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Editorial: Sodium-ion batteries: From materials discovery and understanding to cell development

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Editorial on the Research Topic
Sodium-ion batteries: From materials discovery and understanding to cell development

The rapid growth in the worldwide battery demand has accelerated the search for efficient, low cost, and sustainable batteries able to satisfy different markets, including portable electronics, the electrified mobility sector, and stationary applications. Several emerging battery technologies are considered to share the dominant position currently held by lithium-ion batteries (LIBs). Among them, owing to their conceivable lower costs and higher sustainabilities, sodium-ion batteries (SIBs) have the potential to dominate the future stationary storage market and to contribute to the electrified transport sector (Hasa et al., 2021; Tapia-ruiz et al., 2021).

The growing interest in SIBs has been accelerated by the successes of several companies that have invested in the technology (Bauer et al., 2018). Among others, it is worth mentioning several pioneering companies: Faradion (United Kingdom) (Rudola et al., 2021), recently acquired by the Indian Reliance (https://faradion.co.uk/reliance-new-energy-solar-to-acquire-faradion-limited/, 2022), and now partnering with AMTE power on the development of upscaled sodium-ion cells; Hina battery (China) (http://www.hinabattery.com/en/, 2022), closely cooperating with the Chinese Academy of Sciences and developing systems for light electric vehicles and stationary storage applications; TIAMAT a spin-out company from the french RS2E network (France) (http://www.tiamat-energy.com/, 2022), accelerating the production of high power sodium-ion cells using polyanionic cathode chemistry; and Natron Energy (United States) (https://natron.energy/, 2022), a spin-out company from Stanford University in California, already commercializing high power batteries using Prussian Blue Analogues (PBAs). In addition, in September 2021, the Chinese global LIB manufacturer, Contemporary Amperex Technology Co. Limited, CATL, announced the release of Its first generation of SIBs (https://www.catl.com/en/news/665.html, 2021).

Despite major achievements in the last decade, several challenges remain in the rational design of high-performance SIB materials. The scientific challenges to be tackled lie at the interfaces of chemistry, materials science, electrochemistry, surface science, and engineering. Studies on novel material design, degradation mechanisms and their mitigation strategies, as well as electrode processing and cell design, are the current focus of the scientific community contributing to the progress of this battery technology.

This Research Topic aims to highlight recent progress and advances in SIB materials with regard to synthetic, characterization (bulk and surface), and electrochemical studies, including active and inactive electrode components. Three papers in this Research Topic highlight achievements in the cathode component, covering material scale-up processes and their associated critical challenges such as moisture sensitivity, the importance of binders in transition metal layered oxides, and the critical role of vacancies in PBA cathode structures.

Pfeiffer et al. comprehensively investigated the phase diagram of the spherical, dense, and Co-free cathode active material, $Na_xMn_{3/4}Ni_{1/4}O_2$. The reported synthetic route, similar to the highly scalable production process of NCM materials, produced a material with technically relevant particle specifications. The influence of storage in humid conditions on the crystal structure, particle surface, and electrochemistry were investigated using model experiments. Material stored in ambient conditions did not exhibit any hydrated phases. Although Na_2CO_3 was detected on the surface, impurities did not affect the electrochemical performance in half-cells. Zilinskaite et al. reported the use of xanthan gum as a water-soluble binder in combination with the positive electrode material P3-$Na_{2/3}Ni_{1/3}Mn_{2/3}O_2$. The excellent electrochemical results, comparable with data obtained using PVDF-containing electrodes, offered a pathway toward aqueous processing, which represents a more sustainable and environmentally benign electrode manufacturing process, without compromising the electrochemical performance. Ericsson et al. reported a Mössbauer spectroscopy study on a Prussian White (PW) cathode material, which represents a promising alternative class of positive electrode materials. Indeed, PW is considered a very attractive material due to its relatively high theoretical capacity and low-cost synthesis; however, wide variability in electrochemical results was observed due to their complex composition and the effect of vacancies in the structure (Brant et al., 2019). This study offers a rigorous methodology for characterizing the composition of PW systems, enabling material optimization owing to a deeper understanding of the structure-property correlation.

The importance of electrolyte systems and interphases in SIBs was investigated by Chen et al., who reported the beneficial effect of water-scavenging electrolyte additives on the lifetime of sodium-ion cells. By adding N,N-diethyltrimethylsilylamine (DETMSA) to the electrolyte, a more robust and less resistive SEI layer was obtained, maximizing the cycle life of the cells, which exhibited an 80% capacity retention after 500 cycles.

In terms of the negative electrode, hard carbon materials appear to be the anode material of choice for state-of-the-art SIB technology (Dou et al., 2019). However, a great deal of research is currently ongoing in the search for high-capacity novel anode materials (Zhang et al., 2018). In this Research Topic, Skurtveit et al. reviewed the benefits and challenges conversion-alloying anode materials for SIB application. The work highlights the complexity of the conversion-alloying mechanisms and reversibility, importance of the development of suitable operando analyses. Willow et al. reported an anode-free SIB cell configuration, the importance of high plating and stripping efficiencies, and providing insights into the effect of pressure on sodium dendrite formation.

In this Research Topic, an important step forward in the development of bipolar sodium-ion cells is reported by (Rudola et al.). Indeed, SIBs are well-suited for bipolar cell configuration, enabling high voltage systems irrespective of the voltage of the coupled cathode/anode. The authors reported a scalable method to fabricate nSmP Na-ion/mixed-chemistry bipolar cells (n cells in series; m cells in parallel) in a single, sealed cell. By using similar manufacturing methods to commercial alkali-ion cells, cost-effective and high-voltage Na-ion bipolar cells were realized.

In conclusion, extremely encouraging results have been achieved in a very short time for SIBs when compared to LIBs. While it is envisioned that further technological improvements will be achieved by cell component fabrication/assembly optimization, efforts are still required in the field of material discovery. Understanding the processes governing SIB systems will consolidate their position as the next-generation, green, safe, sustainable, and low-cost energy storage of the future.

Author contributions

Authors guest edited this special collection. IH wrote the editorial. NT-R and MM edited and reviewed.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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