

Rechargeable Magnesium Batteries: New Electrolyte Additives for Next-Generation of Bivalent Batteries

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INTRODUCTION

Li-Ion batteries, despite their widespread use, face significant challenges in Europe due to limited raw material availability and continuously increasing costs, which are especially noticeable in consumer electronics. This situation has driven interest in novel battery technologies. Among them, bivalent metal-organic batteries have emerged as promising candidates for next-generation energy storage systems owing to their high energy density, cost-effectiveness, and environmental sustainability. However, these systems are still in the early stages of development and face several obstacles, including poor cycling stability and sluggish electrode kinetics. Rechargeable magnesium batteries (RMBs) and rechargeable calcium batteries (RCBs) are particularly affected by electrolyte speciation, which leads to ion pair formation and hinders multivalent ion desolvation. Additionally, their anodes exhibit inefficient metal plating/stripping and formation of passivation layers with low conductivity.

EXPERIMENTAL/THEORETICAL STUDY

Our research focuses on electrolyte additives that can act as ion pair scavengers and functional agents capable of capturing cations or anions to mitigate ion pair formation and enhance multivalent ion desolvation. We investigated not only the interactions between bivalent metal cations and chelating additives but also explored the bonding between salt anions and selected anion receptor additives. Particular attention was given to molecular design strategies aimed at enabling partial immobilization of anions and promoting efficient salt dissociation. In our systematic approach, we considered factors such as additive solubility, redox stability, and chemical compatibility with RMB and RCB components. Additionally, we utilized computational modeling to support the design and optimization of these electrolyte additives.

RESULTS AND DISCUSSION

We present a comprehensive roadmap for the development of electrolyte additives tailored to improve the performance of multivalent metal-organic batteries. Key strategies for increasing cycling stability, minimizing side reactions, and enhancing ion transport kinetics are discussed in detail. We also address recent advancements in the synthesis and structural characterization of electrolyte additives. The study outlines methods for evaluating additive performance through thorough electrochemical analysis, highlighting the importance of analytical tools in assessing additive efficacy and ensuring practical implementation. The integration of computational methods allowed us to better understand structure-property relationships and predict the behavior of novel additive molecules, thereby accelerating the development process.

CONCLUSION

Electrolyte additives are pivotal in overcoming the critical challenges faced by bivalent metal-organic batteries. Through a combination of experimental design, computational modeling, and analytical evaluation, we demonstrate that tailored additive molecules can significantly improve electrolyte performance by reducing ion pairing, enhancing salt dissociation, and stabilizing electrochemical cycling. Our roadmap provides a foundation for further innovation and optimization in this field, offering promising directions for future battery technologies.

ACKNOWLEDGMENTS

"Additives to high-energy batteries based on divalent metal ions and organic cathode" is financed by the National Science Centre (NCN) (OPUS 22 LAP number 2021/43/I/ST4/02521).