Capitalized Analysis of the Development Status and Prospects of Power Batteries for New Energy Vehicles

Bohan Zhang

School of Energy and Environment, Anhui University of Technology, Ma’anshan, 243002, China,

bohanzhang@stu.ahut.edu.cn

**Abstract.** Power batteries, as one of the most important parts of new energy vehicles, will directly affect the vehicle's power performance, safety, service life, range and so on. However, there are still some difficulties in power battery technology, its low energy density, unstable working conditions, safety hazards, high cost, environmental pollution of raw materials and other problems can have a negative impact on purchasing power and the development of power batteries to some extent. Based on this, this paper starts from today's mainstream new energy vehicle power battery types, gives a brief overview of their working principles and research progress, and at the same time, compares and analyzes the advantages and disadvantages, and finds that lithium batteries and solid-state batteries will become the main development direction of future power batteries; and further puts forward the specific direction that can improve the power battery technology, and analyzes the prospects for the development of power batteries.

# INTRODUCTION

In recent years,the global automobile industry's transformation and upgrading is being driven by the development of new energy vehicles as a strategic direction, and according to the statistics,in China, the year-on-year growth rate of 24.4% is expected for new energy vehicle sales to reach 16 million in 2025 [1].The power battery determines the power performance, service life and range of the vehicle, so it is urgent to increase the investment in power battery research and development.

At present, global power battery technology has been developing rapidly, and a variety of power batteries, especially lithium batteries, have made significant progress in energy density, cycle life, safety and other aspects. However, the power battery industry is still facing challenges such as the bottleneck of energy density improvement, cost reduction pressure, and resource and environmental constraints.

For the battery energy density problem, Xu. et al. pointed out that Polyplus and Sion Power in the United States and BASF in Germany have made a number of excellent research progress in lithium-sulfur batteries, and the energy density of a single lithium-sulfur battery can be up to 400 Wh/kg, however, the cycling performance is far from meeting the actual requirements and is experiencing a serious self-discharge [2]. Therefore many scholars have changed their research direction, Wanison. et al. have explored alternative technologies for batteries, and found that sodium-ion batteries will be a huge competitor to the current mainstream battery-lithium-ion batteries because of their rich sodium content, low cost and high safety, but they still face some challenges in thermal management and service life [3][4].

Therefore, in-depth research on the development status of power batteries and analysis of future trends are of great significance to promote the progress of power battery technology and promote the high-quality development of the new energy vehicle industry. This paper will comprehensively analyze the development of new energy vehicle power batteries from the types of power batteries, current problems, future development direction, etc., in order to provide a reference for research and practice in related fields.

# Types of Power Battery

## Lithium Ion Battery

As the mainstream technology of new energy vehicle power batteries, lithium battery dominates the market with its high energy density, long life and mature technology route. According to the different cathode materials, lithium batteries can be divided into lithium ternary batteries, lithium iron phosphate batteries, lithium cobalt batteries, and lithium manganate batteries. The first two are the more widely used, while the latter two are less used due to performance limitations.

For Li-ion ternary battery and Li-FePO4 battery, Gong.et al. simulated the discharge characteristics of the two batteries under three different working conditions, and found that Li-FePO4 batteries have a good track record when it comes to maintaining the voltage plateau and maintaining the stability of the discharge voltage, while ternary lithium batteries have higher energy density and longer battery life [5]; Fan.et al. compared the entire life cycle of Li-FePO4 and Li-ion ternary batteries in terms of their environmental impact and found that the recycling of lithium ternary batteries is more environmentally beneficial [6]. By comparing the performance parameters of lithium iron phosphate battery and ternary lithium battery [7], as shown in table 1, it is found that the former has abundant positive electrode material resources and is excellent in cost control and service life. However, the latter battery has a higher specific capacity, fast charging speed, low-temperature resistance, and excellent magnification performance.

**TABLE 1** Comparison of the performance of lithium iron phosphate and lithium ternary batteries [7].

|  |  |  |
| --- | --- | --- |
| **Performance Parameters** | **Lithium Iron Phosphate Battery** | **Nickel-cobalt-manganese Ternary Lithium Batteries** |
| Anode Structure | Olivine | Stratiform |
| Anode Material Resources | Rich in iron and phosphorus resources | Scarce cobalt resources |
| Theoretical Specific capacity/[(mA·h)·g-1] | 170 | 275 |
| Actual specific Capacity/[(mA·h)·g-1] | 130~150 | 150~200 |
| Voltage platform/V | 3.2 | 3.7 |
| Cycle life / Times | 2000+ | 1500~2000 |
| Charging Speed | Slow | Fast |
| Thermal Stability | Superior | Good (deteriorates with increasing nickel content) |
| Low Temperature Resistance | Mediocre | Good |
| Magnification Performance | Mediocre | Superior |
| Environmental Character | Non-polluting | Nickel, cobalt contaminated |
| Comprehensive Cost | Low | High |
| Global installed capacity in 2021/(GW·h) | 79.8 | 74.3 |

## Nickel-metal Hydride Battery

In new energy vehicles, nickel-metal hydride batteries are mainly used in hybrid vehicles. When it is charged, hydrogen ions are released from the positive electrode and stored in the negative alloy; when discharged, the hydrogen ions leave the negative alloy to the positive electrode, releasing electrical energy to drive the vehicle. Its advantages are higher safety, longer life and environmental friendliness, but its slow charging speed, the need for special charging equipment, and high price limit its use in some fields [8].

With the popularization of lithium-ion batteries, nickel-metal hydride batteries are gradually shrinking their market share in new energy vehicles, but they are still used in hybrid vehicles and models with higher safety requirements. Nickel-metal hydride batteries can continue to play a role in hybrid vehicles and energy storage by improving energy density and lowering costs through material innovation and process improvement. Despite the competition from lithium-ion batteries, nickel-metal hydride batteries can still maintain a certain position in specific application scenarios by virtue of their higher safety advantages.

## Solid-state Batteries

Solid-state batteries use a solid-state electrolyte instead of the traditional liquid electrolyte. Energy can be stored and released by the movement of lithium ions between the positive and negative electrodes. The principle of operation is similar to that of lithium-ion batteries, but the solid-state electrolyte has higher ionic conductivity and safety. Compared with conventional batteries, solid-state batteries have more powerful performance, such as higher energy density, higher specific energy, and better safety [9].

Solid-state batteries are currently in the R&D and testing phase and have not yet been commercialized on a large scale. In 2024, GAC AION released a full-solid-state battery, CATL also released a cohesive-state battery in succession, and Dongfeng Motor and AIO also announced mass production plans for solid-state batteries and launched high-range models with semi-solid-state battery packs, respectively [10]. However, solid-state batteries still have technical problems in the short term, especially the stability of the solid electrolyte and motor interface in many aspects (chemical, electrochemical, and mechanical), and the overall manufacturing of the battery is yet to be broken through [11].

Zhao. et al. discussed battery management technologies in depth in terms of battery technology, commercial applications and life cycle management and found that lithium-ion batteries will still be the mainstream power battery in the new energy vehicle market in a few years, but if the process and technology of solid-state batteries make a breakthrough, it is very likely to dominate the next generation of power battery market [12].

## Lead-acid Batteries

At present, lead-acid batteries are mainly used in electric bicycles, electric tricycles and other situations with lower prices and little range requirements due to their advantages of mature technology, low cost and high reliability. The limitations of the battery's own factors, such as energy, specific power, and energy density, lead to a poor range, which cannot meet the needs of more users, making it rarely used in pure electric vehicles and plug-in hybrid vehicles. Moreover, lithium-ion batteries are constantly popularizing, making lead-acid batteries in the field of new energy vehicles market share gradually shrinking.

In the future, lead-acid batteries may still have a place in the short-range segment, but they will likely be replaced by higher energy-density batteries in the mainstream new energy vehicle market.

# Problems Faced by Power Batteries and Ways to Deal with Them

At the moment, the power battery is facing multiple challenges such as energy density and range, cost and safety. Energy density directly affects the range, the current battery technology still difficult to meet the demand for long-distance travel. The high cost leads to high vehicle prices, making it difficult to popularize new energy vehicles in the market. Safety issues similar to thermal runaway can also threaten user safety. In addition, battery production relies on resources such as lithium and cobalt, the scarcity of which leads to an unstable supply chain and environmental risks. Solving these problems is crucial to the development of power batteries.

## Energy Density and Range

Energy density is a key factor in determining the range of new energy vehicles. The current mainstream ternary lithium battery has a single energy density of about 200-300 Wh/kg, which has improved from the early days, but still cannot realize long-distance travel. Low energy density leads to short range and users need to charge frequently. To address this problem, based on the original vehicle supercapacitor, Guo. Et al. add lithium-ion battery materials into it, trying to make the supercapacitor and lithium-ion battery materials play their respective advantages at the same time, so that the supercapacitor battery of the new hybrid electric vehicle energy storage system can achieve fast charging and discharging while maintaining high energy density characteristics. Thus, new energy vehicles can show excellent peak power under different driving conditions [13]. However, high energy density means lower safety of the battery, which is more likely to be dangerous in the case of overcharging and overheating, so it is important to find a balance between technological breakthroughs and safety.

## Cost

Power battery cost accounts for 30%-40% of the vehicle cost is the main reason for the high price of new energy vehicles. In recent years, battery costs have been declining, but still need to be further reduced to increase consumer acceptance of new energy vehicles. Take lithium-ion battery as an example, lithium-ion battery consists of positive and negative electrodes, diaphragm, an organic electrolyte and a battery shell, the diaphragm occupies a great part of the cost, because China's diaphragm production technology can not meet the huge demand, more dependent on foreign imports, so it should be increased to lithium-ion battery diaphragm emphasis, so as to meet the performance needs and reduce costs [14].

In addition, adequate recycling of batteries can also reduce production costs. If it is possible to recycle some of the valuable and scarce materials found in end-of-life batteries and put them back into the production of batteries, the shortage of raw materials can be effectively alleviated, thus indirectly reducing the production cost of batteries. In this regard, Fan. Et al. proposed the 4H strategy as a new battery recycling evaluation standard to promote the sustainable development of batteries through comprehensive consideration of technology, economy, environment, safety and data collection [15]. Therefore, the vigorous development of recycling technology for batteries can also make a great contribution to reducing the production cost of batteries.

## Safety

The power batteries, especially lithium batteries, are greatly affected by the working temperature, which is -20 ~ 55 ℃, exceeding or falling below the temperature range can affect the internal temperature uniformity of the batteries, resulting in performance degradation and triggering potential safety hazards. At present, the thermal runaway problem of the battery is more abrupt, the battery in overcharging, over-discharging, high temperature or mechanical damage, etc. may occur thermal runaway, resulting in fire or even explosion. To address this problem, Guo. et al. established a control-oriented nonlinear battery thermal model to predict the temperature change in the thermal management system, and used a dynamic programming algorithm to solve the nonlinear free control problem, so that the temperature control, computational efficiency, and energy saving to achieve a balance, and the results of the study found that the strategy can achieve a great deal of energy saving in different temperatures and standards, and under actual driving conditions [16].

Meanwhile, the existing temperature sensing technology is not capable enough to provide sufficient accuracy and stability, which also leads to inaccurate temperature control and reduces the safety of batteries. Wang.et al. based on the improved safety monitoring method of magnetic field sensing model of the lithium-ion battery, which utilizes the BP neural network and the laws of mathematical statistics to predict and warn of abnormal currents, and found that the accuracy of this method's prediction is as high as 96.4% [17].

In addition to this, compared to lithium batteries, although solid-state batteries have non-flammable characteristics themselves, If a short-circuit or catastrophic solid electrolyte failure occurs, solid-state batteries could lead to thermal runaway with significant consequences [18].The main cause of this problem is the interface reaction between the electrode and the electrolyte and electrode crosstalk, if the problems can be solved, such as the use of surface coatings and an increase in the stability of the cathode [19], then the safety of solid-state batteries will be greatly improved.

# Prospective Analysis of Power Battery

The power battery industry is growing at a rapid pace, and it has a bright future, but still faces problems such as energy density, cost, safety, etc. However, if we can explore a new type of replaceable electrode materials, reduce the production cost of solid-state batteries, so as to realize their wide application, then it will not only greatly promote the development of the industry and facilitate life, but also reduce environmental pollution, making a great contribution to environmental protection.

On the one hand, it is necessary to ensure the supply of raw materials and enhance the survey of resources needed for batteries such as cobalt and lithium; however, a more effective way is to fully recycle batteries, which not only ensures the supply of raw materials but also reduces costs and pollution. Dunn. et al. conducted a dynamic global material analysis of battery pack electrode materials, including the chemistry of the ever-changing battery cathode and the demand for electric vehicles scenario analysis, and found that in perfect conditions, batteries that have been used could supply more than half of the world's raw metal resources for the power battery by 2040 [20].

On the other hand, consolidating the current battery technology types is necessary, while researching new types of power batteries. For such as lithium-ion batteries are widely used in the market battery, to take full advantage of the relative maturity of the technology in these areas, focusing on solving cutting-edge problems, so as to play the biggest benefit of this type of battery; For such as solid-state batteries, a class of immature power battery, because of its own advantages in terms of safety and so on, so focus on solving the problem of their high cost, process complexity and so on. Whether it is the progress of existing battery technology or new battery technology innovation, will help new energy vehicles power batteries to achieve significant development.

# Conclusion

By analyzing the development status quo of mainstream power batteries, this paper obtains the advantages of these types of power batteries, the main problems faced and the direction of improvement. The main problem is reflected in the energy density and safety of the battery, in this regard, the need to find a balance between the energy density and safety, to improve the energy density of the battery at the same time reduce the probability of battery safety hazards; and in terms of cost. To achieve full recycling of the battery, thus indirectly reducing the cost of input. Lithium batteries as the mainstream battery in the current new energy vehicle market, although there are some problems, but its performance is better than most power batteries, and in the next few years will still occupy a dominant position; if the solid-state battery process and materials can be innovated to reduce costs, in the near future may also realize the wide application of solid-state batteries.

# References

1. L. Yu, "New Energy Vehicle Industry Chain Headline Companies See Continued Growth in 2024," Shanghai Securities Journal, p. 006 (2025).
2. J. Xu, X. Cai, S. Cai et al., "High‐energy lithium‐ion batteries: recent progress and a promising future in applications," Energy & Environmental Materials, 6(5), p. e12450 (2023).
3. R. Wanison, W. N. H. Syahputra, N. Kammuang-lue et al., "Engineering aspects of sodium-ion battery: an alternative energy device for Lithium-ion batteries," Journal of Energy Storage, 100, p. 113497 (2024).
4. M. Li, J. Hong, Y. Shen et al., "Research on safety management strategy for the whole-life-cycle of power batteries in electric vehicles," Journal of Cleaner Production, 490, p. 144804 (2025).
5. M. Gong, J. Chen, J. Chen et al., "Study on Discharge Characteristic Performance of New Energy Electric Vehicle Batteries in Teaching Experiments of Safety Simulation under Different Operating Conditions," Energies, 17(12), p. 2845 (2024).
6. T. Fan, W. Liang, W. Guo et al., "Life cycle assessment of electric vehicles' lithium-ion batteries reused for energy storage," Journal of Energy Storage, 71, p. 108126 (2023).
7. M. Zhang, "New energy vehicle power battery development status and trend analysis," Smart Internet of Things (IoT) Technology, 56(01), pp. 5–8 (2024).
8. Z. Zhang, "Research on new energy vehicle battery and its service life," Automotive Test Report, (23), pp. 61–63 (2023).
9. A. Joshi, D. K. Mishra, R. Singh et al., "A comprehensive review of solid-state batteries," Applied Energy, 386, p. 125546 (2025).
10. M. Xie and W. Luo, "Application of solid-state battery technology in new energy vehicles," Automotive Test Report, (18), pp. 50–52 (2024).
11. X. Yu, R. Chen, L. Gan et al., "Battery safety: From lithium-ion to solid-state batteries," Engineering, 21, pp. 9–14 (2023).
12. G. Zhao, X. Wang and M. Negnevitsky, "Connecting battery technologies for electric vehicles from battery materials to management," Iscience, 25(2) (2022).
13. L. Guo, P. Hu and H. Wei, "Development of supercapacitor hybrid electric vehicle," Journal of Energy Storage, 65, p. 107269 (2023).
14. J. Gong, "Analysis of the development status of new energy vehicle battery industry," Modern Industrial Economy and Informatization, 13(03), pp. 21–22+30 (2023).
15. E. Fan, L. Li, Z. Wang et al., "Sustainable recycling technology for Li-ion batteries and beyond: challenges and future prospects," Chemical Reviews, 120(14), pp. 7020–7063 (2020).
16. R. Guo, Z. Sun and M. Luo, "Energy-efficient battery thermal management strategy for range extended electric vehicles based on model predictive control and dynamic programming," Energy, 307, p. 132769 (2024).
17. T. Wang, H. Liu, W. Wang et al., "Research on charging monitoring method for lithium-ion batteries based on magnetic field sensing," International Journal of Electrochemical Science, 19(9), p. 100711 (2024).
18. J. Charbonnel et al., "Preliminary study of all-solid-state batteries: Evaluation of blast formation during the thermal runaway," Iscience, 26(11) (2023).
19. Y. He, J. Wang, C. Rong et al., "Status of cell-level thermal safety assessments toward optimization of all-solid-state batteries," Cell Reports Physical Science (2024).
20. J. Dunn, M. Slattery, A. Kendall et al., "Circularity of lithium-ion battery materials in electric vehicles," Environmental Science & Technology, 55(8), pp. 5189–5198 (2021).