Crimson Publishers
Wings to the Research

Review Article

Review on Thermal Behavior & Development of Li-Ion Battery for Different Applications

ISSN: 2576-8840

Purushottam Kumar* and BP Singh

Department of Physics, Dr. Bhimrao Ambedkar University, India

*Corresponding author: Purushottam Kumar, Department of Physics, Dr. Bhimrao Ambedkar University, Agra, India

Submission: July 03, 2024
Published: July 24, 2024

Volume 20 - Issue 3

How to cite this article: Purushottam Kumar* and BP Singh. Review on Thermal Behavior & Development of Li-Ion Battery for Different Applications. Res Dev Material Sci. 20(3). RDMS. 000990. 2024.
DOI: 10.31031/RDMS.2024.20.000990

Abstract

Lithium-Ion Batteries (Li-ion) are the advance form of batteries recently utilized in various applications. Li-ion batteries are the preferred technology for hybrid and fully electric vehicles, power tools, and portable gadgets due to their unmatched combination of high energy and power density. In this battery the electrolyte acts as a conduit for the ion exchange that generates electricity. Batteries of all shapes and sizes are thought to be one of the best methods for storing energy; nonetheless, the environmental effects of widespread battery use continue to be a significant issue that needs further research. The high-energy materials and the organic components of a Li-ion battery are unstable at temperatures above 130-150 °C and are prone to produce greater heat. The battery temperature will rise further and the heat-releasing process will quicken if the created heat is not expelled. The main Li-ion battery components are presented and contrasted in this study, along with the accompanying battery management systems and methods for enhancing battery efficiency, capacity, and lifespan. The thermal runaway mechanism is discussed in this work, along with a number of thermal runaway mitigation strategies, such as separators, flame retardants, and safety vents.

Keywords: Battery efficiency; Li-ion batteries; Battery management systems; Electrode materials; Thermal runaway

Introduction

The invention of lithium-ion (Li-ion) batteries has completely changed a number of markets and uses, including consumer electronics, electric cars, renewable energy storage, and more. Li-ion batteries provide many benefits over conventional energy storage technologies, such as a long cycle life, high energy density, and lightweight construction. Li-ion battery thermal behavior must be understood in order to maximize performance, guarantee safety, and customize the battery for various uses. This introduction acts as a bridge to a thorough examination of the development of Li-ion batteries for a range of applications and their thermal behavior. It describes the role Li-ion batteries play in modern society, identifies the critical elements influencing their thermal performance, and emphasizes how important it is to take thermal management into account when designing batteries [1].

With the ability to power a vast array of products and systems, including laptops, electric vehicles (EVs), and smartphones, lithium-ion batteries have become essential in today's environment. They are essential for storing energy produced by renewable sources like solar and wind power, hence their contribution to the shift to sustainable energy sources cannot be overstated. The need for high-performance Li-ion batteries is growing as we move away from fossil fuels, which emphasizes the necessity of ongoing research and development in this area. The kind of active materials used in the battery's electrodes, the battery's level of charge, current rates, and the surrounding temperature all have an impact on how Li-ion batteries behave thermally. Together, these elements affect the battery's overall performance, safety, and efficiency. Comprehending these affects is essential to creating batteries that may satisfy the particular requirements of various applications. Li-ion battery safety and performance optimization depend on efficient temperature control. Problems like overheating, capacity loss, and even safety risks like thermal runaway can result from inadequate thermal control. For high-demand applications like electric vehicles (EVs) and grid storage systems, where Li-ion batteries are subjected to variable ambient conditions and heavy usage, temperature control is especially important [2].

We shall examine the thermal behavior of Li-ion batteries in various applications as well as the relevant development and enhancement techniques in this series of papers. We will investigate the special difficulties and demands that Li-ion batteries encounter in a variety of industries, such as consumer electronics, electric vehicles, renewable energy storage, and more [3]. Our objective is to offer insightful information about the state of Li-ion battery technology today and the breakthroughs propelling its progress. In the pages that follow, we will examine the particular thermal issues and solutions for Li-ion batteries in each application area, providing a thorough summary of the ongoing research and development activities. By the time this investigation is through, readers will know more about the significance of thermal management in Li-ion battery design and how it affects a variety of businesses.

Types of batteries

There are several different battery kinds, each with different chemistries and properties:

Primary batteries: Also known as non-rechargeable batteries, these are single-use batteries. If their chemical reactions stop working, they cannot be regenerated.

Secondary batteries: Also known as rechargeable batteries, these batteries may be recharged by reversing the chemical reactions with the help of an external power source (Figure 1).

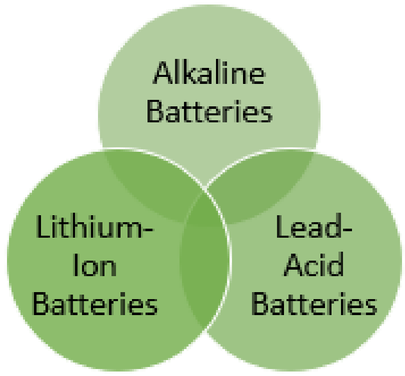

Figure 1: Different types of secondary batteries.

Alkaline batteries: They use an alkaline electrolyte, are reasonably long-lasting, and are commonly found in household appliances.

Lithium-Ion batteries: These batteries are commonly found in electric cars and portable devices due to their high energy density and several recharge cycles (Table 1, [4,5]).

Table 1: Primary batteries components.

Name	Definition
Lead-Acid Batteries	They are typically seen in cars and utilized lead and lead dioxide electrodes in an electrolyte of sulfuric acid.
Lead-Acid Batteries	Older rechargeable batteries with a high cycle life, but they contain toxic cadmium and have been largely replaced by newer chemistries.
Consumer Electronics	supplying energy to gadgets like remote controls, computers, cameras, and smartphones.
Transportation	supplying power for hybrid and electric autos as well as electric aero planes.
Renewable Energy Storage	preserving extra power produced by wind turbines or solar panels for use when production is low.
Emergency Power	Uninterruptible power supply (UPS) for computers is one example of a device that provides backup power during power outages.
Medical Devices	supplying energy to hospital equipment, portable medical devices, and implantable medical devices [4,5].

Because they provide portability, convenience, and sustainability in a wide range of technological applications, batteries are indispensable to modern life. Experts are investigating novel materials and designs in an effort to increase battery longevity, safety, and efficiency as technology develops [6]. Lithium-ion (Li-ion) batteries are a type of rechargeable energy storage technology that has become indispensable to modern living due to their high energy density, efficiency, and versatility. They provide power to a wide range of devices, such as laptops, telephones, renewable energy systems, and electric cars [7]. Because lithium-ion batteries are so good at storing and releasing electrical energy, they are becoming more and more common.

There are the Fundamental Elements Li-ion batteries are made up of numerous essential parts, including (Figure 2; Table 2, [8]):

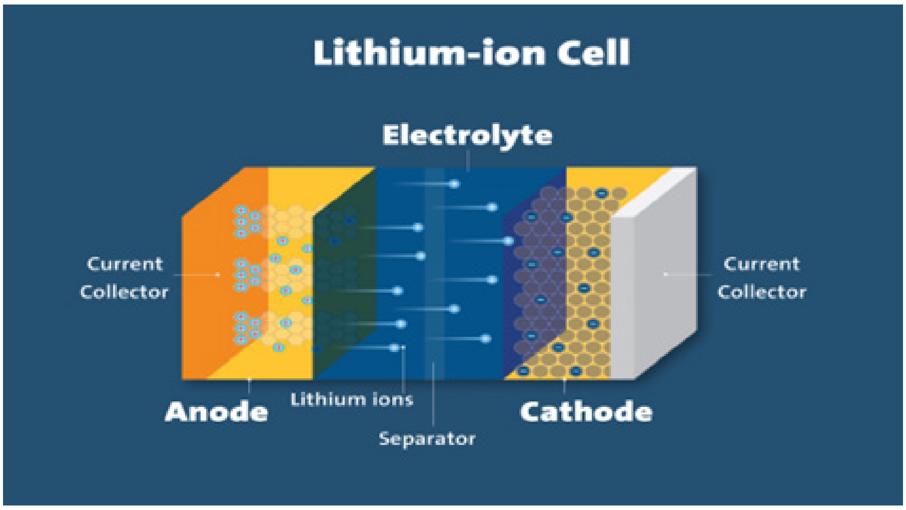

Figure 2: Lithium-ion cell batteries.

Table 2: Batteries component.

Name	Characterization
Anode	Typically made of graphite, the anode is the electrode where lithium ions are stored during charging.
Cathode	The cathode, usually composed of various metal oxide materials, is the electrode where lithium ions migrate during discharge.
Electrolyte	A lithium salt dissolved in a solvent form the electrolyte, facilitating the movement of lithium ions between the anode and cathode.
Separator	A thin, porous separator physically separates the anode and cathode while allowing the passage of lithium ions [8].
Operation	During charging, lithium ions move from the cathode to the anode through the electrolyte, where they are stored within the anode's structure. During discharge, these ions move back to the cathode through the electrolyte, releasing electrical energy in the process.

Principal of lithium-ion batteries

A battery is a device that converts chemical energy into electrical energy by storing it. During chemical reactions in batteries, electrons flow from one substance (electrode) to another through an external circuit. The movement of electrons can produce an electric current, which can then be used to carry out operations. The electrolyte, which separates the two terminals and is composed of various substances (often metals), the anode, and the cathode are the three essential components of a battery. Between the cathode and anode, an electrical charge can flow through the electrolyte, a chemical medium [9]; (Figure 3).

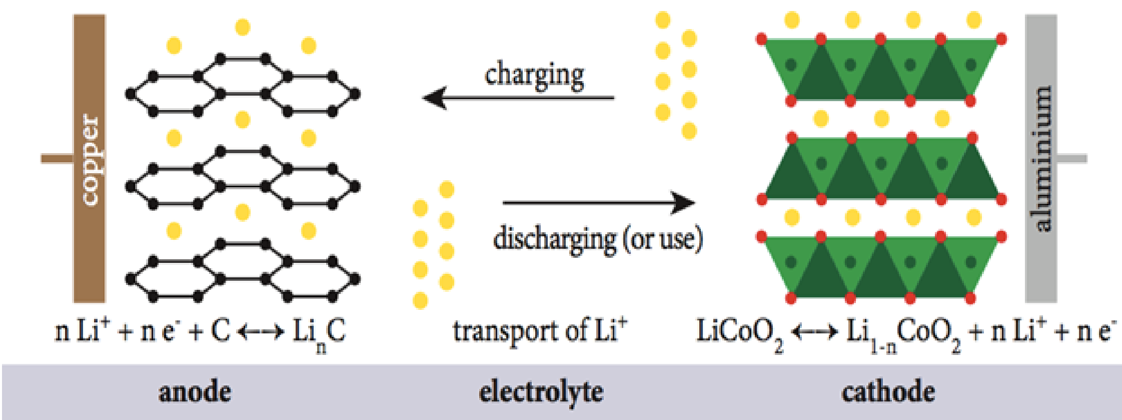

Figure 3: Charge and discharge lithium-ion batteries.

Battery power

The battery's storage capacity is measured in Ampere hours, or Ah. If V is the battery voltage, then the energy storage capacity of the battery can be Ah x V = Watt-hour. Usually, battery capacity will be specified for a given discharge/charge rating or C rating. The actual capacity depends on operating conditions such as load, temperature, etc.

Depth of Discharge (DOD)

It provides a measurement of the amount of energy expended from a battery in relation to its maximum capacity. The state of charge of a battery is the difference between the full charge and the depth of discharge of the battery in percentage.

If the DOD is 25% then the state of charge is (100 - 25) = 75% (Figure 4).

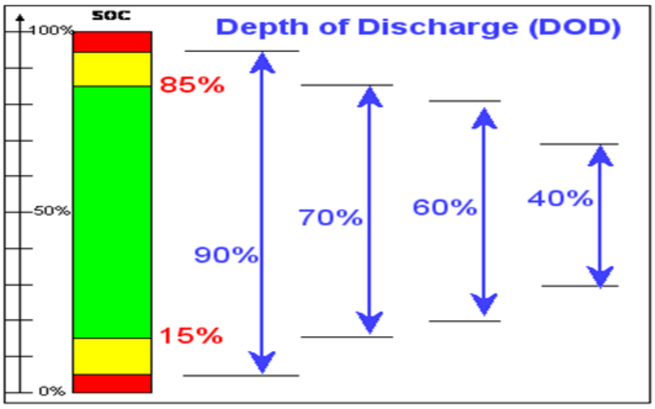

Figure 4: Lithium & solar power lifepo4 -Depth of Discharge (DOD) all battery.

SOC estimation methodologies

Various battery frameworks can be monitored to monitor the health of a battery in an EV, while the vital parameters considered are the State of Charge (SOC) and the State of Health (SOH). SOC is described as the ratio of the available battery storage capacity to the nominal battery storage capacity [10].

SOC=Q (capacity of the battery available now)/Q nominal capacity of the battery)

While SOH is supposed to be an indicator of state, it is yet to be discovered, Rahimi-Eichi et al. says. The reason for SOH deterioration is the aging of battery which leads to increased internal resistance and increased terminal voltages.

Health estimation

The methods previously discussed are used to determine the SOC of a battery, which is the capacity of a battery at a given point. SOH is a somewhat ambiguous term, but here, the focus is on monitoring battery performance over time, including parasitic cell resistances, bad wire connections, and degradation in cell capacity. Detecting an unhealthy battery pack provides awareness of a battery pack's capabilities, allowing for the proper battery pack to be selected for a given mission. It may also allow detection and replacement of defective cells before they cause a dangerous event, such as a battery fire [11].

Recalibration capacity

The easiest method of checking degradation in battery capacity is to monitor it for a full charge cycle. The BMS' microcontroller can be set up to detect whether or not the battery is full or empty based on the voltage thresholds. When one of these thresholds is reached, the BMS can begin coulomb counting until the other threshold is reached. This will give an approximation of the capacity, which will reduce as the battery health degrades. The BMS needs to provide a notification when the capacity drops below a predetermined threshold [12]. If recalibration is occurring, and the pack alternates between charging and discharging too many times before reaching the opposite threshold, calibration needs to stop. Charging and discharging the battery too many times before the battery reaches the opposite threshold results in the coulomb counting slowly accumulating errors. These errors can distort battery capacity measurements.

An important consideration for calculating a battery's SOH is capacity measurement. Battery cycle life is often calculated as the number of cycles required to recover 80% of the battery's initial capacity. This takes from several hundred to several thousand cycles, depending on the battery. Capacity fade is typically slow; however, battery health can change more rapidly, and assessing this before high consequence applications of batteries is important. Other tools can be used to make this sort of assessment [13].

Battery voltage

Working voltage or nominal voltage refers to the terminal voltage under normal operating conditions. Manufacturers will specify this voltage.

It could be 3V, 6V, 12V, 24V, etc.

Cycle of a battery

A battery's nominal capacity is the number of full charges and discharges it can withstand before falling below 80% of its rated initial capacity. The battery will continue to function with decreased capacity after the designated life cycle. Although it can be used, the capacity will be reduced.

Charge rate, discharge rate, or C-rate: C rating is the result of dividing the battery's capacity by the number of hours required for a full charge or discharge, expressed as C/X, where X is the required amount of time in hours. The C-rating is C/10 or 0.1C if X = 10h [14].

Electrode materials: Electrical components are made up of electrodes and electrode materials, which might be made of metals or other materials. They serve as the parts of a system that conduct electrical current and are used to establish contact with a circuit's nonmetallic elements. Metallic electrodes with coated carbon are widely accepted as a good option for BES because of the enhanced conductivity and resilience of metals and the high biocompatibility of carbon-based materials [15]. Copper and stainless steel are inappropriate anode materials because of their toxicity and tendency to corrode. Platinum is a commonly used electrode material because of its endurance, despite its high cost. Alkaline water electrolyzes usually use metals based on nickel as a point of reference for the remaining elements. Graphite is a stable material but not very catalytic. The most popular materials for working electrodes are platinum, gold, carbon, and mercury. A standout candidate among them, platinum is perhaps the easiest to produce in a range of forms and has a good electrochemical inertness [16].

Among the materials used as electrolytes are LiPF6, LiClO4, LiAsF6, and Li CF3SO3. In addition to these main ingredients, there are additional ones including a binder, flame retardant, gel precursor, and electrolyte solvent. Lithium-ion batteries (LIBs) are used extensively and have proven to be more environmentally friendly and energy dense than a variety of portable electronic devices. Notwithstanding these benefits, further development is still needed in the cycle life and power density for use in large-scale energy storage systems, electrically driven vehicles (EVs), and other diverse applications [17].

Despite major advancements in battery technology, modern batteries are still far from meeting the energy consumption requirements of electric vehicles. This is mostly because of the battery's inherent risk as a result of its non-monotonic energy consumption and abrupt fluctuations during the discharge process [18]. One of the most reliable ways to solve this issue is to combine the battery with a super capacitor, which has a similar architecture to the battery but a longer life cycle, higher energy density, and the ability to provide additional energy in the event that the battery runs out. Another option is to create electrode materials with low diffusion distances, high mechanical strength, high surface to dimension ratios in bulk, and fully exposed active surfaces in order to improve the electrochemical performance of LIBs [19-21].

Two more significant issues with Li-ion batteries are their unsteady high-temperature behavior and a reduction in their low-temperature charge-discharge performance. Furthermore, it has been found that a decrease in temperature leads to a fall in the charge-discharge performance of Li-ion batteries. The main causes of this include a slowdown in reaction kinetics, a decrease in Li+ ion transport, and an increase in SEI layer resistance. In this succinct overview, we go over a number of cutting-edge methods for creating lithium-ion battery electrodes as well as recent developments in electrode composition. Other promising materials with enhanced electrochemical performance have also been demonstrated [22], in addition to the traditional electrodes, which have been modified to improve their performance and stability.

Thermal runaway

A potentially dangerous situation known as "thermal runaway" occurs when a system or process encounters an uncontrollably high temperature rise that could have catastrophic consequences. This behavior is common in many various situations, such as electronics, chemistry, and engineering. The concept of "thermal runaway" refers to a self-reinforcing process in which temperature increases cause additional temperature increases, creating a feedback loop that could lead to the collapse of the system in a number of situations.

Several instances of thermal runaway are given below:

Chemical reactions: In chemistry, thermal runaway can happen when an exothermic reaction generates more heat than it can possibly escape. The additional heat may speed up the response rate and produce even more heat. If the heat is not effectively extinguished, the temperature may rise uncontrollably and could cause explosions or flames. When using reactive substances in industrial processes, this is a serious concern [23].

Batteries: Rechargeable batteries, particularly lithium-ion batteries, are susceptible to thermal runaway from internal short circuits, overcharging, and physical damage. Increased chemical reactions may result from the battery heating up, which would release more heat. This cycle has the potential to intensify quickly, swelling, leaking, or in extreme situations blowing up the battery [24].

Electronics: Transistors and integrated circuits, for example, are susceptible to thermal runaway when exposed to high voltages, high currents, or inadequate cooling. These components' electrical resistance may decrease with temperature, increasing current flow and producing more heat. The components may be harmed or destroyed as a result of this self-sustaining cycle [25].

Power Systems: Inadequate design or maintenance can lead to thermal runaway in power distribution systems. Transformers or electrical lines that are overloaded can produce an excessive amount of heat, which could cause failures that spread throughout the system. Widespread power disruptions, fires, and other dangers may arise from this [26].

It is imperative to include appropriate design, monitoring, and safety procedures in order to minimize or mitigate the risks associated with thermal runaway. Incorporating cooling systems, utilizing suitable materials, putting safety interlocks in place, and adopting thermal management techniques, for example, can all assists reduce or eliminate the effects of thermal runaway. In general, thermal runaway is a phenomenon that emphasizes how crucial it is to comprehend and control heat creation and dissipation in a variety of systems in order to guarantee security and avert disastrous failures [27].

Including separators

In rechargeable batteries, such lithium-ion batteries, separators are essential because they keep the positive and negative electrodes from coming into direct contact while yet enabling ion flow. In order to enable the passage of ions during charging and discharging, the separator is typically a thin, porous, insulating substance put between the electrodes [28].

Here now the thermal runaway in batteries can be exacerbated by separator-related issues.

a) Direct contact between the electrodes may become possible if the separator material degrades or is weakened. An internal short circuit, in which current moves straight between the positive and negative electrodes without going via the external circuit, may arise from this. Because of the high current flow in this short circuit, heat is produced, which may cause thermal runaway or localized heating [29].

b) If the battery sustains physical damage, the separator may become perforated or deformed, resulting in direct contact between the electrodes. External forces, improper handling, or manufacturing flaws can all result in this damage. Once more, a short circuit and thermal runaway may be caused by this direct contact [30].

c) During normal operation and especially during overcharging, some lithium-ion batteries can generate gases. If the separator becomes compromised, these gases can lead to swelling or pressurization within the battery cell. The increased pressure can further damage the separator, exacerbating the potential for thermal runaway [31].

d) In addition to its other function as a thermal insulator, the separator also helps to shield the electrodes from direct heat transmission. The risk of thermal runaway increases if the insulating qualities of the separator are weakened because heat produced during regular operation can more readily transfer between the electrodes [32]. Manufacturers use a number of precautions to lessen the possibility of thermal runaway in separators.

e) The overall safety and dependability of the battery can be improved by using superior separator materials that are both mechanically strong and chemically stable [33].

f) Protective coatings can be applied to separators to increase their thermal stability and resistance to harm. Design and Manufacturing: Defects that could jeopardize the integrity of the separator can be avoided by making sure batteries are designed and manufactured in accordance with strict guidelines [40[By controlling and dispersing heat, efficient thermal management systems can help lower the risk of temperature-related problems in battery designs [34].

g) Another factor influencing overall battery safety is the selection of electrode materials that are less prone to thermal runaway [35].

h) Without a doubt, safety vents and flame retardants are extra parts and techniques that help reduce the danger of thermal runaway in a variety of systems, including batteries [36].

Flame retardants

Flame retardants are chemicals or materials that are designed to reduce a material's combustibility and to slow down or stop the spread of flames. In the context of thermal runaway and battery safety, flame retardants can be added to battery designs to lessen or completely prevent fires that could come from overheating or other issues [37]. It is possible to add flame retardant chemicals to the electrolyte or other battery components in lithium-ion batteries to increase their fire resistance. In the unlikely event that thermal runaway occurs and the battery overheats, these additives can help suppress the combustion of volatile components within the battery, reducing the risk of a fire or explosion.

Safety vents

Safety vents, sometimes referred to as pressure relief vents, are made to let go of pressure that has accumulated inside a system in order to stop disastrous malfunctions like explosions. Safety vents are crucial for controlling the pressure created during thermal runaway in the context of batteries [38]. The pressure inside a battery cell can rise dramatically when it experiences thermal runaway and releases gases. If the pressure is not released, it may cause additional harm to the separator or other parts, which can have more dire consequences. When a battery's internal pressure rises above a predetermined point, safety vents are meant to open, letting gases out and releasing pressure. By doing this, the battery may be kept from exploding or rupturing [39]. Particularly prevalent in lithium-runaway. Thermal runaway-prone devices can be made safer overall by incorporating safety vents and flame retardants in addition to other safety precautions like high-quality materials, appropriate manufacturing procedures, thermal management systems, and separator integrity. Together, these tactics reduce the risks that could arise from producing too much heat and the possibility of cascading consequences that could result in disastrous failures [40].

Working

There are the three fundamental parts of a battery Anode, cathode, and electrolyte. If the electrolyte is insufficient, a separator is frequently utilized to keep the anode and cathode from coming into contact. Batteries typically have some sort of housing to store these parts [41]. The study of the thermal behavior of Li-ion batteries is essential for understanding and ensuring the safe operation of these energy storage devices. Li-ion batteries are widely used in portable electronics, electric vehicles, and renewable energy systems, and their thermal behavior is of paramount importance to prevent overheating, thermal runaway, fires, and explosions [42]; (Table 3, [43-50]).

Table 3: Thermal behavior of Li-ion batteries working.

Name	Definition
Temperature Monitoring and Measurement	Temperature sensors are placed at various locations within the battery to monitor temperature changes during different operational conditions. These sensors can help researchers understand how temperature evolves over time and under different loads, charging rates, and environmental conditions [43].
Thermal Imaging	Thermal cameras can be used to visualize temperature distributions across the battery during operation. This can provide insights into localized temperature variations, hotspot formation, and heat dissipation patterns [44].

Calorimetry	Calorimetry involves measuring the heat generated or absorbed by a system during chemical reactions. Differential scanning calorimetry (DSC) and other calorimetric techniques can provide information about the heat generation and heat absorption associated with various electrochemical processes in the battery [45].
Thermal Modeling	Mathematical models are developed to simulate the thermal behavior of Li-ion batteries. These models take into account factors such as heat generation during charging and discharging, heat transfer mechanisms, heat dissipation, and the influence of battery geometry and materials. Computational simulations help predict how the battery temperature will change under different operating conditions [46].
Cycling and Abuse Tests	Batteries are subjected to controlled experiments that involve charging and discharging cycles, as well as abuse tests to simulate extreme conditions like short circuits, overcharging, and physical damage. These tests help researchers understand how the battery responds to stressful conditions and how thermal runaway might be initiated [47].
Material Characterization	The thermal properties of battery materials, including electrodes, electrolytes, and separators, are studied to determine their influence on heat generation, heat transfer, and overall thermal behavior. This can involve techniques like thermal conductivity measurements, thermal analysis, and more [48].
Safety Mechanisms and Strategies	Researchers investigate the effectiveness of safety mechanisms such as flame retardants, safety vents, thermal management systems, and separator materials to prevent or mitigate the effects of thermal runaway [49].
Environmental Factors	The thermal behavior of Li-ion batteries can be affected by environmental conditions, such as ambient temperature and humidity. Studies might explore how temperature extremes and environmental factors impact battery performance and safety [50].

By combining experimental observations, mathematical modeling, and simulations, researchers can gain a comprehensive understanding of the thermal behavior of Li-ion batteries. This knowledge is crucial for improving battery design, enhancing safety measures, and developing effective thermal management strategies to ensure the reliable and safe operation of these energy storage devices in various applications [51]; (Table 4, [52]); (Table 5, [53]); (Figure 5).

Table 4: Advantages.

Name	Definition
High energy density	Li-ion batteries store a significant amount of energy in a compact size, making them suitable for portable electronics and electric vehicles
Low self-discharge	Li-ion batteries have a relatively low self-discharge rate, meaning they can hold their charge for extended periods when not in use.
Long Cycle Life	With proper care, Li-ion batteries can undergo hundreds to thousands of charge and discharge cycles before significant capacity loss occurs.
Fast charging	Li-ion batteries can be charged relatively quickly, depending on the battery's design and charging technology.
No memory effect	Li-ion batteries do not suffer from the "memory effect," a phenomenon where the battery's capacity decreases if it's not fully discharged before recharging [52].

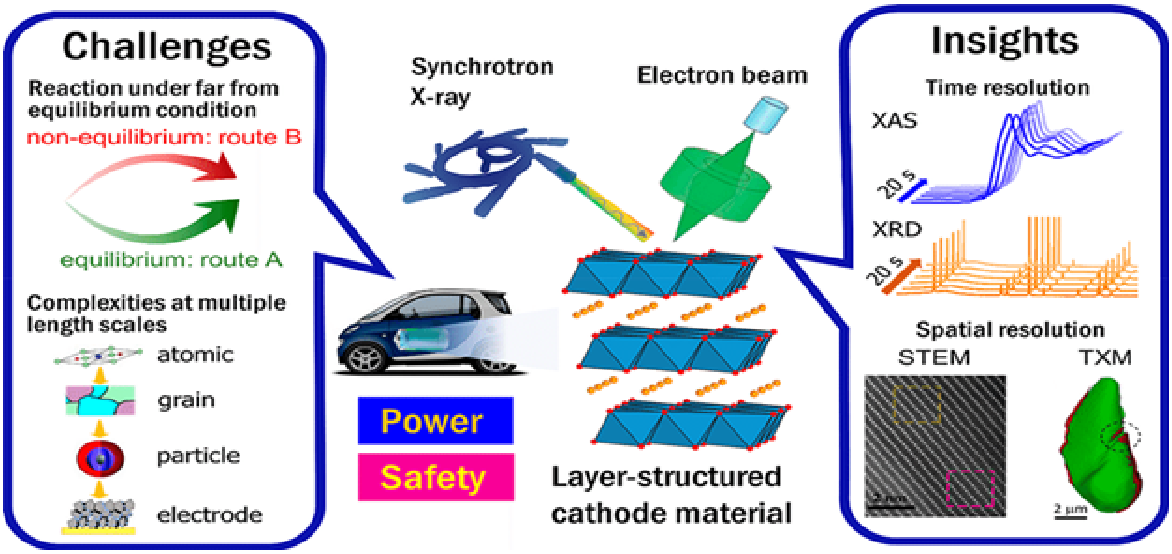

Figure 5: Probing the complexities of structural changes in layered oxide cathode materials for Li-ion batteries during fast charge–discharge cycling and heating.

Table 5: Challenges: While Li-ion batteries offer numerous benefits, they also face certain challenges.

Name	Definition
Safety Concerns	Overcharging, high temperatures, physical damage, or manufacturing defects can lead to thermal runaway, a condition where the battery heats up uncontrollably, potentially causing fires or explosions.
Limited Lifespan	Over time, Li-ion batteries experience capacity degradation due to factors like chemical reactions, cycling, and temperature changes [53].
Resource Constraints	The materials used in Li-ion batteries, such as lithium and cobalt, can be limited resources and subject to price fluctuations.
Environmental Impact	The production, use, and disposal of Li-ion batteries can have environmental implications due to the extraction of raw materials and challenges in recycling.

Li-ion battery technology continues to evolve, driven by research and innovation aimed at improving safety, energy density, lifespan, and sustainability. As technology advances, Li-ion batteries are expected to play a pivotal role in addressing energy storage needs in various sectors, including transportation, electronics, and renewable energy integration [54].

Conclusion

Batteries are essentially a form of storage that consists of an electrolyte and two electrodes, an anode and a cathode. This electrolyte acts as a conduit for the ion exchange that generates electricity. There are Batteries use and Primary and Secondary data base introduction. In this use the Lithium-ion batteries are different components, using Challenges applications and different type Principal of lithium-ion batteries- Battery power, Depth of discharge (DOD), SOC Estimation Methodologies, Health Estimation, Recalibration Capacity, Battery voltage, Cycle of a battery, Charge rate, discharge rate, or C-rate, Electrode materials. In This case study The Thermal runaway is the different components-Including separators, Puncture or Damage, Gas Generation, Heat Insulation, High-Quality Materials, Separator Coatings, Thermal Management, Electrode Materials, Flame Retardants, and Safety Vents, Flame Retardants, Safety Vents. This is the working principal are use-Temperature Monitoring and Measurement, Thermal Imaging, Calorimetry, Thermal Modeling, Cycling and Abuse Tests, Material Characterization, Safety Mechanisms and Strategies, Environmental Factors in using batteries.

References

1. Broussely, Biensan M, Bonhomme P, Blanchard F, Herreyre P, et al. (2005) Main aging mechanisms in Li ion batteries. Journal of Power Sources 146(1-2): 90-96.
2. Miao Y, Hynan P, Von Jouanne A, Yokochi A (2019) Current Li-ion battery technologies in electric vehicles and opportunities for advancements. Energies 12(6): 1074.
3. Velumani D, Bansal A (2022) Thermal behavior of lithium-and sodium-ion batteries: A review on heat generation, battery degradation, thermal runway–perspective and future directions. Energy & Fuels 36(23): 14000-14029.
4. Sudworth JL (2001) The sodium/nickel chloride (ZEBRA) battery. Journal of Power Sources 100(1-2): 149-163.
5. Horiba T (2014) Lithium-ion battery systems. Proceedings of the IEEE 102(6): 939-950.
6. Hannan MA, Hoque MM, Hussain A, Yusof Y, Ker PJ (2018) State-of-the-art and energy management system of lithium-ion batteries in electric vehicle applications. Issues and Recommendations IEEE Access, 6: 19362-19378.
7. Nguyen TH, Fraiwan A, Choi S (2014) Paper based batteries A review. Biosensors and Bioelectronics 54: 640-649.
8. Ju F, Deng W, Li J (2015) Performance evaluation of modularized global equalization system for lithium-ion battery packs. IEEE Transactions on Automation Science and Engineering13(2): 986-996.
9. Wei J, Dong G, Chen Z (2017) Remaining useful life prediction and state of health diagnosis for lithium-ion batteries using particle filter and support vector regression. IEEE Transactions on Industrial Electronics 65(7): 5634-5643.
10. Wei J, Dong G, Chen Z, Kang Y (2017) System state estimation and optimal energy control framework for multicell lithium-ion battery system. Applied Energy 187: 37-49.
11. Ghalkhani M, Habibi S (2022) Review of the Li-Ion battery: Thermal management and AI-based battery management system for EV application. Energies 16(1): 185.
12. Aurbach D, Markovsky B, Levi MD, Levi E, Schechter A, et al. (1999) New insights into the interactions between electrode materials and electrolyte solutions for advanced nonaqueous batteries. Journal of power sources 81: 95-111.
13. Ng KS, Huang YF, Moo CS, Hsieh YC (2009) An enhanced coulomb counting method for estimating state-of-charge and state-of-health of lead-acid batteries. In INTELEC 2009-31st International Telecommunications Energy Conference IEEE 1-5.
14. Nugroho A, Rijanto E, Wijaya FD, Nugroho (2015) Battery state of charge estimation by using a combination of Coulomb Counting and dynamic model with adjusted gain. In 2015 International Conference on Sustainable Energy Engineering and Application (ICSEEA) IEEE, pp: 54-58.
15. Eftekhari A, Li L, Yang Y (2017) Polyaniline supercapacitors. Journal of Power Sources 347: 86-107.
16. Majerová T, Novotný P, Krylova E, Konvalinka J (2019) Exploiting the unique features of Zika and Dengue proteases for inhibitor design. Biochimie 166: 132-141.
17. Castiglione T, Perrone DL, Gamba D, Bova S, Sequino L, et al. (2023) Numerical modelling and experimental validation of the thermal behavior of Li-ion batteries for EVs Applications. SAE Technical Paper 2023: 24-0153.
18. Hasani AH, Mansor M, Kumaran V, Zuhdi AW, Ying YJ, et al. (2021) Thermal behavior of lithium-ion battery in microgrid application: Impact and management system. International Journal of Energy Research 45(4): 4967-5005.
19. Zheng F, Kotobuki M, Song S, Lai MO, Lu L (2018) Review on solid electrolytes for all-solid-state lithium-ion batteries. Journal of Power Sources 389: 198-213.
20. Shu J, Shui M, Huang F, Ren Y, Wang Q, et al. (2010) A new look at lithium cobalt oxide in a broad voltage range for lithium-ion batteries. The Journal of Physical Chemistry C114(7): 3323-3328.

21. Kouchachvili L, Yaïci W, & Entchev E (2018) Hybrid battery/supercapacitor energy storage system for the electric vehicles. Journal of Power Sources 374: 237-248.

22. Zhang D, Wang S, Ma Y, Yang S (2018) Two-dimensional nanosheets as building blocks to construct three-dimensional structures for lithium storage. Journal of energy chemistry 27(1): 128-145.

23. Chandra P, Noh HB, Won MS, Shim YB (2011) Detection of daunomycin using phosphatidylserine and aptamer co-immobilized on Au nanoparticles deposited conducting polymer. Biosensors and Bioelectronics 26(11): 4442-4449.

24. Eshetu GG, Grugeon S, Laruelle S, Boyanov S, Lecocq A, et al. (2013) In-depth safety-focused analysis of solvents used in electrolytes for large scale lithium-ion batteries. Physical Chemistry Chemical Physics 15(23): 9145-9155.

25. Zou L, Li J, Liu Z, Wang G, Manthiram A, et al. (2019) Lattice doping regulated interfacial reactions in cathode for enhanced cycling stability. Nature Communications 10(1): 3447.

26. Rahardian S, Budiman BA, Sambegoro PL, Nurprasetio IP (2019) Review of solid-state battery technology progress. In 2019 6th International Conference on Electric Vehicular Technology (ICEVT). IEEE pp: 310-315.

27. Peng P, Wang Y, Jiang F (2022) Numerical study of PCM thermal behavior of a novel PCM-heat pipe combined system for Li-ion battery thermal management. Applied Thermal Engineering 209: 118293.

28. Levartovsky Y, Chakraborty A, Kunnikuruvan S, Maiti S, Grinblat J, et al. (2021) Enhancement of structural, electrochemical and thermal properties of high-energy density Ni-rich $LiNi_{0.85}Co_{0.1}Mn_{0.05}O_2$ cathode materials for li-ion batteries by niobium doping. ACS Applied Materials & Interfaces 13(29): 34145-34156.

29. Velumani D, Bansal A (2022) Thermal behavior of lithium-and sodium-ion batteries: A review on heat generation, battery degradation, thermal runway perspective and future directions. Energy & Fuels 36(23): 14000-14029.

30. Li W, Peng J, Xiao W, Wang H, Zeng J, et al. (2017) The temperature distribution and electrical performance of fluid heat exchanger-based thermoelectric generator. Applied Thermal Engineering 118: 742-747.

31. Levartovsky Y, Chakraborty A, Kunnikuruvan S, Maiti S, Grinblat J, et al. (2021) Enhancement of structural, electrochemical and thermal properties of high-energy density Ni-rich $LiNi_{0.85}Co_{0.1}Mn_{0.05}O_2$ cathode materials for li-ion batteries by niobium doping. ACS Applied Materials & Interfaces 13(29): 34145-34156.

32. Weng J, Ouyang D, Yang X, Chen M, Zhang G, et al. (2021) Experimental study on thermal behavior of PCM-module coupled with various cooling strategies under different temperatures and protocols. Applied Thermal Engineering 197: 117376.

33. Alrashdan A, Mayyas AT, Al-Hallaj S (2010) Thermo-mechanical behaviors of the expanded graphite-phase change material matrix used for thermal management of Li-ion battery packs. Journal of Materials Processing Technology 210(1): 174-179.

34. Buidin TIC, Mariasiu F (2022) Parametric evaluation of thermal behavior for different Li-Ion battery chemistries. Batteries 8(12): 291.

35. Tan K, Li W, Lin Z, Han X, Dai X, et al. (2023) Operando monitoring of internal gas pressure in commercial lithium-ion batteries via a MEMS-assisted fiber-optic interferometer. Journal of Power Sources 580: 233471.

36. Hu W, Peng Y, Wei Y, Yang Y (2023) Application of electrochemical impedance spectroscopy to degradation and aging research of lithium-ion batteries. The Journal of Physical Chemistry C 127(9): 4465-4495.

37. Tan K, Li W, Lin Z, Han X, Dai X, et al. (2023) Operando monitoring of internal gas pressure in commercial lithium-ion batteries via a MEMS-assisted fiber-optic interferometer. Journal of Power Sources 580: 233471.

38. Madani SS, Ziebert C (2022) A model-based approach for temperature estimation of a lithium-ion battery pack in 2022 Asia Power and Electrical Technology Conference (APET). IEEE, pp: 357-360.

39. Shi H, Cheng M, Feng Y, Qiu C, Song C, et al. (2023) Thermal management techniques for lithium-ion batteries based on phase change materials: a systematic review and prospective recommendations. Energies 16(2): 876.

40. Legala A, Li X (2022) Hybrid data-based modeling for the prediction and diagnostics of Li-ion battery thermal behaviors. Energy and AI 10: 100194.

41. Wu Y, Wang S, Li H, Chen L, Wu F (2021) Progress in thermal stability of all-solid-state-Li-ion-batteries. Info Mat 3(8): 827-853.

42. Obrovac MN, Krause LJ (2006) Reversible cycling of crystalline silicon powder. Journal of The Electrochemical Society 154(2): A103.

43. Kirkels AF, Bleker J, Romijn HA (2022) Ready for the road? A socio-technical investigation of fire safety improvement options for lithium-ion traction batteries. Energies 15(9): 3323.

44. Shi H, Cheng M, Feng Y, Qiu C, Song C, et al. (2023) Thermal management techniques for lithium-ion batteries based on phase change materials: a systematic review and prospective recommendations. Energies 16(2): 876.

45. Maher S, Casettari L, Illum L (2019) Transmucosal absorption enhancers in the drug delivery field. Pharmaceutics 11(7): 339.

46. Zhao J, Zhao L, Dimov N, Okada S, Nishida T (2013) Electrochemical and thermal properties of α-$NaFeO_2$ cathode for Na-ion batteries. Journal of The Electrochemical Society 160(5): A3077.

47. Chen M, Yue Z, Wu Y, Wang Y, Li Y, et al. (2023) Thermal stable polymer-based solid electrolytes: Design strategies and corresponding stable mechanisms for solid-state Li metal batteries. Sustainable Materials and Technologies 36: 587.

48. Samimi F, Babapoor A, Azizi M, Karimi G (2016) Thermal management analysis of a Li-ion battery cell using phase change material loaded with carbon fibers. Energy 96: 355-371.

49. Lai SC (1976) Solid lithium-silicon electrode. Journal of The Electrochemical Society 123: 1196.

50. Cheng XB, Zhang Q (2015) Dendrite-free lithium metal anodes: stable solid electrolyte interphases for high-efficiency batteries. Journal of Materials Chemistry A 3(14): 7207-7209.

51. Xu W, Wang J, Ding F, Chen X, Nasybulin E, et al. (2014) Lithium metal anodes for rechargeable batteries. Energy & Environmental Science 7(2): 513-537.

52. Cheng XB, Zhang R, Zhao CZ, Zhang Q (2017) Toward safe lithium metal anode in rechargeable batteries: a review. Chemical Reviews 117(15): 10403-10473.

53. Kolodziejczyk F, Mortazavi B, Rabczuk T, Zhuang X (2021) Machine learning assisted multiscale modeling of composite phase change materials for Li-ion batteries thermal management. International Journal of Heat and Mass Transfer 172: 121199.

54. Buidin TIC, Mariasiu F (2022) Parametric evaluation of thermal behavior for different Li-Ion battery chemistries. Batteries 8(12): 291.