

Novel Advancements and Problems in the Formation of Sodium ion batteries (SIB): A Mini Review

Muhammad Hanan Khan*

NFC IEFER, Faisalabad, Pakistan

Citation: Khan MH. Novel Advancements and Problems in the Formation of Sodium ion batteries (SIB): A Mini Review. *J Petro Chem Eng* 2025;3(4):244-245.

Received: 27 October, 2025; **Accepted:** 09 December, 2025; **Published:** 12 December, 2025

***Corresponding author:** Muhammad Hanan Khan, NFC IEFER, Faisalabad, Pakistan

Copyright: © 2025 Khan MH., This is an open-access article published in J Petro Chem Eng (JPCE) and distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

ABSTRACT

Because sodium is so readily available, sodium-ion batteries (SIBs) are starting to demonstrate to be an effective and affordable alternative to lithium-ion batteries for large-scale storage of energy. The most recent advancements in SIB technology are compiled in this review, with an emphasis on enhancements in each of the key components: dependable electrolytes, effective separators, or high-performance cathodes and anodes. It also critically examines the primary issues preventing SIBs from reaching their full commercial potential. In addition, it examines in detail the primary factors preventing sodium-ion batteries (SIBs) from achieving commercial success. The specific issues being dealt with include the larger ionic radius of Na^+ which causes big changes in the volume causing it challenging for the host material to cycle, as well as problems with making a stable and uniform solid-electrolyte interphase (SEI).

Keywords: SEI; LIB; Electric Vehicles; Renewable energy

Introduction

The most recent developments in SIB formation are critically created in this mini-review, which also identifies the basic issues that need to be resolved in order to fully realise what is possible with these systems for a variety of applications, ranging from electric vehicles to static grid storage^{1,2}. A compelling and sustainable alternative to the commercially available but resource-constrained Lithium-ion batteries (LIBs), sodium-ion batteries (SIBs) are attracting attention due to the growing demand for large-scale energy storage solutions worldwide (**Figure 1**), which is being driven by the increasing use of sources of renewable energy as well as electric vehicles^{1,3}. Similar to LIBs, SIBs move Na^+ ions between a cathode and an anode during charge and discharge using a “rocking-chair” mechanism⁴. Their main selling point is the enormous quantity and low cost of sodium (Na) resources, which are easily

obtainable from seawater and the Earth’s crust and greatly lower the lack of resources and global problems related to lithium (Li)^{2,3}.

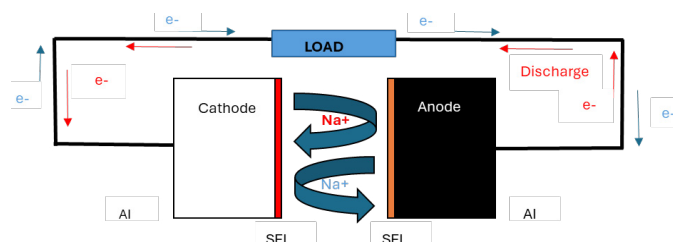


Figure 1: Sodium ion Batteries⁵

The greater ionic radius of Na^+ (1.02 Å compared to Li^+ 0.76 Å)⁶ presents a barrier to industrial competition with LIBs, despite their fundamental similarities and inherent cost benefits. The electrode materials must meet critical requirements

due to this dimensional difference, which frequently results in slower Na⁺ diffusion kinetics, as increased volume expansion, and structural failure during the ion intercalation/de-intercalation process (**Figure 2**). As a result, overall energy density, cycle life, and rate capability are limited^{1,6}. In particular, the development of stable, high-capacity materials like layered transition metal oxides, poly-anionic compounds, and the Prussian Blue Analogues (PBA) has been the focus of recent research devoted to resolving these problems by innovative material design and engineering^{3,7,8}.

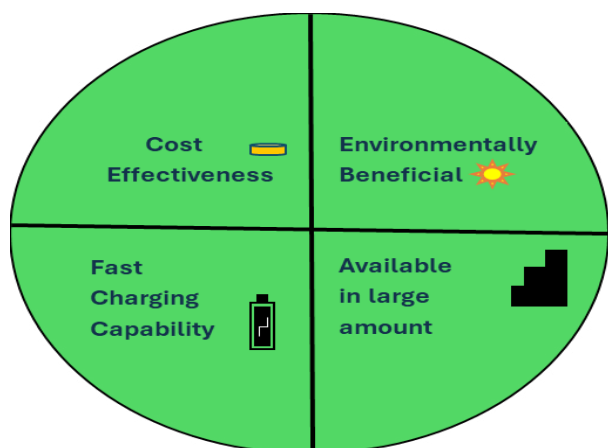


Figure 2: Suitability Factors of Sodium ion Batteries⁹.

Electrochemical Principle and Key Components

Sodium-ion batteries (SIBs) function based on electrochemical principles that are comparable to those of lithium-ion batteries (LIBs)¹⁰.

Hard carbon

Hard carbon materials are considered the primary candidates for use as anodes in SIBs due to their distinct characteristics. These materials are produced from oxygen-diverting precursors that cannot be converted into graphite, even when subjected to very high carbonization temperatures. Hard carbons are distinguished by a random arrangement of graphitic domains, which possess a larger interlayer spacing than standard graphite (>0.34 nm), and these domains are interconnected by disordered regions of carbon¹⁰.

Evaluation of specific capacity, power density and energy density

Specific capacity, typically expressed in milliampere-hours per gram (mAh/g), is a vital metric for assessing SIB performance. It quantifies the amount of charge that can be stored per unit mass of the electrode material. This parameter is fundamentally dependent on the electrochemical properties of the active materials used in the anode and cathode. For instance, hard carbon, which is a widely utilized anode material, typically demonstrates a specific capacity of approximately 300 mAh/g, while layered transition metal oxides¹⁰.

Challenges and Limitations

The development of SIBs has garnered substantial interest because they present a sustainable and more economical alternative to LIBs. However, despite their promising attributes, SIBs encounter several obstacles that impede their widespread adoption. Understanding these constraints is essential for guiding future research and development efforts aimed at enhancing SIB performance¹⁰.

Conclusions

Sodium-ion batteries (SIBs) are emerging as a compelling and sustainable successor to lithium-ion batteries (LIBs), effectively tackling crucial challenges like resource scarcity, high cost, and environmental impact. Leveraging the abundance and low cost of sodium, SIBs represent an economical solution particularly well-suited for large-scale energy storage. Substantial progress across cathode and anode materials, electrolyte compositions, and battery architecture has significantly enhanced the overall performance, stability, and safety of SIB technology¹⁰.

References

1. <https://www.researchgate.net/publication/385488>
2. Hwang JY, Myung ST, Sun YK. Sodium-ion batteries: present and future. *Chem Soc Rev* 2017;46:3529-3614.
3. Wathoni AZ, Madurani KA, Lai CW, Kurniawan F. Comprehensive review of sodium-ion battery materials: Advances and performance challenges. *ChemPhysMater* 2025;4(4):344-359.
4. Sodium-ion battery. Wikipedia 2025.
5. Zeng X, Peng J, Guo Y, Huang X. Research Progress on Na₃V₂(PO₄)₃ Cathode Material of Sodium Ion Battery. *Frontiers in Chem* 2020.
6. Bai X, Wu N, Yu G, Li T. Recent Advances in Anode Materials for Sodium-Ion Batteries. *Inorganics* 2023;11(7):289.
7. Gao Y, Zhang H, Peng J, Li L. A 30-year overview of sodium ion batteries. *Carbon Energy* 2024;6(6).
8. Transforming Sodium-Ion Battery Technology: New Strategy Boosts Hard Carbon Anodes 2025.
9. What Is Sodium Ion Battery? Delongtop.
10. Phogat P, Dey S, Wan M. Comprehensive review of Sodium-Ion Batteries: Principles, Materials, Performance, Challenges, and future Perspectives. *Materials Science and Engineering: B* 2025;312:117870.