material, and conductive element. Several solid ionic conductors have succeeded in achieving the first objective, but high impedance at different solid/solid contacts continues to be a problem. Recently, computational models based on ab initio calculations have reliably predicted the stability of solid electrolytes in a range of scenarios.

Additionally, a substantial amount of experimental data for different SSB interfaces has been collected. In this study, we summarize the experimental data for several types of solid electrolytes and relate them to computational predictions in order to improve understanding of the interfacial processes and provide insight for future interface design and engineering in SSBs. We find that the electrochemical stability and interfacial reaction products can often be described by a small set of chemical and physical principles.[1]

Guolong Lu, Wenyan Li, Qiqi Tao, Caihong Shi, Huile Jin, Guang Chen, Shun Wang, Liguang Wang, and Jun Li Materials Frontiers 7, 111, 2020 Compared to traditional lithium-ion systems, solid-state batteries have the potential to offer significantly higher energy density and safety. Despite significant advancements, particularly in solid-state electrolytes, fundamental chemistry and mechanical problems still plague solid-state systems.

Three key phenomena are highlighted in this review, which outlines the basic problems with solid-state batteries: (i) the development of high ionic conductors; (ii) structural evolution at chemically unstable electrolyte-electrode interfaces; and (iii) The implications of producing solid- state batteries, encompassing electrode and electrolyte design. [9]

Gerbrand Ceder, Jae Chul Kim, Yan Wang, Lincoln J. Miara, and William D. Richards Materials Chemistry 28 (1), 266-273, 2016. Despite the rapid advancement in the creation of high-conductivity solid-state electrolytes for lithium-ion batteries, integrating these innovative materials into high-performance batteries has proven to be hard. In this study, we create a computational approach to investigate the thermodynamics of resistive interfacial phase generation. Battery performance and experimental interfacial observations show a strong correlation with the projected interfacial phase development.

According to our calculations, thiophosphate electrolytes have a limited electrochemical stability window and particularly significant reactivity with high voltage cathodes. Furthermore, we find that several well-known electrolytes are not inherently stable; rather, they react with the electrode in situ to form ionically conductive but passivating barrier layers. We tabulate the stability and projected breakdown products for a variety of electrolyte, coating, and electrode materials, including several high-performing combinations that have not yet been tried experimentally, as a reference for experimentalists.[3]

Maximilian Fichtner, Venkataraman Thangadurai, Musa Ali Cambaz, and Syed Atif Pervez ACS Interfaces Applied Materials 11 (25), 22029-22050, 2019 Compared to traditional Li-ion batteries, all-solid-state batteries (ASSBs) based on inorganic solid electrolytes offer greater safety, a better energy density, an extended life cycle, and a cheaper cost. However, the large resistance that develops at the solid solid electrode electrolyte interface hinders their practical use. The charge transfer phenomena at the interface is governed by several chemical, electrochemical, and chemo-mechanical processes, albeit the precise mechanism underlying this interface resistance is still unclear. This study describes how the interfacial behaviour of the cathode and lithium in oxide and sulphide inorganic solid electrolytes impacts the overall performance of the battery.[6]

Guanglei Cui, Shu Zhang, Jun Ma, and Shanmu Dong Electrochemical Energy Reviews 6 (1), 4, 2023 Because of their all-solid-state batteries have a high energy density and are very safe (ASSBs). with solid-state electrolytes and lithium-metal anodes have been seen as a viable battery technology to address safety concerns and reduce range anxiety. For battery development, it is crucial to comprehend the basic physical and chemical physics of ASSBs.

Theoretical computation offers a potent way to examine the thermodynamic and kinetic behaviour of battery materials and their interfaces, confirming and enhancing experimental research and leading to the creation of improved batteries. We evaluate current advancements in the theoretical calculations regarding solid electrolytes and the points where the electrodes and electrolytes meet of ASSBs in this paper. We go over how theoretical computation is used to study the following topics: dendrite growth at electrode/electrolyte interfaces, space-charge layers, interface buffer layers, ion transport mechanisms, grain boundaries, phase stability, chemical and electrochemical stability, mechanical properties, design strategies, and high-throughput screening of inorganic solid electrolytes. Lastly, we offer viewpoints on the limitations, difficulties, and possibilities of theoretical computation with respect to ASSBs.[4]

METHODOLOGY

Research on several solid-state battery types

Different varieties of solid-state batteries are distinguished by the type of electrolyte they contain. However, understanding the electrolyte’s operation in batteries that are solid-state is crucial. Solid electrolyte’s primary function is to facilitate the ions’ flow between the anode (negative) and cathode (positive). When it is being charged and discharged operation.

The reaction’s electrons are then utilised to increase a load in an external circuit [1]. Electrolytes that are solid are therefore strong contenders to enhance the overall functionality of batteries that are smaller in size. [4] There are numerous varieties of solid-state batteries; in order to determine which is ideal for the given application, one must examine each form of solid-state battery. The classification is shown in fig.1

Solid-state organic electrolytes

Dissolution sats in a polymer matrix make up the high molecular weight membranes of polymer electrolytes. They can be produced cheaply and are simpler to process.

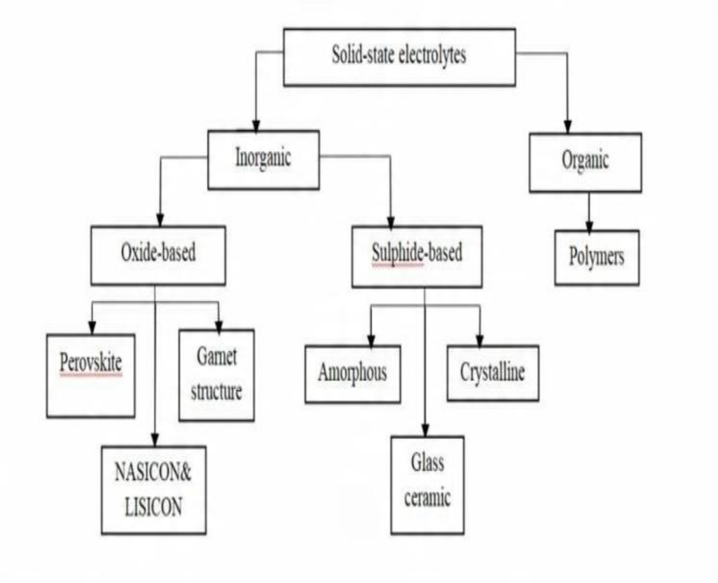

Fig.1:-*Classification of solid state batteries*

How- ever, their low ionic because of their conductivity, they are appropriate for room temperature battery operation. Electro- chemical devices make extensive use of them. In contrast to conventional batteries, polymer electrolyte batteries offer several benefits. This is because polymer electrolyte has several qualities, including transparency, low weight, high flexibility, enhanced ionic conductivity, ease of processing, and a broad electrochemical window. Polymer electrolytes are further categorized as natural and synthetic depending on their origin and source, and as gel-based, solid-based, and composite-based based on their composition and physical state. The classification is shown in figure 2.

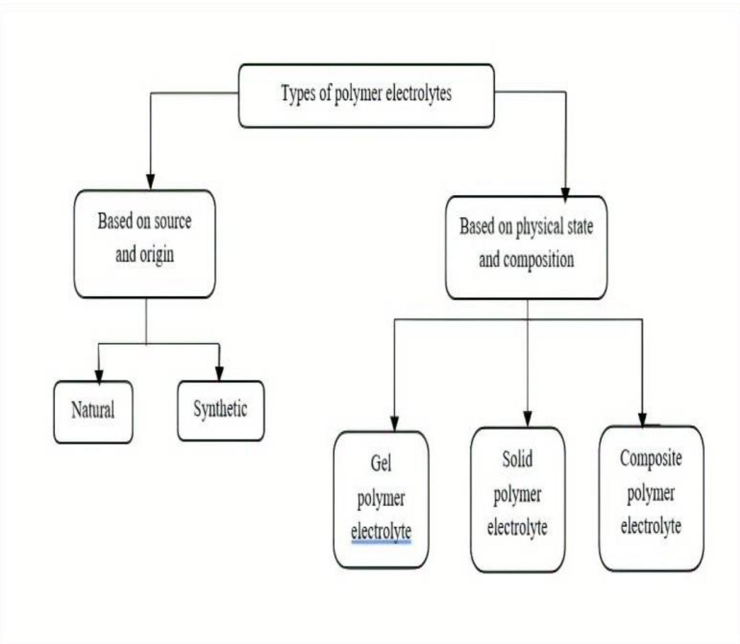

Fig.2:- *Classification of polymer electrolyt*e

Gel based polymer electrolyte

Given its comparatively higher efficiency when compared to conventional liquid electrolyte batteries, gel-based polymer electrolytes do, in fact, represent a significant improvement in battery technology. This electrolyte is composed of a polymer matrix that holds a liquid electrolyte, usually as a gel [3]. They are more stable and have better conductivity than their traditional equivalents because to this special mix.

Faster charging and discharging were made possible by the gel matrix, which maintained structural integrity while permitting the electrolyte to flow freely. The improved safety profile of gel-based polymer electrolytes is among their common characteristics. They don't corrode as much as conventional solutions, which lowers the possibility of damage leaking. This is particularly important in applications like electric automobiles.

Solid polymer electrolyte

Another name for solid polymer electrolyte is solvent-free polymer electrolyte. Coordination of the inorganic salt within the polymer matrix is the primary function. The performance of electrochemical cells using solid-state polymer electrolyte is determined by the active amount of salt. The activity determines the effectiveness of change transport through the electrolyte and affects the possible distinction between several stages inside the cell.[4]

Composite polymer electrolyte

Lithium salts and polymer matrices with active inorganic fillers are compared in composite electrolytes. Fillers and the polymer matrix are both ion conductive. In general, their conductive behaviour is intricate. Strong connections between electrodes, high mechanical stress and strain tolerance, and threshold ionic conductivity are all capabilities of composite electrolytes. When compared to batteries that use inorganic or polymer-based electrolytes, all of these features demonstrate better performance.

Inorganic solid electrolyte

As seen in Figure 1, inorganic solid electrolytes are categorized as oxide-based and sulphide-based according to their chemistry with oxygen or sulphur. There are numerous varieties of oxide-based inorganic electrolytes, but only a few number are widely utilised and have shown encouraging research outcomes. They are further classified as lithium-stuffed garnet type oxide, perovskite (CaTiO3), and(Li7La3Zr2O12), LISICON (Lithium super ionic conductor), and NASICON (solid super ion conductor)are acronyms.

However, sulphide-based there are three other categories for electrolytes based on their composition: crystalline, amorphous, and glass-ceramic. Inorganic electrolytes are highly stable in harsh environments and at high temperatures. Ion transit is made simple by the abundance of vacancies and coordination defects seen in inorganic materials.[11]

1.Finding the best solid-state battery for an electric vehicle. Because solid-state batteries are more dependable than Li- ion batteries, researchers are prepared to invest much in them. thus they might continue to be stable under harsh circumstances, sulphide and oxide batteries are more suit- able. In particular, LLZO (Li7La3Zr2O12), a lithium-stuffed garnet type oxide electrolyte, has been discovered to be more suitable for use in electric vehicle applications. The lithium- stuffed garnet type oxide battery's key feature is its great environmental stability, which contributes to its extended lifespan, safety, and excellent performance. Additionally, this stability slows down the degradation process, increasing durability. [5]. High ionic conductivity, ranging from 10-4 to 10-3S Cm-1, is a characteristic of garnets. Of course, LLZO is more stable than other electrolyte types like LISICON and argyrodite,

However, they also possess greater ionic conductivity. The remarkable electrochemical window of LLZO is up to 6V. High voltage operations and increased energy density are made possible by this. Additionally, when Li metals are utilized as the anode, LLZO remains stable. With a Li metal anode, this solves a significant issue with electrolyte reactivity. Lithium metal's reactivity with the electrolyte causes lithium dendrites to form, which lowers battery efficiency. In conclusion, LLZO shows compatibility with a range of cathode materials that are often utilized in lithium-ion batteries. Because of this interoperability, solid- state batteries with a variety of electrode designs may be designed and manufactured, possibly increasing the range of applications for these cutting-edge energy storage devices.[2]

2.SEM analysis

It is essential to overcome a few issues, including as the battery's performance in harsh environments and variations. When it is being charged and discharged processes, in order to reach broad commercial use. Understanding how electrode materials and interfaces change mechanically and electrochemically during battery operation is crucial for this. Among the most crucial instruments for observing the changes in a battery is scanning electron microscopy, or SEM. SEM can produce high-resolution pictures that offer thorough details regarding the composition, morphology, and structure of battery interfaces and materials.[6]

3.Working of EV solid state batteries

Solid-state batteries (SSBs) are a new technology that improves safety, energy density, and charging speeds by substituting a solid electrolyte for the conventional liquid electrolyte in lithium-ion batteries. SSBs in electric vehicles (EVs) operate as follows:

Components :
1. The Anode, which stores lithium ions, is composed of silicon, graphite, or lithium.
2. Cathode: Contains substances that release lithium ions, such as lithium cobalt oxide, nickel manganese cobalt oxide, or lithium iron phosphate.
3. Solid Electrolyte: To improve energy density and safety, a solid substance such as phosphates, oxides, or sulfides replaces the conventional liquid electrolyte.
4. Separator: The anode and cathode are divided by a thin, porous substance called a separator.[10]

Principle of Operation:
1. Charging: Lithium ions transfer from the cathode to the anode via the solid electrolyte when the EV is connected to a charger, storing energy.
2. Discharging: Lithium ions transfer energy from the anode to the cathode via the solid electrolyte when the EV is in operation.
3. Lithium ions can travel more easily among the cathode and anode thanks to the solid electrolyte.[7]

Advantages of EVs:
1. **Improved Safety**: Solid electrolytes, as opposed to liquid ones, electrolytes do not have the possibility of thermal runaway or fires.
2. **Longer driving** ranges are made

possible by SSBs' increased energy density, which allows them to hold more energy per unit of weight and volume.
3. **Faster Charging:** SSBs can shorten charging periods by charging more quickly than conventional lithium-ion batteries.
4. **Longer Lifespan:** SSBs have a longer lifespan since they can tolerate more charge-discharge cycles.[5]

Challenges:
1. As of right now, SSBs are more expensive than traditional lithium-ion batteries.
2. **Scalability:** SSB mass production remains difficult.
3. **Materials Science:** It remains difficult to create appropriate ingredients for solid electrolytes with strong ionic conductivity and stability.[8]

We may anticipate broad EV adoption as SSB technology develops further, allowing for safer, more effective, environmentally friendly transportation.[9]

RESULT
In comparison compared to traditional lithium-ion batteries, Electric vehicles using solid-state batteries (EVs) pro- vide increased energy density, improved safety, and quicker charging times, according to study findings. SSBs are A safer substitute to EVs because of their solid electrolyte that allows removes the possibility of thermal escape and fires. Furthermore, SSBs have an increased capacity per unit for energy storage of weight and volume, which allows for longer driving distances and less frequent charging.

Additionally, the study discovered that SSBs may charge more quickly than conventional lithium-ion batteries, which shortens charging periods and increases the practicality of EVs for everyday use. Overall, the findings imply that SSBs, by offering a safer, more effective, and sustainable battery option, have the capacity to fully transform the EV market.

CONCLUSION
Electric cars represent the world's sustainable future. Therefore, research into it is crucial in order to establish it as a competitive substitute for automobiles that run on petrol. One of these research initiatives is to use solid-state batteries rather as opposed to conventional lithium-ion batteries to power electric cars. This study concludes by examining a wide range of solid-state battery types and analyzing their characteristics, composition, benefits, and drawbacks.

As a result, lithium filled garnet type oxide (LLZO) is determined to serve as the best solid-state battery for electric cars applications. But under several circumstances, solid-state batteries must be used more widely and produced on a huge scale. As a result, SEM analysis highlights these difficulties.
The battery's microstructural investigation under SEM has provided information on how to prevent ion loss (in this example, lithium ions) and surface impurity buildup. As a result, SEM offers useful insights into other battery processes that contribute to improving a battery's energy density, power density, efficiency, and life cycle.

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