Studies and Research in Onomastics and Lexicology **(SCOL)**
ISSN: 2065-7161
E-ISSN: 2247-7330
Vol. 19 (2) 2026

Advanced Electric Vehicle Battery Technologies: Lithium-Ion and Solid-State Batteries Comparison

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Received: 28/04/2025 Accepted: 30/06/2026 Published: 07/07/2026

Abstract:
The increasing demand for electric vehicles (EVs), whose efficiency and durability are directly correlated to the capacity of their batteries, has spurred significant advancements in this area of technology. conducted a study contrasting lithium-ion batteries and solid-state batteries, the two main types of electric car batteries. The development of electric vehicles has been largely supported by lithium-ion batteries due to their low cost, high energy density, and optimal charge/discharge efficiency. Scientists are investigating solid-state batteries as an alternative to liquid electrolytes due to the former's drawbacks in safety, cycle life, and energy density. evaluation of their current forms with respect to their practicality, efficiency, longevity, energy density, and security criteria. Additionally, it highlights recent breakthroughs in SSB technology that may assist in overcoming present commercialization obstacles. The main objective of this study is to provide a comprehensive analysis of the future of the electric car battery business. It will focus on the pros and cons of current Li-ion technology as well as the revolutionary potential of Solid-State Batteries.

Keywords: Electric Vehicles (EVs), Lithium-Ion Batteries, Solid-State Batteries, Battery Technology, Energy Density

Introduction:

Over the course of the past ten years, the electric vehicle (EV) sector has experienced unprecedented growth as a result of the growing worries regarding climate change and the requirement for more ecologically friendly means of transportation. In light of the fact that batteries constitute the fundamental component of electric vehicles, the development of more advanced battery technology is a key component of this shift. Batteries have an impact on the efficiency, range, safety, and cost of electric vehicles. When compared to the many different kinds of batteries that are being researched, lithium-ion (Li-ion) batteries have been the most successful in terms of market share. This is because of their low cost, high energy density, and well-established production techniques. Although Li-ion batteries are quite popular, there are some limitations associated with their use. Concerns regarding energy density, safety (such as thermal runaway), cycle life, and the impact on the environment caused by resource extraction and disposal have brought to light the necessity of developing solutions that are superior and more sustainable over the long term. Solid-State Batteries, often known as SSBs, are a very new and intriguing technology that has recently come to light. These batteries provide various advantages over previous Li-ion batteries. Solid-state batteries have the ability to increase their energy density, make them safer, lengthen their cycle life, and make them more thermally stable than Li-ion batteries. These benefits are all a result of the solid electrolyte that is used in these batteries. A number of challenges, including high production costs, scalability issues, and material compatibility, are among the factors that hinder SSBs from being utilized on a widespread scale. This article takes a look at the benefits, drawbacks, and potential future applications of Li-ion and Solid-State Battery technology in relation to electric vehicle applications. In this article, we will examine the most recent advancements in both technologies to determine how the two different battery systems are influencing the future of electric vehicles and how they might contribute to the development of a transportation system that is more environmentally friendly and technologically advanced.

The Present and Future of Lithium-Ion Batteries

The efficiency, longevity, and high energy density of lithium-ion (Li-ion) batteries have led to their rapid adoption as the go-to power source for electric vehicles (EVs). For many years now, Li-ion batteries have been the standard for portable devices and electric cars because of their low cost and high efficiency. Several challenges remain, however, that can threaten their long-term viability in the rapidly developing electric car industry, despite their extensive use.

1. Battery Chemistry and Structure

A separator, a liquid electrolyte, a cathode (usually lithium metal oxide), and an anode (commonly graphite) make up a lithium-ion battery. The electrolyte facilitates the transfer of lithium ions between the cathode and the anode during battery charging. The ions return to the cathode during discharge, creating an electric current. The cathode and anode materials' composition greatly affects the energy density, power output, and lifespan of the battery.

2. Energy Density and Efficiency

When compared to other rechargeable battery types, such lead-acid or nickel-metal hydride (NiMH), Li-ion batteries have a comparatively high energy density, which is one of its main advantages. Their capacity to store massive quantities of energy in a very small footprint makes them ideal for uses such as electric vehicles. Electric vehicles are able to cover respectable distances thanks to Li-ion batteries, which normally have an energy density of 150-250 Wh/kg. Future electric vehicles may need an even higher energy density to meet their increased range requirements.

3. Cycle Life and Degradation

After many charges and discharges, Li-ion batteries start to fail. The range of electric vehicles is diminished as a result of this deterioration, which gradually reduces the capacity of the batteries. The lifespan of Li-ion batteries is still an issue, even though it has been increased to 1,000-2,000 cycles because to developments in BMS and better chemistry. The long-term performance of electric vehicles and the cost-effectiveness of lithium-ion battery technology can be compromised by factors such rapid deterioration, extreme temperatures, and overcharging.

4. Safety Concerns

Although Li-ion batteries are often safe when used as intended, they can cause serious harm if damaged, overcharged, or exposed to harsh environments. Internal short circuits, punctures, or

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manufacturing flaws can cause the Li-ion battery to overheat and ignite, a process known as thermal runaway. The liquid electrolyte in these batteries is extremely flammable. Electric vehicle fires and explosions have occurred as a result of this safety issue; however, the risks have been diminished as a result of attempts to improve thermal management, battery management systems, and manufacturing standards.

5. Environmental and Sustainability Issues

Another major problem with Li-ion batteries is the damage they do to the environment. Raw elements like nickel, cobalt, and lithium are needed to make Li-ion batteries, which are a greener option than fossil fuels. In some areas, human rights violations, habitat loss, and environmental deterioration may emerge from the mining and extraction of these resources. Additionally, there are still major obstacles to recycling and end-of-life disposal of Li-ion batteries because the majority of recycling methods are not cost-effective or efficient. To lessen the impact of these problems, more environmentally friendly methods of making and recycling batteries must be found.

6. Cost Considerations

Technological advancements and economies of scale have caused Li-ion battery prices to drop significantly over the last decade. A major component of electric car prices, though, is the cost of these batteries. For electric vehicles to be accessible to a wider audience, the price of lithium-ion batteries—which make up around 30–40% of the overall cost—must be lowered even further. The cost of these batteries could be reduced by research into making Li-ion manufacturing techniques more efficient and creating cheaper alternative materials.

7. The Need for Next-Generation Solutions

There is growing concern about the safety, longevity, sustainability, and energy density of Li-ion batteries due to the increasing number of electric vehicles on the road. Even while present Li-ion technologies work well for a lot of things, new battery technologies that can overcome these issues are needed more and more often. New chemistries are being investigated by researchers as possible answers to the increasing demands of electric vehicles and other sectors. These include lithium-sulfur, lithium-air, and solid-state batteries.

Although there is still more work to be done, lithium-ion batteries are currently the clear leader in the race to become the de facto standard for future electric vehicles. Innovations in price, safety, environmental impact, cycle life, and energy density will determine whether new technologies can supplant Li-ion batteries or meet the evolving needs of the electric vehicle industry.

Conclusion

There is a significant amount of credit that can be given to lithium-ion (Li-ion) batteries for the development of electric vehicles (EVs). These batteries are well-known for their high energy density, efficiency, and affordability. Electric mobility has developed as a feasible means of lessening dependency on fossil fuels and emissions of greenhouse gases as a result of its widespread acceptance on the continent. Nevertheless, there are a number of challenges that lithium-ion batteries need to conquer, including concerns surrounding cost, safety, environmental sustainability, cycle life, and energy density. These are only some of the

ISSN: 2065-7161
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barriers. When these challenges are taken into consideration, it is abundantly evident that additional research and development are required in order to overcome the deficiencies of the technology that is currently available. Battery technology needs to advance in order for electric vehicles to meet the demands of consumers, comply with industry rules, and achieve environmental goals. Despite the fact that Solid-State Batteries and other emerging technologies have the potential to significantly enhance traditional Li-ion systems in important aspects such as safety, energy density, and lifespan, Li-ion batteries continue to hold the majority of the market share. It is likely that the future of electric vehicles will consist of both the enhancement of the existing Li-ion technology and the investigation of additional possibilities. If the electric car industry is going to reach its full potential, it is absolutely necessary to have a complete plan that takes into account the development of new battery manufacturing techniques, improved recycling procedures, and the production of materials that are favorable to the environment. The evolution of battery technology is already having an impact on the future of electric vehicles and the movement toward more environmentally friendly modes of transportation, and this trend is only going to intensify as scientific knowledge and technological capabilities continue to progress.

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