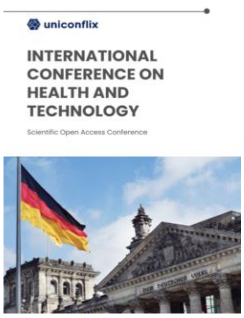

CHEMICAL PROCESSES IN LITHIUM-ION BATTERIES AND METHODS TO IMPROVE THEIR EFFICIENCY

Dilshod Shamsiddinov
Adizova Nargiza

https://doi.org/10.5281/zenodo.17702961

ARTICLE INFO

Received: 22nd November 2025
Accepted: 23rd November 2025
Online: 24th November 2025

KEYWORDS

lithium-ion batteries, chemical processes, ion transport, SEI layer, electrode reactions, electrolyte decomposition, battery degradation, silicon anode, solid-state electrolyte, battery efficiency.

ABSTRACT

This article examines the fundamental chemical processes in lithium-ion batteries, focusing on ion transport, electrode reactions, electrolyte decomposition, and solid–electrolyte interphase (SEI) formation. The study highlights how these processes influence battery performance parameters such as energy density, cycle life, thermal stability, and charging speed. Special attention is given to degradation mechanisms, including electrode material fatigue, electrolyte oxidation, and lithium plating during fast charging. The article further analyzes modern methods to improve the efficiency of lithium-ion batteries, including the development of high-nickel cathode materials, silicon–carbon composite anodes, solid-state electrolytes, advanced SEI engineering, nanoscale electrode design, and smart battery management systems (BMS). By integrating insights from electrochemistry and materials science, the work provides a comprehensive overview of current technological advancements aimed at improving battery durability, safety, and performance.

Introduction

Lithium-ion batteries are among the most essential types of modern energy storage technologies. They are widely used in mobile phones, laptops, electric vehicles, and solar energy storage systems. Lithium-ion batteries stand out due to their high energy density, long service life, and ability to be recharged many times.

The aim of this research is to analyze the chemical processes in lithium-ion batteries and explore methods to improve their efficiency.

Structure of a Lithium-Ion Battery

A lithium-ion battery consists of three main components: the anode, cathode, and electrolyte.

Anode: Typically made of graphite or graphite–silicon, which stores incoming Li^+ ions.

Cathode: Materials such as $LiCoO_2$, $LiFePO_4$, or NMC (nickel–manganese–cobalt), responsible for releasing and reabsorbing ions.

Electrolyte: A solution containing $LiPF_6$ salt dissolved in organic solvent, enabling free ion movement.

Chemical Processes

During charging, Li^+ ions move from the cathode to the anode, while electrons travel through the external circuit.

During discharging, ions move back from the anode to the cathode, releasing electrical energy.

Reactions:

Anode:

$Li^+ + e^- + C_6 \rightarrow LiC_6$

Cathode (example: $LiCoO_2$):

$LiCoO_2 \rightleftarrows Li_{1-x}CoO_2 + xLi^+ + xe^-$

Methods to Improve Battery Efficiency

Nanostructured electrodes: Reduce ion travel distance and enable faster charging.

Solid electrolytes: Increase safety by lowering risk of ignition.

Silicon anodes: Store more lithium compared to graphite, increasing energy density.

Stable cathode materials ($LiFePO_4$): Provide long lifetime and lower degradation.

Battery Degradation and Safety

Over time, lithium-ion batteries undergo degradation due to several factors:

Electrolyte decomposition

Thickening of the SEI (Solid Electrolyte Interphase) layer

Breakdown of electrode crystal structures

Formation of lithium dendrites

Using nanomaterials and solid-state electrolytes helps slow down these processes.

Modern Research and Promising Technologies

In recent years, significant scientific advancements have been made to optimize lithium-ion batteries.

Nanostructured materials, highly stable cathodes, and solid electrolytes significantly improve battery capacity and safety.

Environmental safety and recyclability have also become major focus areas in current research.

Conclusion

Lithium-ion batteries are one of the most promising directions in energy storage technology.

Efficiency can be improved through optimization of chemical processes and development of advanced electrode and electrolyte materials.

Nanostructures, solid electrolytes, and silicon anodes help increase energy density, enhance safety, and extend battery lifespan.

Future developments aim to produce environmentally friendly and fully recyclable batteries.

References:

1.Zamirovna A. N., Bahodirovna Z. R. The Role of Advanced Pedagogical Technologies in Teaching the Topic "Proteins" in Chemistry. PEDAGOGS Journal. 2022. Vol. 22. No. 2. pp. 49–51.

2.Kuldasheva Sh. A., Akhmadjanov I. L., Adizova N. Z. Stabilization of Mobile Sands in Desert Regions of Surkhandarya Using Salt-Resistant Compositions. Scientific Research. 2020. p. 101.
3.Mavlanov B. A., Adizova N. Z., Rakhmatov M. S. Study of Bactericidal Activity of Co-polymers Based on (Meth)acrylic Derivatives of Heterocyclic Compounds. Future of Science — 2015. pp. 207–209.
4.Adizova N. Z. et al. Adsorption Isotherms of Mobile Sands in the Aral and Bukhara-Khiva Region. Universum: Chemistry and Biology. 2020. No. 8-2 (74). pp. 15–18.
5.Kuldasheva Sh. A. et al. Mechanism of Structure Formation in Chemical Stabilization of Mobile Sands Using Complex Additives. Academy of Sciences of Uzbekistan. 2019. p. 147.
6.Kuldasheva Sh. A., Adizova N. Z. Optimization of Chemical Stabilization of Mobile Soils and Sands in the Aral and Surkhandarya Regions. Universum: Technical Sciences. 2018. No. 9 (54). pp. 36–40.