

Solid-State Vs Lithium-Ion Batteries in Evs: A Performance and Safety Perspective

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Abstract: In recent years, the global trend toward vehicle electrification has emerged as a crucial effort to combat climate change and meet carbon emission reduction targets. At the center of this transformation, electric vehicle (EV) batteries play a decisive role from energy efficiency and range to operational safety. Although lithium-ion (Li-ion) technology currently dominates the market, various challenges such as the risk of thermal runaway, limited cycle life, and reduced durability at extreme temperatures are driving the search for alternative battery technologies. Solid-state batteries (SSB) have emerged as a cutting-edge solution by replacing flammable liquid electrolytes with solid electrolyte materials. This model is expected to offer higher energy density, superior thermal stability, and longer lifespan. This study conducted a systematic literature review (SLR) using the PRISMA framework to select and analyze 16 journal articles published between 2020 and 2025 that compared SSBs and Li-ion batteries based on two main dimensions: safety (RQ1) and vehicle performance (RQ2). The analysis results indicate that SSBs consistently exhibit better safety profiles, thanks to the presence of non-flammable solid electrolytes, structures that prevent the formation of lithium metal dendrites, and the ability to withstand high temperatures without significant degradation. In terms of performance, SSB also excels through high ionic conductivity enabling fast charging rates a cycle life exceeding 1,900 cycles at 60°C, and performance stability across extreme temperature ranges. Meanwhile, traditional Li-ion batteries still require material modifications such as the addition of graphene or lithium iron phosphate to enhance durability and charging speed. These findings collectively confirm that solid-state batteries not only address safety challenges but also enhance the durability and operational efficiency of electric vehicles. Therefore, accelerating the development and adoption of SSB technology is expected to be a strategic step toward achieving safer, more reliable, and sustainable electric mobility.

Keywords: Solid-State Battery, Lithium-Ion Battery, Electric Vehicle, Battery Safety and Performance

I. Introduction

The worldwide trend toward vehicle electrification has been rapidly accelerating in recent years, driven by mounting environmental concerns and government policies to reduce carbon emissions (DeCampos, 2018; K. & M., 2016). Electrification has emerged as a pivotal catalyst in the ongoing transformation of the transportation and mobility sectors, offering substantial opportunities, including environmental benefits and the mitigation of CO₂ emissions from the transportation sector (Passerini et al., 2024).

Electric vehicle (EV) sales are increasing on a global scale, with major automotive manufacturers projected to dominate production by the year 2030 (Sakno et al., 2024). In the context of sustainable transportation, electric vehicles (EVs) have emerged as a pivotal area of focus, precipitating advancements in various domains. These include the development of charging infrastructure, the adoption of EVs, thermal management systems, and route optimization algorithms (Haghani et al., 2023). China has emerged as a global leader in EV research, with automotive manufacturers collaborating closely with academic institutions to further advance the field (Pohl & Karlström, 2023). A significant challenge confronting researchers is the development of a thermal management system for hybrid and electric vehicles that will enhance efficiency and durability (Tung et al., 2020). The battery management system (BMS) plays a pivotal role in optimizing the performance and safety of batteries in electric vehicles (EVs) (Vaideeswaran et al., 2019). The fundamental functions of battery management encompass the acquisition of battery data, the development of battery models, the estimation of battery status, the prediction of battery aging, the diagnosis of battery faults, and the process of charging (Liu et al., 2022).

Batteries are not just supporting components in EVs; they are key determinants of EV range, energy efficiency, service life, and operational safety (Shrivastava, 2024). Lithium-ion (Li-ion) batteries currently dominate the EV market due to their high energy density and long cycle life (Muslimin et al., 2022). However, these batteries also present various challenges, including the potential for thermal runaway, limited cycle life, fire risk due to flammable electrolyte fluids, and performance degradation under extreme temperatures (Khan, 2024; Shahapure et al., 2022). Lithium-ion batteries are subject to a gradual decline in performance over time. Battery aging has been demonstrated to have a deleterious effect on both battery capacity and safety (Dai & Zhu, 2024).

Electrolytes have been demonstrated to compromise the safety of batteries and battery packs. Solid-state batteries (SSBs) have emerged as a leading alternative candidate by replacing flammable liquid electrolytes with solid electrolytes (Salgado et al., 2021; Schmaltz et al., 2023). This technology offers the potential benefits of increased energy density, enhanced thermal stability, expedited charging times, and a prolonged service life (Shrivastava, 2023; Zhao, 2024). Significant investments in the development of SSBs have been made by various automotive manufacturers and research institutions, with several prototypes undergoing testing in limited EV models (Thomas et al., 2024).

A multitude of studies have purported the superiority of SSB over Li-ion batteries. However, the majority of these studies are predicated on laboratory data or predictive models, eschewing large-scale vehicle testing. The absence of literature that systematically synthesizes these research results underscores the necessity for a comprehensive review that compares these two battery technologies in the context of EV applications.

To date, there has been no SLR that has made a direct comparison between SSB and Li-ion batteries from the perspectives of vehicle performance (energy efficiency, charging rate, cycle life) and vehicle safety (thermal stability, fire potential, failure mechanisms). Consequently, the objective of this SLR is to methodically analyze and synthesize recent studies that compare the two battery types in the context of EVs:

1. "How do solid-state batteries compare to lithium-ion batteries in terms of safety?"
2. "How do solid-state batteries compare to lithium-ion batteries in terms of performance in vehicles?"

II. Methodology

Literature Search Procedure

A thorough and methodical search of the extant literature was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. This systematic review focused on journal articles pertinent to the integration of technology in evaluating students' competencies in the scientific domain. The primary database, SCOPUS, was employed in the screening of independent journal articles to identify high-quality publications and ensure consistent search results. The systematic literature review procedure comprised the following stages: identification based on selection criteria, screening, data collection, and data analysis of the articles obtained. The established criteria, which included year of publication, document type, language, and field of study, were used to identify a total of 16 articles.

Article Search Keywords

The keywords used in the search for articles in the SCOPUS database are "solid-state battery" OR "solid state battery" OR "solid-state batteries" OR "SSB" AND "lithium-ion battery" OR "Li-ion battery" OR "lithium ion battery" OR "LIB" AND "electric vehicle" OR "EV" OR "electric cars" AND safety OR "fire hazard" OR "stability" AND performance OR "energy density" OR "power density" OR efficiency OR range OR "charging time". Search results using these keywords recoded 336 articles in the Scopus database.

Criteria of Article

The selection criteria for articles accepted from the Scopus database have been established as outlined in Table 1. The reviewers established a set of criteria, one of which pertains to the year of publication, which is between 2020 and 2025, encompassing the previous five years. The selection of articles within this time frame is based on the consideration that the topics explored are still the subject of vigorous debate and are pertinent to current issues. It is important to note that articles published prior to 2020 are not considered in this context and are immediately rejected. The types of documents accepted are limited to journal articles. Other documents, including but not limited to proceedings, theses, books, and review articles, are not accepted. This is due to the widely accepted notion that journal articles represent the most reliable form of reference material, offering comprehensive and in-depth reporting of data and findings. The articles under consideration are written in English, as is the majority of scientific publications. It is imperative to note that articles in languages other than English will not be considered. The search on Scopus is constrained to the field of engineering.

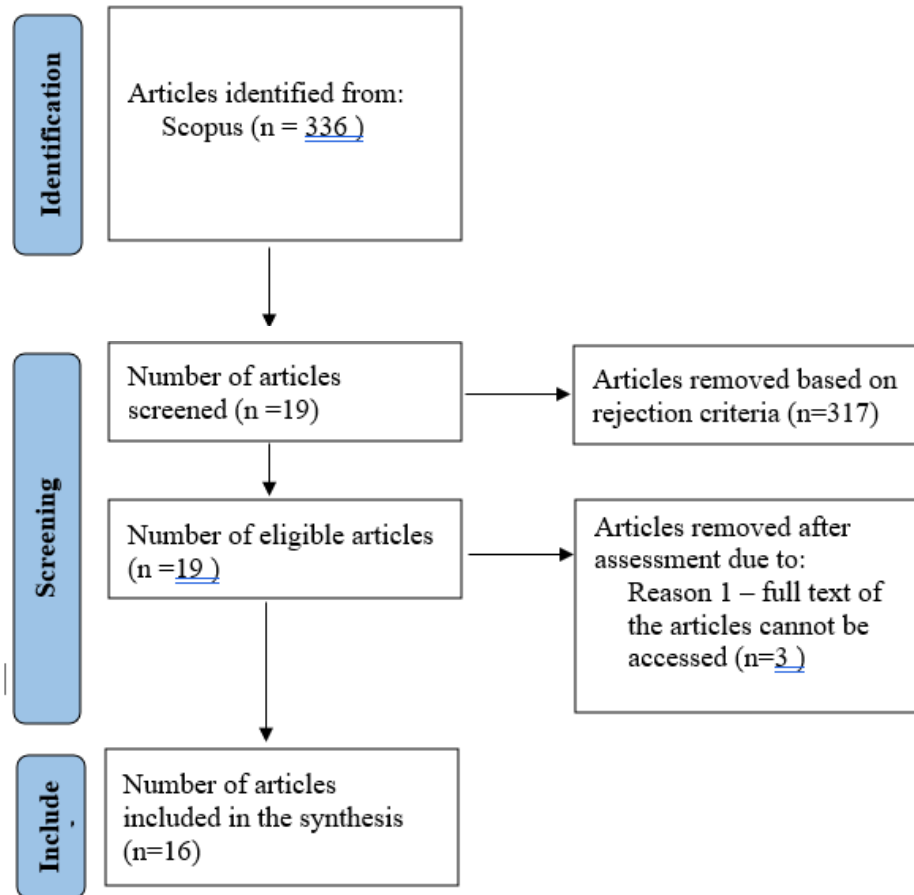
Table 1. Criteria of Article

General Criteria	Acceptance Criteria	Rejection Criteria
Year of Publication	2020-2025	2019 and before
Document Type	Journal Article	Proceedings, theses, books, literature review articles
Language	English	Other Languages
Field of Study	Scopus: Engineering	Other than Engineering Research
Open Access	All	None
Full Text	All	None

Article Selection Process

As illustrated in Figure 1, the PRISMA flowchart was utilized to trace articles related to the use of technology in assessing students' scientific skills. A total of 336 articles were identified in the preliminary search, and subsequent to the screening process, 16 articles were determined to be suitable for inclusion in this study.

Figure 1. PRISMA Model Flow Chart



The data collection process entailed the extraction of pertinent information from each review article, including article titles, author names, publication years, technologies employed in the assessment of scientific skills, technology usage procedures, the implications of technology usage, and the challenges or problems associated with technology usage. This information was then compiled into a table using Microsoft Excel 365 software. The analysis was conducted using the table, followed by the categorization of the articles to address the research questions. The results of the data analysis are presented in tabular form. Table 2 presents a comprehensive list of 16 independent research articles, accompanied by the respective authors' names. The selection of articles was conducted in accordance with a predetermined set of criteria for acceptance and rejection.

Table 2. Articles based on established acceptance and rejection criteria

No	Authors	Title	Year
1	Ladenstein et al.	Ionic Transport and Electrochemical Properties of NaSICON-Type $\text{LiI} + x\text{Hf}_{2-x}\text{Ga}_x(\text{PO}_4)_3$ for All-Solid-State Lithium Batteries	2022
2	Krause et al.	A Super-Ionic Solid-State Block Copolymer Electrolyte	2024
3	Scaltrito et al.	An Enhanced Ageing Model for Solid-State Batteries	2024
4	Negi et al.	A Dry-Processed $\text{Al}_2\text{O}_3/\text{LiAlO}_2$ Coating for Stabilizing the Cathode/Electrolyte Interface in High-Ni NCM-Based All-Solid-State Batteries	2022
5	Lu et al.	A Dual-Layered Anode Buffer Layer Structure for All Solid-State Batteries	2025
6	Setyawati et al.	High power and thermal-stable of graphene modified $\text{LiNi}_{0.8}\text{Mn}_{0.1}\text{Co}_{0.1}\text{O}_2$ cathode by simple method for fast charging-enable lithium ion battery	2024
7	Gao et al.	The Dilemma of C-Rate and Cycle Life for Lithium-Ion Batteries under Low Temperature Fast Charging	2022

8	Zakariyaou et al.	Synthesis and Characterization of Lithium Phosphate (Li ₃ PO ₄) as a Solid Electrolyte	2024
9	Choi et al.	Triple-doped Argyrodite Sulfide Electrolyte with Improved Air Stability and Lithium Compatibility for All-Solid-State Li-Metal Batteries	2024
10	Botros et al.	Influence of Grain Size on the Electrochemical Performance of Li _{7-3x} La ₃ Zr ₂ Al _x O ₁₂ Solid Electrolyte	2024
11	Yuan et al.	Two-dimensional layered materials for modifying solid-state electrolytes in lithium batteries via interface engineering	2023
12	Block & Song	Exploring the characteristics of technological knowledge interaction dynamics in the field of solid-state batteries: A patent-based approach	2022
13	Giraldo et al.	Preparation of composite electrodes for all-solid-state batteries based on sulfide electrolytes: An electrochemical point of view	2021
14	Muto et al.	STEM-EELS Spectrum Imaging of an Aerosol-Deposited NASICON-Type LATP Solid Electrolyte and LCO Cathode Interface	2022
15	Tan et al.	Li-Ion Mobility and Solvation Structures in Concentrated Poly(ethylene carbonate) Electrolytes: A Molecular Dynamics Simulation Study	2025
16	Bardenhagen et al.	Solid electrolyte based on 2-adamantanone for all-solid-state lithium-ion batteries	2022

III. Results & Finding

The present literature review focuses on a comparison of solid-state batteries and lithium-ion batteries. These two categories are classified into two additional categories based on vehicle safety and performance. As illustrated in Table 3, the two categories are as follows:

Table 3. Categories based on vehicle safety and performance

No	Source	Safety Aspects RQ1	Performance Aspects of Vehicles RQ2
1	(Ladenstein et al., 2022)	The utilisation of solid electrolytes has been demonstrated to be a more secure option in comparison to liquid electrolytes, due to the absence of a risk of leakage or fire. The electrochemical stability of solid-state battery materials in the voltage range of 2.4 V to 4.6 V has been demonstrated to reduce the risk of lithium dendrite formation, which has been shown to cause damage and fire hazards.	Solid-state battery materials have been demonstrated to exhibit high levels of ionic conductivity, coupled with a notable degree of long-term stability. The capacity of solid-state batteries to endure elevated currents and multiple cycles without exhibiting performance degradation renders them well-suited for electric vehicles that necessitate rapid charging and the ability to withstand over 1900 cycles at 60°C.
2	(Krause et al., 2024)	Solid-state structures with solid-state polymer electrolyte membranes have been shown to reduce the risk of leakage and fire. The implementation of robust block structures serves to mitigate the potential for short circuits and battery failure.	High ionic conductivity supports fast energy charging and discharge, thereby improving charging speed and overall performance. Stable conductivity performance from very low to high temperatures allows for optimal operation in a wide range of climatic environments.
3	(Scaltrito et al., 2024)	The utilisation of solid electrolytes in solid state batteries has been demonstrated to reduce the risk of leakage or fire, given that alterations in the solid electrolyte layer can impact battery stability.	The advanced solid-state battery demonstrates an impressive capacity to predict battery degradation (99%) under diverse operational temperatures.

4	(Negi et al., 2022)	The utilisation of solid-state electrolyte materials and oxide-based protective coatings has been demonstrated to enhance interfacial stability and mitigate the risk of degradation, which can lead to overheating and battery failure during operation.	The protective coating layer permits high current usage and long-term utilisation without significant capacity degradation.
5	(Lu et al., 2025)	Solid-state batteries have been demonstrated to exhibit superior safety features in comparison to conventional lithium-ion batteries. This enhancement in safety can be attributed to the utilisation of solid electrolytes, which possess the advantageous property of being non-flammable. The implementation of a double buffer layer on the anode has been demonstrated to assist in mitigating the risk of battery damage or failure.	The utilisation of an ultra-thin zinc layer (286 nm) as an anode buffer has been demonstrated to enhance cycle performance, characterised by increased stability and reduced capacity loss during charging and discharging cycles. The incorporation of a carbon black layer has been demonstrated to enhance cycle life and Coulombic efficiency, thereby augmenting the battery's durability and capacity for energy storage.
6	(Setyawati et al., 2024)	The utilisation of graphene in lithium-ion batteries has the potential to enhance safety measures. This assertion is supported by the observation that the maximum temperature recorded at a current of 5C is 46.52°C, which is regarded as safe for lithium-ion batteries operating at high currents. The incorporation of graphene-modified cathodes into batteries has been demonstrated to contribute to the mitigation of the risk of overheating.	Lithium-ion batteries with a 7% graphene addition have been shown to maintain a capacity of 64.75% after 3,500 recharge cycles, indicating a prolonged service life and high performance stability. The capacity degradation is a mere 5.44% after 200 cycles under fast charging and discharging conditions (5C), rendering them suitable for vehicles that require rapid charging.
7	(Gao et al., 2022)	The phenomenon of fast charging in low-temperature environments in lithium-ion batteries has been shown to increase the risk of lithium plating. This, in turn, has been demonstrated to cause rapid battery degradation and increase the potential for fire or other damage due to excess lithium metal accumulation.	The fast charging of lithium-ion batteries at low temperatures has been shown to result in a significant reduction of battery life, due to the occurrence of lithium plating.
8	(Zakariyaou et al., 2024)	The utilisation of lithium phosphate as an electrolyte confers elevated thermal stability, thereby mitigating the potential for explosion and fire hazards by virtue of its non-flammable properties.	Lithium phosphate has high ionic conductivity, which improves battery performance.
9	(Choi et al., 2024)	Solid-state batteries utilising argyrodite electrolytes have been shown to reduce toxic H₂S gas emissions by up to 78%. This reduction in emissions can be attributed to a reduction in the risk of crystal structure damage, thereby maintaining electrolyte ionic conductivity. The Li-Sb alloy present within the anode layer has been shown to inhibit lithium dendrite formation, thereby preventing internal short circuits and damage to the battery. The electrolyte displays optimal cycle stability during testing, demonstrating no degradation over a duration of 2,000 hours when subjected to continuous evaluation.	This electrolyte facilitates the rapid movement of lithium ions, thereby enabling the battery to function efficiently. Solid-state batteries incorporating this electrolyte demonstrate exceptional power capacity.
10	(Botros et al., 2024)	The utilisation of garnet-type solid electrolytes enhances the safety of batteries due to their non-	Ceramic material with a grain size of approximately 2-3 micrometers is considered optimal for utilisation as an electrolyte, given its

		flammable nature, which eliminates the risk of leakage and fire.	significant impact on the battery's capacity to facilitate lithium ions, a factor that determines the rate and efficiency of the charging and discharging processes.
11	(Yuan et al., 2023)	The utilisation of solid-state electrolytes (SSE) is purported to ensure enhanced safety in comparison with liquid electrolytes, which have been observed to be susceptible to leakage and explosion. The utilisation of 2D materials has been demonstrated to reduce the risk of degradation and safety risks, while also inhibiting the formation of lithium dendrites.	2D materials can increase ionic conductivity, thereby positively impacting battery capacity and capacity retention during charging and discharging cycles. 2D materials improve thermal stability, enabling batteries to operate at higher temperatures.
12	(Block & Song, 2022)	Solid-state batteries (SSB) have been demonstrated to enhance safety due to their utilisation of solid electrolytes as opposed to flammable liquid electrolytes employed in lithium-ion (LIB) batteries.	Solid-state batteries (SSB) are regarded as the technology of the future for electric vehicles (EVs) due to their higher energy density, longer life cycle, and faster charging capabilities when compared to lithium-ion batteries (LIB).
13	(Giraldo et al., 2021)	All-solid-state batteries (ASSBs) offer high energy density and a solution to critical safety issues in conventional lithium-ion batteries, such as fire and explosion.	The initial capacity enhancement was achieved through the implementation of a solution processing method, which resulted in the establishment of enhanced solid contact between the sulfide electrolyte and the active material particles. The function of the argyrodite-type sulfide electrolyte as an enhanced ionic conductor is to facilitate the maintenance of high capacity and enable operation at elevated voltages.
14	(Muto et al., 2022)	All-solid-state batteries (ASSBs) have been demonstrated to offer enhanced safety in comparison to conventional lithium-ion batteries (LIBs). The latter utilise liquid electrolytes, which have been shown to present a risk of combustion and explosion under extreme conditions. The utilisation of NASICON-type LATP solid electrolytes in conjunction with LCO through aerosol deposition techniques holds promise for the development of batteries with enhanced safety characteristics.	The utilisation of LATP/LCO-based ASSB demonstrates that the interfacial resistance between the electrolyte and cathode exerts a significant influence on battery performance, particularly ionic conductivity and charging efficiency. Thermal annealing at temperatures ranging from 250 to 300°C has been demonstrated to reduce interfacial resistance, thereby enhancing performance.
15	(Tan et al., 2025)	Solid polymer electrolytes (SPEs) are a promising solution for all-solid-state batteries, as they can overcome the safety concerns associated with flammable and leak-prone liquid electrolytes.	The utilisation of PEC/LiTFSI electrolytes has been demonstrated to result in a rapid decline in the number of lithium ions as the salt concentration increases. Nevertheless, these ions contribute approximately 70% of the total cation transport, indicating that high ion mobility can be attained.
16	(Bardenhagen et al., 2022)	Solid electrolytes, such as 2-adamantanone, offer enhanced thermal and electrochemical stability, thereby mitigating the risk of leakage and flammability frequently associated with liquid electrolytes. The capacity to function at up to 5.10 V and to withstand volume changes has been demonstrated to enhance the overall safety of the battery.	Solid electrolytes, such as 2-adamantanone, offer relatively high ionic conductivity, low activation energy, and good thermal stability over extreme temperature ranges. This renders them highly suitable for electric vehicle batteries that must operate under various temperature conditions and have good cycle life.

Safety Aspects (Research Question #1)

The column discussing safety aspects (RQ1) demonstrates that solid-state batteries offer a higher level of safety than conventional lithium-ion batteries. This phenomenon can be attributed to the utilisation of solid electrolytes, which possess the advantageous qualities of being non-flammable, non-leaking, and exhibiting enhanced thermal and electrochemical stability. Additionally, the solid-state structure has been demonstrated to prevent dendrite formation, reduce the risk of short circuits, and lower harmful gas emissions, thereby enhancing overall safety.

Performance Aspects in Vehicles (Research Question #2)

In the column discussing vehicle performance aspects (RQ2), it is demonstrated that solid-state batteries exhibit high ionic conductivity, long-term performance stability, and superior cycle life, rendering them highly suitable for electric vehicles (EVs). This technology is capable of operating at extreme temperatures, facilitating rapid charging, and sustaining capacity over thousands of cycles without substantial degradation. The utilisation of innovative materials, including 2D materials, sulfide electrolytes, ultra-thin zinc, and graphene, serves to further enhance the efficiency, stability, and overall lifespan of the battery.

IV. Discussion**Comparison of Solid-State Batteries with Lithium-Ion Batteries in Terms of Safety**

Solid-state batteries (SSBs) have been shown to generally offer a higher level of safety than conventional lithium-ion batteries (LIBs) in the context of electric vehicles (Lu et al., 2025). The implementation of non-flammable solid electrolytes, augmented thermal and electrochemical stability, and the capacity to impede lithium dendrite growth have been identified as pivotal factors in enhancing safety measures (Bardenhagen et al., 2022; Ladenstein et al., 2022; Zakariyaou et al., 2024). The utilization of solid electrolytes in solid-state batteries leads to the development of batteries that exhibit enhanced resistance to high temperatures and are non-flammable (Block & Song, 2022). Several studies have shown that electrolytes in SSBs can operate stably over a wider voltage range up to 5.10 V and demonstrate long-term durability during more than 2000 hours of continuous testing without significant degradation (Bardenhagen et al., 2022; Choi et al., 2024).

The physical structure of solid-state batteries is also of paramount importance in enhancing safety. A variety of solid electrolyte structures have been demonstrated to be effective in impeding the development of lithium dendrites, a phenomenon that frequently precipitates internal short circuits and fires in LIBs (Choi et al., 2024; Yuan et al., 2023). The implementation of material alloys in the anode effectively impedes the propagation of dendrites, thereby enhancing the structural and electrochemical reliability of SSB (Choi et al., 2024; Lu et al., 2025).

Lithium-ion batteries continue to manifest a number of deficiencies with regard to safety. A number of studies have sought to enhance the performance and safety of LIBs through modifications such as the incorporation of graphene or the utilization of more thermally stable lithium phosphate. However, the employment of liquid electrolytes continues to pose a significant challenge (Setyawati et al., 2024; Zakariyaou et al., 2024). The utilization of liquid electrolytes carries with it certain risks, including the possibility of lithium plating during rapid charging at low ambient temperatures. This phenomenon can result in battery degradation, excessive lithium metal accumulation, and an elevated risk of fire or explosion (Gao et al., 2022).

A comprehensive review of the extant literature reveals that solid-state batteries offer substantial safety advantages over lithium-ion batteries. The utilization of solid electrolytes not only mitigates the risk of leakage and fire, but also ensures long-term stability and the capacity to withstand extreme conditions. It has been demonstrated that certain SSB technologies exhibit the capacity to curtail toxic gas emissions of H_2S by up to 78%, thereby rendering SSBs not only technically safe but also more environmentally friendly. Solid-state batteries have emerged as a promising alternative to lithium-ion batteries, which have historically dominated the market due to the stringent safety standards that are currently and will continue to be a prerequisite for vehicles in the near future.

Comparison of Solid-State Batteries with Lithium-Ion Batteries in Terms of Performance in Vehicles

Solid-state batteries have been shown to exhibit significant performance advantages over lithium-ion batteries in the context of electric vehicle applications. The primary attribute that distinguishes SSBs is their exceptional ionic conductivity, which facilitates expedited and more efficient energy storage and release (Krause et al., 2024). SSB exhibits remarkable stability across a broad spectrum of temperature conditions, ensuring its versatility for application in diverse climatic regions. SSB has demonstrated the capacity to maintain stable capacity for over 1,900 cycles at 60°C, making it well-suited for electric vehicles that require long-term battery durability and rapid charging capabilities (Krause et al., 2024).

The merits of SSB are further bolstered by material advancements, including the implementation of protective coatings, the utilization of ultra-thin zinc buffer layers, and the incorporation of additives such as carbon black. These innovations enhance capacity stability and coulombic efficiency during charging and discharging cycles (Lu et al., 2025; Negi et al., 2022). Some solid-state batteries are even capable of predicting capacity degradation with up to 99% accuracy across a wide range of operating temperatures (Scaltrito et al., 2024). The utilization of solid electrolytes, including argyrodite sulfide and two-dimensional (2D) materials, has been demonstrated to enhance ionic conductivity, capacity retention, and thermal stability (Choi et al., 2024; Giraldo

et al., 2021; Yuan et al., 2023). Furthermore, manufacturing techniques such as thermal annealing at 250–300°C have been demonstrated to reduce interfacial resistance between the electrolyte and active particles, thereby enhancing ion transfer efficiency and overall battery performance (Botros et al., 2024; Muto et al., 2022; Tan et al., 2025).

Conversely, lithium-ion batteries exhibit enhanced performance following material modifications, such as the incorporation of graphene and lithium phosphate. Lithium-ion batteries containing 7% graphene demonstrate a capacity retention of 64.75% after 3,500 cycles, exhibiting a mere 5.44% decline after 200 fast charging cycles (5C) (Setyawati et al., 2024). Lithium phosphate has been shown to exhibit high ionic conductivity and adequate thermal stability (Zakariyaou et al., 2024). However, LIBs are not without their limitations. For instance, significant performance degradation at low ambient temperatures due to lithium plating, which accelerates degradation, is a well-documented phenomenon. Additionally, there is a risk of decreased conductivity due to degradation of the liquid electrolyte (Gao et al., 2022). This finding suggests that, while LIB retains its viability for utilization, its performance in resisting extreme environmental conditions and rapid charging cycles falls short of the benchmark set by SSB.

A comprehensive evaluation of the available data indicates that solid-state batteries consistently demonstrate superior performance in electric vehicle applications when compared with lithium-ion batteries. Advantages such as high energy density, extended service life, charging efficiency, and stability across a wide range of temperatures make solid-state batteries the technology of the future for electric vehicles. Advancements in materials, interface design, and processing techniques have rendered solid-state batteries a more reliable, efficient, and durable energy storage solution in comparison to conventional lithium-ion batteries. Consequently, SSBs are regarded as a more suitable solution for meeting the performance demands of increasingly complex next-generation electric vehicles.

V. Conclusion

A systematic literature review has indicated that solid-state batteries (SSBs) exhibit significant advantages over lithium-ion batteries with respect to safety and performance in the context of electric vehicles. In regard to safety (RQ1), SSBs demonstrate superiority due to their utilization of solid electrolytes that are non-combustible, resistant to dendrite formation, and possess enhanced thermal and chemical stability.

The composition and materials of SSBs, including buffer layers, protective oxides, and 2D materials, have demonstrated efficacy in mitigating the risk of leakage, short circuits, and explosions. With regard to performance (RQ2), SSBs demonstrate high ionic conductivity, extended cycle life, and stable performance under various temperature conditions, enhancing their efficiency and reliability for electric vehicles.

The utilization of materials such as garnet and argyrodite electrolytes, in conjunction with advancements such as thermal annealing and functional coatings, enhances charging efficiency and ensures long-term capacity retention. While LIBs can be enhanced through the incorporation of additives such as graphene and lithium phosphate, their inherent limitations concerning fast cycling and extreme temperatures present considerable challenges.

In summary, solid-state batteries provide a safer and higher-performance solution for the energy needs of future electric vehicles. Consequently, the trajectory of battery technology should prioritize the acceleration of SSB implementation to bolster the efficiency, safety, and sustainability of global electric mobility.

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