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Editorial Overview

Editorial overview: Energy storage: Rechargeable batteries (2022) beyond organic electrolytes

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The modern world is increasingly dominated by smartphones, tablet PCs, laptop computers, and electric vehicles, all of which are powered by lithium-ion batteries (LIBs); thus, no one can deny that LIBs have been extremely successful. Nonetheless, the commercial LIBs in use today have been optimized with carbonate-based electrolytes. Because of the flammability of these electrolytes, the community has been driven to develop innovative solutions based on nonflammable counterparts, pointing to the fact that we are at another inflection point in the history of battery technology. This themed issue presents a collection of review articles that summarize current advancements in emerging battery systems based on nonflammable electrolytes, such as all-solid-state and aqueous batteries. Each review focuses on a topic that is, to a greater or lesser extent, unique to each cell system. This is done to provide readers information on the latest developments in individual cell components and relevant cell technologies while keeping up with the overall trend in this post-LIB field.

In the area of all-solid-state batteries (ASSBs), Brezesinski et al. reviewed the distinct functions and characteristics of single-crystalline and polycrystalline cathode materials in an ASSB cell from both comparative and complementary viewpoints. Because the high resistance of the electrode—electrolyte interface greatly degrades crucial electrochemical performance, these two distinct crystalline constituents are expected to be the primary research focus in the coming years. In this regard, it would be most intriguing to see if single-crystalline materials may find a unique and beneficial position among ASSBs, as many researchers are doing with traditional liquid-based LIBs. With a similar concern regarding interfacial stability, Han et al. summarized the important challenges and current understanding of the interfacial degradation mechanism by elucidating the atomic perturbation and evolution. The most catastrophic and long-standing issue in ASSBs, the rise in interfacial resistance with cycling, is explained for various electrode—electrolyte combinations, and the origins of these undesired phenomena are revealed. This atomic-level understanding could provide a basic foundation for addressing the challenges by offering a guideline for atomically engineering the interface. Jung et al. highlighted recent progress in sheet-type electrodes at the other end of the spectrum, that is, scaling up sulfide-based ASSBs. Because most ASSBs are still in their infancy in terms of manufacturing, establishing a production scheme based

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on either a wet or dry fabrication process necessitates immediate action, but as the authors pointed out, many technical factors must be taken into account. Constructing a fabrication scheme involves a multitude of tasks aimed at extracting cell components with mutual (electro)chemical compatibility. Polymer electrolytes have emerged as an alternative choice in the solid-electrolyte portfolio due to their apparent processing benefit. Cui et al. evaluated recent advances in in-situ polymerized electrolytes with a particular focus on those containing sulfide skeletons in an attempt to create a conformal, ionically seamless interface. Lee et al. were likewise interested in gel and polymer electrolytes, but especially in printable lithium metal batteries. Printability and on-board solidification are two distinct printing considerations that set their work apart from the others. These printed lithium metal batteries are expected to find their first applications in wearable IT and robotics, where unusual form factors and electrode shapes of installed batteries may benefit from the printing process. Finally, Kim et al. viewed the solid-electrolyte layer as a subsequent generation of separators in LIBs by connecting the requirements of this layer to the evolution of conventional olefin-based membrane separators. In the pursuit of designing effective solid-electrolyte layers, important properties of conventional separators such as smooth contact with the electrodes and resistance to dendrite penetration are still important.

Cells based on aqueous electrolytes constitute another major stream in the development of safe batteries, however, they are primarily aimed at grid-scale energy storage. Kim et al. reviewed flowless zinc-bromine batteries by taking various parameters and trade-offs into consideration. Once the major concerns, such as crossover contamination and uneven zinc plating, are addressed, this technology will find itself in a sweet spot between conventional redox flow batteries and static aqueous zinc-ion batteries. In a similar context, Kundu et al. detailed the development of cathode materials for aqueous zinc-ion batteries. Aside from comprehensively describing cathode materials by focusing on their various physicochemical and crystallographic features, the authors highlight complicated degradation mechanisms such as proton co-intercalation that might lead to misinterpretation of data. In the flow schemes of aqueous organic batteries, identification of the degradation mechanism is equally critical, as outlined by Xu et al. in their article. From an organic molecular engineering viewpoint, understanding the electrochemical decomposition of active molecules is essential because it guides structural fine-tuning of the related molecules to avoid decomposition. On the other hand, the growing interest in grid-scale energy storage has fueled research into nickel-hydrogen gas ($Ni-H_2$) cells, which have long been adopted in aerospace and satellite systems. Chen et al. highlighted the importance of materials innovation, such as substituting platinum catalysts with less costly alternatives, in advancing $Ni-H_2$ battery technology. Another effective strategy for advancing $Ni-H_2$ batteries is to optimize cell design.

With tremendous progress being made in the aforementioned emerging battery systems with enhanced safety, both academia and industry are looking forward to overcoming intellectual challenges and cultivating the rewards of their efforts. We hope readers will enjoy the series of reviews in this issue and that they will be inspired to help bring these post-LIBs to fruition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.