

Research on Electrolytes and Energy Storage Materials

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The global transition toward sustainable and efficient energy storage solutions has placed research on electrolytes and energy storage materials at the heart of scientific and technological innovation [1]. As the demand for cleaner, more reliable, and environmentally responsible energy sources continues to grow, the development of advanced batteries, capacitors, and emerging energy storage technologies has become increasingly critical [2]. This Special Issue of *Crystals* brings together a diverse collection of original research articles and reviews that address the most pressing challenges and opportunities in this rapidly evolving field [3]. Electrolytes serve as the lifeblood of energy storage systems, enabling the movement of ions and the efficient transfer of electrical energy [4]. The optimization of electrolyte properties such as ionic conductivity, interfacial stability, and environmental compatibility is essential for the performance, safety, and longevity of next-generation energy storage devices. The contributions in this Special Issue reflect the breadth and depth of ongoing research, from the synthesis and characterization of novel solid-state electrolytes to the design and optimization of composite materials for photoelectrochemical and battery applications.

Huang et al. present a detailed study on poly(vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP)-based composite solid electrolytes, addressing the challenges of low ionic conductivity and high interfacial resistance at room temperature [5]. PVDF-HFP is widely recognized for its robust mechanical strength, excellent thermal stability, and ability to facilitate lithium salt dissociation due to its strong electron-withdrawing groups. The authors demonstrate that incorporating inorganic fillers into the polymer matrix significantly enhances ionic conductivity and electrochemical stability, making these composite electrolytes promising candidates for high-energy all-solid-state lithium metal batteries. Their work also highlights the importance of optimizing the filler content and distribution to achieve uniform phase morphology and minimize interfacial resistance, which are critical for practical battery applications.

Montoya et al. investigate lithium volatilization and phase changes during the processing of aluminum-doped cubic $\text{Li}_{6.25}\text{La}_3\text{Zr}_2\text{Al}_{0.25}\text{O}_{12}$ (c-LLZO), a promising Li^+ -conducting ceramic for solid-state batteries [6]. c-LLZO garnets are known for their high ionic conductivity and excellent chemical stability, making them ideal candidates for next-generation solid electrolytes. The authors reveal that careful control of processing conditions such as sintering temperature and atmosphere are crucial to minimize lithium loss and stabilize the cubic phase, which exhibits superior Li-ion transport compared to the tetragonal phase. Their findings provide valuable insights into the structure–property relationships in LLZO-based electrolytes and offer practical guidance for the scalable production of high-performance solid-state batteries.

Salem et al. report on the TCAD-based design and optimization of flexible organic/Si tandem solar cells, demonstrating the potential of tandem architectures to surpass the



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efficiency limits of single-junction devices [7]. Tandem solar cells combine the advantages of organic and silicon materials, enabling broader light absorption and higher power conversion efficiencies. The authors use advanced device simulation to optimize the layer thicknesses, bandgaps, and interface engineering, achieving efficiencies above 23% in their proposed designs. Their work underscores the importance of material selection and device engineering in advancing photovoltaic technologies and highlights the potential of flexible tandem solar cells for portable and wearable energy applications.

Neelakanta et al. describe the synthesis of melamine cyanurate microrods decorated with SnO₂ quantum dots for photoelectrochemical water-splitting applications [8]. The hybrid nanostructure leverages the high surface area and strong stability of SnO₂ quantum dots, which exhibit tunable bandgaps due to quantum confinement effects. The authors demonstrate that the decoration of melamine cyanurate microrods with SnO₂ quantum dots enhances charge separation and photocatalytic activity, leading to improved water-splitting performance under visible light. This study highlights the potential of hybrid nanostructures to advance clean hydrogen production technologies and provides a cost-effective approach for scalable synthesis of photoelectrochemical materials.

Zhao et al. examine the growth, structure, and electrical properties of AgNbO₃ antiferroelectric single crystals, providing fundamental insights into the behavior of lead-free antiferroelectric materials [9]. AgNbO₃ exhibits unique antiferroelectric properties and narrow bandgap semiconductivity, making it suitable for high-power energy storage and conversion devices. The authors successfully grow high-purity single crystals and characterize their structural and electrical properties, revealing a stable antiferroelectric phase over a broad temperature range. Their work opens new avenues for the design of environmentally friendly energy storage and conversion devices, with potential applications in dielectric, piezoelectric, and photocatalytic systems.

These contributions collectively illustrate the vibrant and interdisciplinary nature of research on electrolytes and energy storage materials. They reflect the collective efforts of scientists and engineers to push the boundaries of what is possible, driving innovation and progress toward a sustainable energy future. As a Guest Editor, I am proud to present this Special Issue and grateful to all the authors for their outstanding contributions. I also extend my thanks to the reviewers and the editorial team for their support and dedication. It is my hope that this collection will serve as a valuable resource for researchers and practitioners in the field, inspiring further exploration and discovery.

Conflicts of Interest: The authors declare no conflict of interest.

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