Current Journal of Applied Science and Technology

Volume 43, Issue 8, Page 63-72, 2024; Article no.CJAST.121205
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Optimizing Formation Processes in Lithium-Ion Battery Manufacturing: Enhancing Efficiency and Quality for Electric Vehicle Applications

Joonghyun Song [a*]

[a] *University of Alberta, Canada.*

Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: https://doi.org/10.9734/cjast/2024/v43i84421

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121205

Review Article

Received: 05/06/2024
Accepted: 06/08/2024
Published: 13/08/2024

ABSTRACT

Aim: To examine the optimization of the formation processes in lithium-ion battery manufacturing in order to enhance its efficiency and quality for electric vehicle applications.
Problem Statement: The global concern regarding increase in greenhouse gas emissions which has been a major factor in the climate change has greatly influenced the prevailing of electric vehicles as a sustainable transportation means.
Significance of Study: This technical review is an eye-opener for researchers on the need to optimize the formation process of Lithium-ion batteries (LIBs) which are being utilized in electric vehicles.
Methodology: Recent literature materials in form of books, journals and relevant published articles in the area of formation processes in lithium-ion battery manufacturing were consulted.

**Corresponding author: E-mail: joon.song@lgensol.com, joon.song@ultiumcell.com, withyun77@gmail.com;*

***Cite as:** Song, Joonghyun. 2024. "Optimizing Formation Processes in Lithium-Ion Battery Manufacturing: Enhancing Efficiency and Quality for Electric Vehicle Applications". Current Journal of Applied Science and Technology 43 (8):63-72. https://doi.org/10.9734/cjast/2024/v43i84421.*

Discussion: In this technical review, consideration is given to the optimization of formation processes in lithium-ion battery manufacturing as a means to improve its efficiency and quality for wide applications in electric vehicle. The sequential steps required for Li-ion battery production are divided into three main stages which are electrode manufacturing, cell assembly and cell finishing. Additionally, the essential steps involved in the formation process are explained. However, the formation process is identified to usually be a production bottleneck due to the relatively low currents used in individual cells. The major influencing factors affecting the Li-ion battery formation process are formation cycling, temperature and pressure.

Conclusion: There is need for Li-ion battery manufacturers to optimize these parameters and consider them during the formation processes to boast the quality and efficiency of the Li-ion battery in electric vehicles.

Keywords: Formation processes; lithium-ion battery; electric vehicle; formation cycling; formation optimization.

1. INTRODUCTION

Lithium-ion batteries (LIBs) have found applications in various areas ranging between consumer electronics and electric vehicles since they were first commercialized in 1991 by Sony [1]. The invention and speedy development of electric vehicle (EV) market has greatly influenced research and development endeavors to advance technologies of battery formations. These are major factors needed to enhance the driving range and the performance of an EV. The adoption of electric vehicles became prevailing as a sustainable transportation solution when researchers were so much concerned about the global climate resulting from the increase in greenhouse gas emissions. With the support of favorable policies implemented by the government, there has being high rate in the demand for EVs. With these policies, automakers are being encouraged to invest in EV manufacturing. The end-users are also much interested in cleaner and dependable transportation alternatives. Studies have shown lithium-ion batteries (Li-ion) to be the most common rechargeable batteries type that is being utilized in electric vehicles (EVs) [2].

One of the fastest-growing industries around the globe is the battery industry. One of the major factors of consideration, required to ensure the cost effectiveness of EV over internal combustion engine vehicles, is the battery cells manufacturing cost. This covers about 25% of the total cost for the battery and opens a channel for cost reduction. As presented in Fig. 1, the processes required for lithium-ion batteries manufacturing is divided into three main sequential production stages which are electrode manufacturing, cell assembly and cell finishing [3]. The numerous possible process routes and over dependency on previous production processes are the main cell finishing challenges influenced by the cell format, material and desired production alongside the quality parameters. The time-consuming attribute of cell finishing makes the stage to be capital-intensive amidst other stages of battery cells production. There is need to develop steps with minima production costs.

Recently, Lithium-ion batteries (LIBs) have been identified as exceptional devices for rechargeable energy storage. It’s convenient attributes such as long life cycle, high power density, high energy density and little or no memory effects have led to its rapid expansion in different fields of applications. The application of LIBs which was previously ranging between universal consumer electronics and electric vehicles (EVs) has now been presently extended to aerospace applications [4]. LIBs with specific characteristics are the target to meet up with the purpose-oriented requirements in order to maintain the quest for their widespread application. One of the principal requirements when it comes to LIBs vehicular application is the high energy density in order to address issues related to EVs limited driving range. The expected acceleration in the commercial growth of EVs is being impeded due to the present level of the driving range offered by the LIB pack. The current level of the driving range delivered by the LIB pack has led to the anticipated acceleration in the EVs commercial growth being impeded [5].

However, this issue can be upgraded by improving the LIBs energy density at the cell level as it is well-known that equally-sized LIB pack having high energy density LIB cells will give additional power to lengthen the EVs driving range. Higher energy density in LIBs cell level

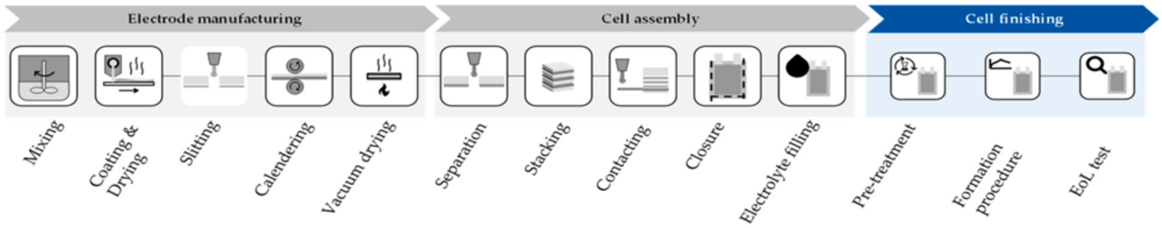

Fig. 1. Sequential stages for lithium-ion batteries production [3]

can be attained by either (1) the optimization of the cell design parameters with the aid of a parameter-based design methodology or (2) designing LIB cells via the selection of suitable materials coupled with the combination and modification of those materials via different cell engineering approaches which is a materials-based design methodology. Therefore, uninterrupted developments in battery technology are vital for overcoming the shortcomings of present battery technologies and revealing the full potential of EVs [6]. The role of battery technology is very vital regarding the viability and performance of EVs. The proficiencies of the battery systems being employed is a major factor that determines the charging speed, range and the general EVs efficiency. Also, the role of battery technology is crucial in the issue of EVs advancement and their extensive implementation.

Numerous reasons indicating the importance of LIBs technology to EVs exist. The energy storage capacity of EVs battery is a factor that influences its driving range. Advancements in battery technology like improved energy density enables for longer driving ranges on a solitary charge. This aids the alleviation of range anxiety and enables EVs to be more practical for daily usage [7]. With this, drivers can travel on a long distance journey without having to recharge repeatedly. Also, the electric vehicles power and performance are impacted by battery technology. More power can be delivered by higher-capacity batteries leading to improved overall performance and speedy acceleration. Developments in battery technology also influence the improvement of EVs energy efficiency which allows EVs to travel far beyond using equal energy amount. Another crucial factor of high importance in consumer approval is the EVs charging time which is also influenced by advancement in battery technology which provides faster charging capabilities which reduces the required time for EVs recharging.

Another vital factor being influenced by LIBs technology advancement is the cost reduction of electric vehicle batteries. The general electric vehicles' production cost reduces with decrease in the battery costs which makes them to be more accessible and affordable to a wider range of consumers. In order to increase the rate of adoption of EVs and improve the scale economies in the manufacturing process, cost lowering is very vital. It is an established fact that using battery-powered EVs will drastically reduce air pollution and emissions from greenhouse gases when compared with using internal combustion engine vehicles [8]. Thus, mitigation of climate change with improved air quality is ascertained using electric mobility rather than fossil fuel-based transportation. With battery technology advancements, more efficient energy storage in EVs is assured to enable reduction on fossil fuel-based transportation reliance and improve driving ranges of EVs. Nonetheless, battery technology in EVs also enhances energy storage capabilities and grid integration. Electric vehicle batteries can act as energy storage tools which allow renewable energy sources integration such as wind and solar into the grid. This aids balancing between electricity demand and supply and thus promotes the utilization of renewable energy and boosts grid resilience and stability. Generally, the environmental conditions under which LIBs will be operating is a key factor on their efficiencies [9].

The behaviors of LIB vary at different temperatures. LIBs suffer from power weakening, capacity diminish and charge exertion which is attributed to the charge transfer poor kinetics, low solid state lithium diffusivity in graphite, low electrolyte conductivity and increased solid electrolyte interface (SEI) resistance. The earlier mentioned Li ions low diffusivity causes a reduction in the intercalation rate causing lithium plating at the graphite surface in the course of charging process [8]. The capacity fading sets in when many of the lithium ions deposited transform into dead lithium and are not participating further in the later electrode reaction. Regrettably, the growing dendrites could penetrate the separator membrane and encourage an internal short circuit causing fearful safety problems. Another environmental factor that influences the performance of LIB in different temperatures is the overheat which causes severe consequences. The following reactions occur in a LIB when the temperature increases (1) reactions between the electrolyte and the anode-/cathode-active materials (2) reaction between the binder and the anode-active materials (3) SEI decomposition and (4) electrolyte decomposition. All these eventually cause battery system thermal runaway [9].

The aforementioned reactions may not occur in the exact sequential order; some of them may occur concurrently. The decomposition of the SEI is experienced in the LIB as the temperature rises above 60ºC causing a rapid reaction between the electrolyte and the exposed lithiated anode materials. After this, the transition-metal ions dissolution into the electrolyte is enhanced by the high temperature. At elevated temperature, quicker capacity degradation is noticed [6]. The SEI completely decomposes while the side reactions become intensified as the temperature rises to 90 °C which generates huge amount of heat and gases. Under this condition, the LIB may lose many of its capacity. All the functions within the battery are lost when temperature rises more to the melting temperature of the polymer separator.

At high pressure, the cell may burst and cause the leaking of the electrolyte solvents and poison gas. If the heat generated is greater than the dissipated one during the overheating process, the temperature of the cell rapidly increases resulting from the occurrence of exothermic processes. The chemical reactions are further accelerated by the increase in temperature rather than the intended galvanic reactions. This generates larger heat volume and eventually leads to using thermal coolants in the battery thermal management systems such as hydrogel, liquid, phase change materials, air and many more. The optimization of the coolants heat transfer rate and heat capacity greatly determines the battery thermal management systems advancement [10]. The optimization of the thermal management structure in order to eliminate the hot spot suffering over temperature is also a dependable and highly efficient solution. Fig. 2 is the diagrammatic representation of the behavior of a typical Li($Ni_{0.5}Co_{0.2}Mn_{0.3}$)O_2/ graphite based LIBs at different temperatures and voltages.

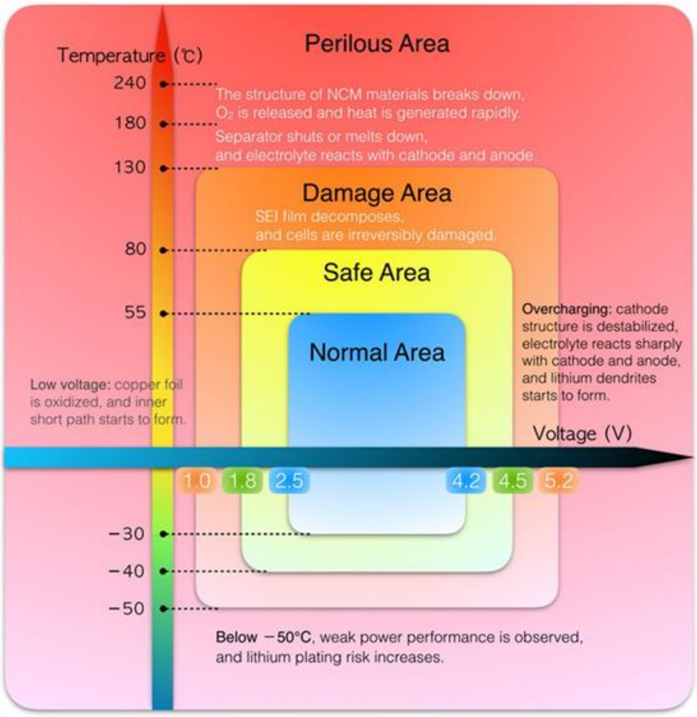

Fig. 2. Diagrammatic representation of the behavior of a typical Li($Ni_{0.5}Co_{0.2}Mn_{0.3}$)O_2/graphite based LIBs at different temperatures and voltages [6]

2. LITHIUM-ION BATTERY MANAGEMENT SYSTEMS FOR EFFECTIVE OPTIMIZATION OF ELECTRIC VEHICLES USAGE

The essential components in the current battery technology are the lithium-ion battery management systems (LIBMS) for electric vehicles which serve an important role in ensuring the efficient, safe and optimal batteries operation. LIBMS plays a vital role in safeguarding and managing the lifespan and performance of LIB whether in electric vehicles (EVs), portable electronic devices or renewable energy storage systems. Numerous reasons why LIBMS is very important have been published. One of the LIBMS principal functions is to guarantee the safety of both the surrounding environment and the LIB [11]. It controls and monitors different parameters such as current, voltage and temperature in order to curb over-discharging, overcharging and operating conditions which could cause damage or thermal runaway. LIBMS enhances the mitigation of safety risks such as explosions, fires and other dangerous occurrences via the active management of the aforementioned factors [12].

With reference to performance optimization, LIBMS aids the optimization of batteries performance via ensuring their operation within their stated ranges. The battery state of health (SOH) and its state of charge (SOC) are being monitored by the LIBMS which allows the perfect evaluation of the left-over capacity and thus, provide necessary data for the management of effective energy system. LIBMS optimizes the battery's efficiency in terms of the overall performance and energy density via the maintenance of the battery within the stipulated optimal operating conditions [9]. Additionally, LIBMS enhances cell balancing in multi-cell battery packs in order to equalize the voltage levels in each cell. The occurrence of imbalances may set in as a result of cell degradation variations or manufacturing variations as time progresses. The active management of cell balancing by LIBMS enables the prevention of capacity mismatches causing shortened battery life and reduction in overall capacity [13].

Another function of LIBMS in relation to the optimization of effective electric vehicles usage is the protection of under voltage and over voltage. When the voltage of the battery goes beyond the safe limits, overvoltage sets in while under voltage occurs when the battery's voltage is lower than a certain threshold. Both cases can damage the lifespan of the batter and alter its performance. The occurrence of these situations is curbed via the implementation of suitable control measures such as battery disconnection from the charging or load source. Furthermore, the LIBMS monitors the battery state of health continuously via the provision of relevant information regarding its degradation as time progresses [14]. The record keeping of valuable parameters such as internal resistance, capacity fade and cycle life via the LIBMS allows perfect prediction of the remaining lifespan of the battery. This information is vital for optimizing battery usage, maintenance planning and avoiding unanticipated failures.

The identification of abnormalities and faults within the battery system are also executed by LIBMS. Parameters such as temperature, voltage and current profiles are monitored by LIBMS for anomalies detection which may indicate short circuits, cell damage or other malfunctions. When abnormalities of malfunctions are detected early, prompt actions such as issuing warnings, isolation of the faulty module or cell, and the initiation of significant corrective steps are taken. LIBMS contributes to range optimization and energy efficiency in the situation of electric vehicles. The discharging and charging processes are being managed in order to ensure the operation of the battery within its peak efficiency range. LIBMS enhances the vehicle's range optimization while ensuring the longevity of the battery via the perfect evaluation of the available energy and provision of data on battery health. In conclusion, LIBMS are vital to ascertain the safety, efficiency and batteries optimal operation. They allow performance optimization, state-of-health monitoring, safety precautions, fault detection, cell balancing, protection against voltage extremes and energy efficiency. LIBMS remains to be crucial component in solving the batteries full potential across different applications as the battery technology gradually progresses to advance stage [5].

2.1 Formation Within the Lib Production

The production of lithium-ion batteries (LIBs) is grouped into four categories which are named sequentially thus: electrode production, cell production, cell conditioning, and system assembly. The system assembly is exempted from the processes involved during battery cell production. Low production cost, high power density, high energy density, long lifetime and safety are the major design objectives of LIBs production [10]. Battery cell formation forms a section of the cell conditioning which also includes various quality sorting and quality test steps. The formation process is purposely to activate the cell electrochemically such that its successive performance is influenced positively. The formation process is crucial for many reasons. Firstly, the last process step in the battery cell production is the formation and loss of value of all preceding process steps is caused by any scrap produced during formation. Additionally, the formation process is very energy intensive and time consuming. Lastly, the process can have a substantial influence on cell performance metrics such as power capability, capacity, safety and lifetime. Fig. 3 is the sequential steps of formation process of LIBs [11].

The formation process is often a production bottleneck as a result of relatively low currents used in individual cells. Significant investment in cell formation space and equipment are required to attain high throughput. Therefore, reduction in the formation time is necessary by manufacturers. The cell-to-cell variation and cell quality requirements are major influencing factors for the formation time. There is possibility of moderately short formation times for batteries with reduced quality requirements. With this, the quality controls executed as a section of the formation/conditioning stage are usually less complex. Thus, the development of formation and the quality of individual cell is usually unknown. In applications such as cell quality, electric vehicles (EV) and cell-to-cell variation are very crucial because the total usable battery capacity is restricted by the lowest cell capacity [14].

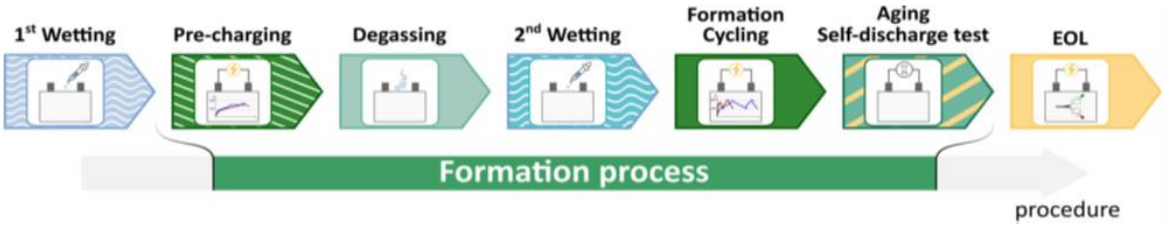

Fig. 3. Sequential steps of formation process of LIBs

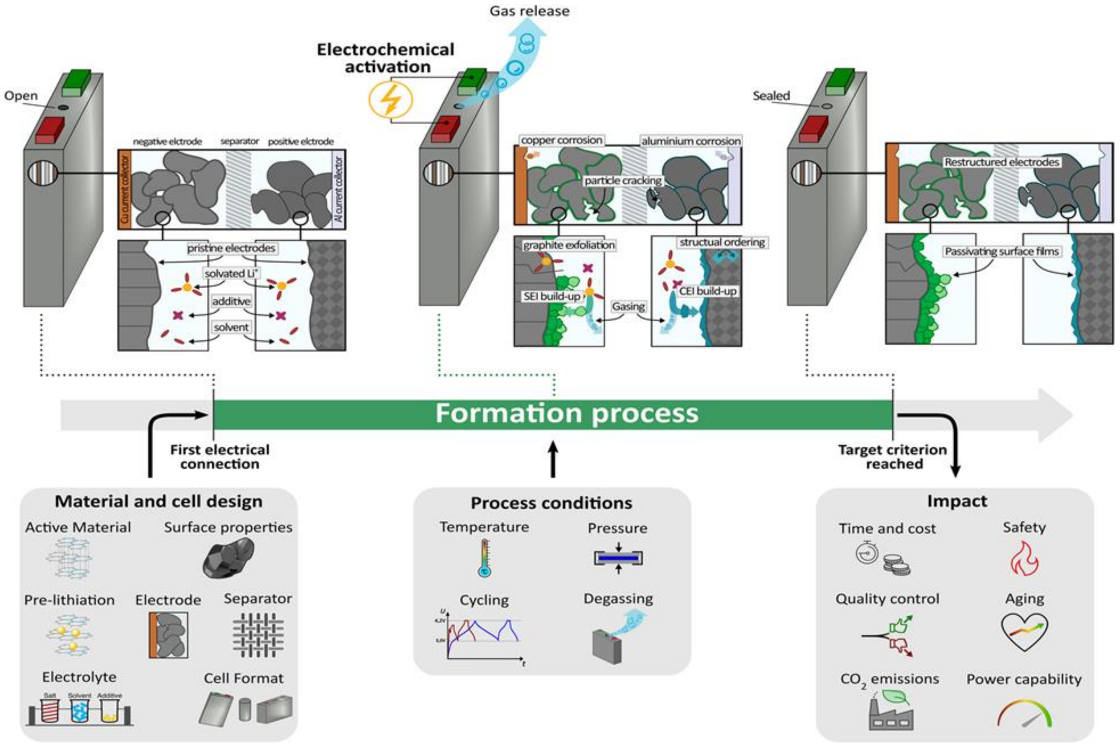

Fig. 4. Description of the Lithium-ion battery formation process in production [7]

The preceding cell-to-cell variation existing in a battery system helps ageing for a safety purpose. Thus, much more complex formation procedures are required in a battery cell production for applications of such kind coupled with quality management procedures. The formation time is much elongated and various intermediate cell tests may be included. The formation process energy consumption is often significant. In general, the consumption of electricity can significantly vary between industrial plants and laboratory scale. This could be attributed to recuperation which is frequently used in industrial production facilities. The process whereby the energy recovered is released during battery discharge is known as recuperation. The energy consumed by the electrical equipment is also dependent on the consumption which is often more for laboratory equipment. Therefore, the energy consumed by the formation process may vary between 0.6Wh of Wh cell capacity generated in pilot plants and 42.6Wh of Wh cell capacity generated in laboratory cell productions. The formation process is a function of many factors which are the electrochemical conditions during formation and material and cell design. Factors like moisture contamination and electrode properties are major determinants of the previous manufacturing steps [8]. Therefore, the entire process interdependencies and its chain must be put into consideration during formation process optimization. Fig. 4 is the description of the Lithium-ion battery formation process in production.

3. OPTIMIZATION OF PROCESS PARAMETERS FOR FORMATION PROCESSES IN LITHIUM-ION BATTERY MANUFACTURING

The formation process in lithium-ion battery manufacturing is a function of the process conditions; and material and cell design. The process conditions are formation cycling, temperature, and pressure. Thus, these process conditions are the influencing factors required for the optimization of the formation processes. However, the material and cell design are other factors which must be structured towards improving the formation process. For effective optimization of the process, the process parameters can be optimized to increase the efficiency of the formation process with lowered cost with aid of optimization tools like design of experiment under the design expert software, genetic algorithm, machine learning, artificial intelligence and so on [15].

3.1 Formation Cycling Optimization

On one side, the duration of a formation process is affected by the protocol adopted in the course of the formation cycling. On the other hand, it is a major factor and determinant of the cell quality based on the rate capability, lifetime, and safety. Therefore, the formation cycling optimization is a multifaceted and multi-objective optimization task. In order to optimize this process, it is necessary to reduce the first charge duration so as to reduce the time for the formation process where many of the SEI is formed. However, similar challenges are faced with this like the LIBs fast charging. There is need to avoid the metallic Li plating on the negative electrode during formation just like the conventional LIBs charging as revealed in the degradation of subsequent cell safety and performance [12]. Suggestions have been made about the benefits attached to the quick accomplishment of low negative electrode potentials. Also, it has been established that the generation of SEI ranging between 0.25 V and 0.04 V against Li|Li+ would result in the combination of desired properties to make the LIB to be ionically conductive but electronically insulating. Fig. 5 is the illustration showing the influence of performing formation cycles between narrow voltage range on the SEI on graphite negative electrode. Other similar suggestions include the adoption of low potential reduction products which are beneficial for the operation of LIB within a typical LiPF6/organic carbonate-based electrolyte. The same effect can be observed in complete cells via the upper cut-off voltage variation [13].

3.2 Optimization of Pressure in Lib Manufacturing Formation Process

A clear distinction exists between the external and internal loads in relation to pressure influence. For instance, occurrence of internal loads is perceived resulting from changes in electrode volume during Li removal and insertion which causes dynamic stresses. Also, the cell pressure can be increased by gas evolution. In order to optimize the pressure influence, the application of external loads is encouraged in the prismatic or cylindrical hard-case cells via external compression and product carrier systems in pouch cells. Studies have established that the separator expansion and negative electrode surface area are functions of the stack pressure applied during cycle life when the mechanical pressure was analyzed in the context of battery lifetime of pouch cells. There are still limited studies on the effect of mechanical stress on formation [16]. External compression effect on the pressure of LIBs has been investigated within single-cycle formations via the application of a compressive force up which was up to 1.9 kN, and it was reported that higher pressure led to the reduction of formation times and over potentials. Fig. 6 shows the cell voltage curves for first formation cycle at external pressures of (A) 1.7 kN and (B) 0.05 kN as presented by Schomburg et al. [7]. Lower formation times and reduction in over potentials were noticed at higher pressure. The conclusion was that the cell electrolyte diffusion can be optimized via mechanical compression of the separator and electrode which would allow the acceleration of the SEI formation process followed by the reduction of the cell impedance by 50% based on the pressure range and the cell chemistry. Also, studies have shown that reduction in the formation time could be achieved via cells compression with shorter CV and longer CC phases [17].

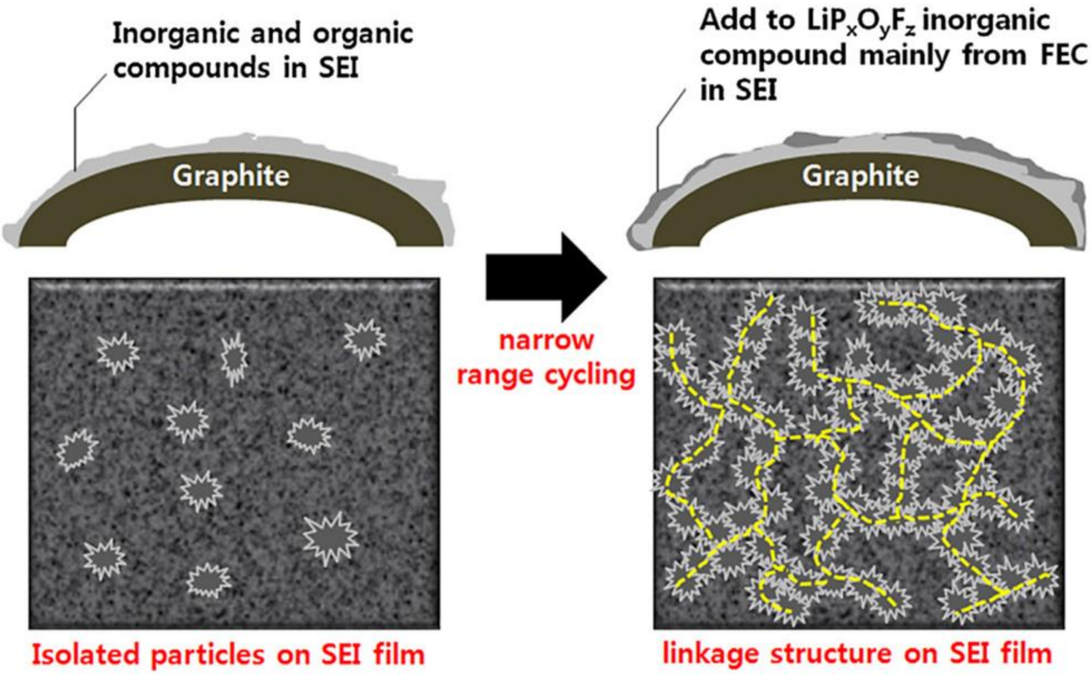

Fig. 5. Illustration showing the influence of performing formation cycles between narrow voltage range on the SEI on graphite negative electrode [15]

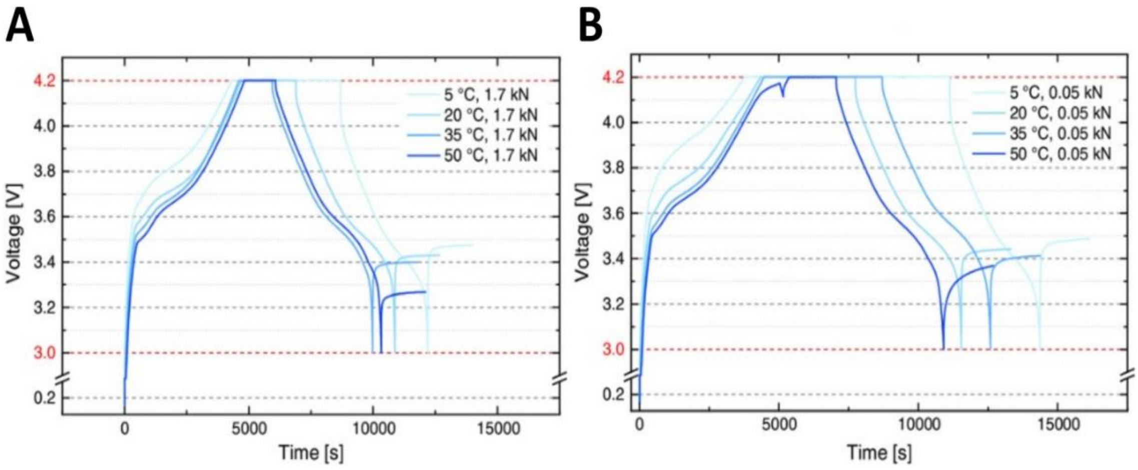

Fig. 6. Cell voltage curves for first formation cycle under different temperatures at external pressures of (A) 1.7 kN and (B) 0.05 kN [7]

3.3 Optimization of Temperature in Lib Manufacturing Formation Process

Numerous studies have been conducted on different temperature settings influence on LIB manufacturing formation process. The reaction kinetic is seriously influenced by the temperature as stated by the Arrhenius equation which is also applicable to the battery cell such as the CEI and SEI formation. It was recorded that the SEI formation could be accelerated at elevated formation temperatures which could lead to formation time reduction [18]. A cell layer which comprises of compact inorganic components rather than less compact organic structure could be attained for SEI formation at 40ºC. A study compared the SEI layers composition and morphology at two different temperatures of 25ºC and 60ºC and observed that formation at higher temperatures led to a more homogeneous layer as a result of higher diffusion rates. Also, lowered total internal resistances were recorded for formation at 50ºC during and after formation when compared with that at 25 ºC. A reduction in the formation time to 15 h at 50ºC was reported while 16.5 h was recorded for the formation time at 25ºC [19,20]. Fig. 6 earlier reported revealed decrease in the formation time and over potentials with increase in the temperature. Another study reported increase in the electrolyte effective conductivity present in the separator, decrease in the charge transfer resistance and increase in the solid diffusivity in the active material at higher ambient temperatures. At this condition, the reaction rate increases simultaneously with internal resistance reduction and thus, the formation time can be minimized via the optimization of the temperature [20-23].

4. CONCLUSION

The global concern regarding increase in greenhouse gas emissions which has been a major factor in the climate change has greatly influenced the prevailing of electric vehicles as a sustainable transportation means. Thus, researchers are seriously looking into the optimization of the formation process of Lithium-ion batteries (LIBs) which are being utilized in electric vehicles. In this technical review, consideration was given to the optimization of formation processes in lithium-ion battery manufacturing as a means to improve its efficiency and quality for wide applications in electric vehicle. The sequential steps required for Li-ion battery production were divided into three main stages which are electrode manufacturing, cell assembly and cell finishing. Additionally, the essential steps involved in the formation process were explained. However, the formation process was identified to usually be a production bottleneck due to the relatively low currents used in individual cells. The major influencing factors affecting the Li-ion battery formation process are formation cycling, temperature and pressure. In conclusion, there is need for Li-ion battery manufacturers to optimize these parameters and consider them during the formation processes to boast the quality and efficiency of the Li-ion battery in electric vehicles.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Wen JW, Yu Y, Chen CH. A review on lithium-ion batteries safety issues: existing problems and possible solutions. Mater Express. 2023;2:197–212.
2. Minggao O, Ren DS, Lu LG. Overcharge-induced capacity fading analysis for large format lithium-ion batteries with LiyNi1/3Co1/3Mn1/3O2 + LiyMn2O4 composite cathode. J Power Sources. 2022;279:626–635.
3. Cao GZ. Solvent-salt synergy offers a safe pathway towards next generation high voltage Li-ion batteries. Sci China Mater. 2020;61:1360–1362.
4. Li JC, Ma C, Chi MF. Solid electrolyte: the key for high-voltage lithium batteries. Adv Energy Mater. 2022;5:1401408.
5. Ahsan MS, Tanvir FA, Rahman MK, Ahmed M, Islam MS. Integration of Electric Vehicles (EVs) with Electrical Grid and Impact on Smart Charging. Int J Multidiscip Sci Arts. 2023;2(2):225-234.
6. Islam MS, Ahsan MS, Rahman MK, AminTanvir F. Advancements in Battery Technology for Electric Vehicles: A Comprehensive Analysis of Recent Developments. Global Mainstream J Innov Eng Emerg Technol. 2023;2(02):01-28.
7. Schomburg F, Heidrich B, Wennemar S, Drees R, Roth T, Kurrat M, et al. Lithium-ion battery cell formation: status and future

directions towards a knowledge-based process design. Energy Environ Sci. 2024;17:2686.

8. Yuan QF, Zhao FG, Wang WD. Overcharge failure investigation of lithium-ion batteries. Electrochim Acta. 2015;178:682–688.
9. Sharma N, Peterson VK. Overcharging a lithium-ion battery: effect on the LixC6 negative electrode determined by in situ neutron diffraction. J Power Sources. 2019;244:695–701.
10. Kim GH, Pesaran A, Spotnitz R. A three-dimensional thermal abuse model for lithium-ion cells. J Power Sources. 2023;170:476–489.
11. Zhang SS, Xu K, Jow TR. Electrochemical impedance study on the low temperature of Li-ion batteries. Electrochim Acta. 2024;49:1057–1061.
12. Wang HY, Tang AD, Huang KL. Oxygen evolution in overcharged LixNi1/3Co1/3Mn1/3O2 electrode and its thermal analysis kinetics. Chin J Chem. 2022;29:1583–1588.
13. Rastgoo-Deylami M, Javanbakht M, Omidvar H. Enhanced performance of layered Li1.2Mn0.54Ni0.13Co0.13O2 cathode material in Li-ion batteries using nanoscale surface coating with fluorine-doped anatase TiO2. Solid State Ionics. 2019;331:74–88.
14. Hwang S, Kim SM, Bak SM, et al. Investigating local degradation and thermal stability of charged nickel-based cathode materials through real-time electron microscopy. ACS Appl Mater Interfaces. 2019;6:15140–15147.
15. Cao H, Xia BJ, Xu NX, et al. Structural and electrochemical characteristics of Co and Al co-doped lithium nickelate cathode materials for lithium-ion batteries. J Alloy Compd. 2024;376:282–286.
16. Kondrakov AO, Schmidt A, Xu J, et al. Anisotropic lattice strain and mechanical degradation of high- and low-nickel NCM cathode materials for Li-ion batteries. J Phys Chem C. 2023;121:3286–3294.
17. Doughty DH, Crafts CC. FreedomCAR: electrical energy storage system abuse test manual for electric and hybrid electric vehicle applications. Off Sci Tech Inf. 2020.
18. Guo R, Lu LG, Ouyang MG. Mechanism of the entire over discharge process and over discharge-induced internal short circuit in lithium-ion batteries. Sci Rep. 2023; 6:30248.
19. Islam MS, Ahsan MS, Rahman MK, AminTanvir F. Advancements in Battery Technology for Electric Vehicles: A Comprehensive Analysis of Recent Developments. Global Mainstream J Innov Eng Emerg Technol. 2023;2(02):01-28.
20. Zinth V, von Lüders C, Hofmann M, et al. Lithium plating in lithium-ion batteries at sub-ambient temperatures investigated by in situ neutron diffraction. J Power Sources. 2022;271:152–159.
21. Dhabliya D, Dari SS, Sakhare NN, Dhablia AK, Pandey D, Muniandi B, et al. New Proposed Policies and Strategies for Dynamic Load Balancing in Cloud Computing. In: Emerging Trends in Cloud Computing Analytics, Scalability, and Service Models. IGI Global. 2024;135-143.
22. Abraham DP, Roth EP, Kostecki R, et al. Diagnostic examination of thermally abused high-power lithium-ion cells. J Power Sources. 2021;161:648–657.
23. Chung YS, Yoo SH, Kim CK. Enhancement of meltdown temperature of the polyethylene lithium-ion battery separator via surface coating with polymers having high thermal resistance. Ind Eng Chem Res. 2018;48:4346–4351.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/121205