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Opinion: Sodium-Ion Batteries – A Sustainable Answer to India’s Energy Storage Challenge

By **Sangita Shetty** - 17th February 2025

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Representational image. Credit: Canva

While lithium-ion batteries (LIBs) dominate the current landscape of battery energy storage systems (BESSs), they have significant safety issues, as evident from the increasing number of LIB-related fire incidents in countries across the world, including India. Further, critical minerals used in LIB electrodes are geographically concentrated, leading to supply chain vulnerabilities.

Meanwhile, driven by global initiatives such as the COP29 Global Energy Storage and Grids Pledge, the deployment of BESS is expected to increase rapidly in all sectors, including electricity and transport sectors. In India, BESS demand from electric vehicles (EVs) and stationary grid applications by 2030 is expected to be 381 GWh and 181 GWh, respectively, as per the 2022 NITI Aayog report. Thus, the challenges with LIBs, coupled with the increasing demand for BESSs, make it imperative to explore alternative battery technologies.

Can sodium-ion batteries (SIBs) be the next choice?

With their lower cost and superior safety features, SIBs show promise as an alternative to LIBs. Sodium is approximately 1,000 times more abundant than lithium, ruling out any shortage of sodium in the future. Further, the cyclability (ability of a battery to withstand stresses imposed during charging and discharging cycles) of SIBs is comparable to that of state-of-the-art LIBs. SIBs also have a wider operating temperature range (−20 °C to 60 °C) than LIBs, allowing them to be used under extreme temperature conditions such as those in the Indian subcontinent.

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Further, the infrastructure used for manufacturing LIBs (such as pouches and prismatic and cylindrical cells) can be directly employed with small adjustments and modifications to make SIBs.

SIB types and the best choice

The global commercial production of SIBs is currently limited to specific cathode and anode materials. Cathodes primarily utilise layered oxides, polyanionic compounds, and Prussian blue analogues (PBA), while hard carbon and PBA materials are the primary anodes. These SIBs are being manufactured by companies across the globe such as those in Asia, Europe, and North America.

The cathode materials differ in terms of their technical characteristics (such as structural stability, working voltage, cycle life, and specific capacity) and structure. PBA cathodes, with a voltage range of 1.5–4.0 V, provide a good balance between specific capacity (65–150 mAh/g) and cycle life (over 2,000 cycles). However, the presence of cyanide in the PBA materials makes these cathodes less environmentally friendly.

Polyanionic compounds offer a wide voltage range (2.0–4.6 V) and robust structural stability. Despite their moderate specific capacity (110–142 mAh/g), high safety and stability characteristics make them reliable.

Layered oxide materials with a cycle life of over 3,000 cycles and a voltage range of 1.25–4.5 V have an excellent specific capacity (70–220 mAh/g). However, they have moderate structural stability.

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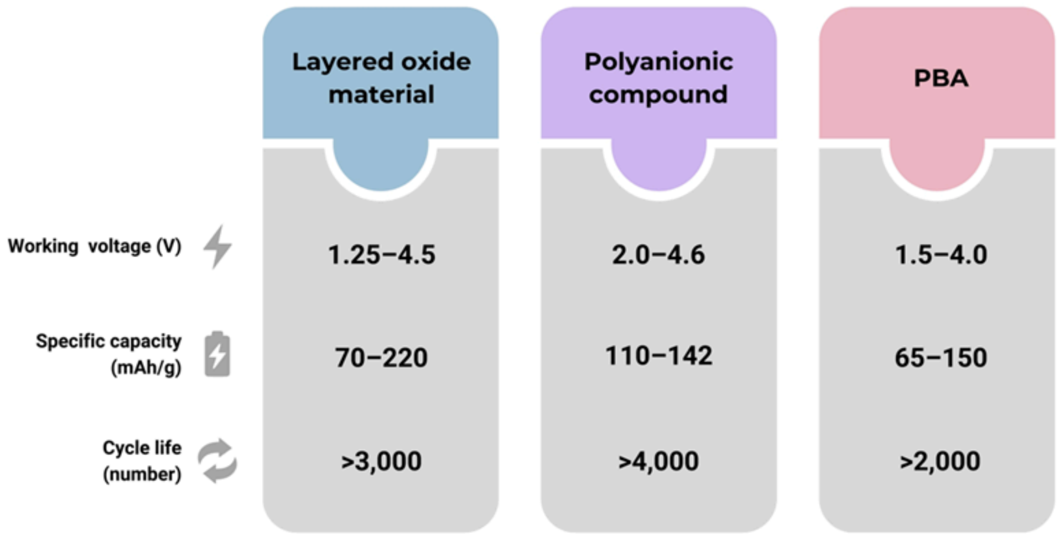
Coming to anodes, hard carbon is the most widely used anode material in SIBs due to its high sodium storage capacity and excellent cycling stability. However, it has the drawback of low coulombic efficiency, indicating faster degradation (side reactions) in the battery and shortened cycle life.

PBA anodes provide high cycle life (up to 50,000 cycles) to the battery, fast charging, and 97% round-trip efficiency. However, similar to PBA cathodes, these anodes have the issue of being harmful to the environment due to the use of cyanide.

Characteristics of cathode materials used in SIBs



Challenges

SIBs have distinct advantages, but they come with some challenges too. SIB chemistries are still evolving. Hence, the sustainable supply chain for the materials required for SIBs is not yet fully established, with only a few companies operating in this segment. Further, as more commercialisation of SIBs is happening in China, South Korea, Japan, and the United States, India might be dependent on these countries for battery imports in the future.

The way forward

In conclusion, to accelerate the development of SIBs, India should focus on procuring the materials and manufacturing SIBs based on layered oxide materials, polyanionic compounds, PBAs, and hard carbon. Ensuring a sustainable supply chain for SIBs is also crucial for supporting the ecosystem growth.

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Further, a collaboration between research institutions and industries is essential for selecting appropriate electrode materials, refining material synthesis processes, and optimising battery-grade materials and manufacturing processes.

Support for research and development to improve the energy density, power density, and cycle life of SIBs is also essential at this stage for widened commercial applications and long-term viability. Once the technology is fully developed, domestic production of SIBs should be supported through supportive policies and government initiatives, such as the **Production Linked Incentive (PLI) scheme**, facilitating SIB commercialisation in India.

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