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1. Recent progress of multilayer polymer electrolytes for lithium batteries

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Abstract

The significant market for electric vehicles and portable electronic devices is driving the development of high-energy-density solid-state lithium batteries. However, the solid electrolyte is still the main obstacle to the development of solid-state lithium batteries, mainly due to the lack of a single solid electrolyte that is compatible with both high-voltage cathodes and lithium metal anodes. These problems can potentially be solved with multilayer electrolytes. The property of each layer of the electrolyte can be tuned separately, which not only meets the different needs of the cathode and anode but also makes up for the shortcomings of each layer of the electrolyte, thereby achieving good mechanical properties and chemical and electrochemical stability. This review first presents a brief introduction to homogeneous single-layer electrolytes. The design principles of multilayer polymer electrolytes and the application of these principles using examples from recent work are then introduced. Finally, several suggestions as guides for future work are given.

Keywords : Solid-state lithium batteries, solid electrolytes, multilayer polymer electrolytes, high energy density

2. Zn-based batteries for energy storage

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Abstract

Zn-based electrochemistry is considered to be the most promising alternative to Li-ion batteries due to its abundant reserves and cost-effectiveness. In addition, aqueous electrolytes are more convenient to be used in Zn-based batteries due to their good compatibility with Zn-chemistry, thereby reducing cost and improving safety. Furthermore, Zn^{2+}/Zn couples involve two-electron redox chemistry, which can provide higher theoretical energy capacity and energy density. Based on this, a series of Zn-based battery systems, including Zn-ion batteries, Zn-air batteries, and Zn-based redox flow batteries, have received more and more research attention. Here, the fundamentals and recent advances in Zn-based rechargeable batteries are presented, along with perspectives on further research directions.

Keywords: batteries, energy storage

3. Lithium metal stabilization for next-generation lithium-based batteries: from fundamental chemistry to advanced characterization and effective protection

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Abstract

Lithium (Li) metal-based rechargeable batteries hold significant promise to meet the

ever-increasing demands for portable electronic devices, electric vehicles and grid-scale energy storage, making them the optimal alternatives for next-generation secondary batteries. Nevertheless, Li metal anodes currently suffer from major drawbacks, including safety concerns, capacity decay and lifespan degradation, which arise from uncontrollable dendrite growth, notorious side reactions and infinite volume variation, thereby limiting their current practical application. Numerous critical endeavors from different perspectives have been dedicated to developing highly stable Li metal anodes. Herein, a comprehensive overview of Li metal anodes regarding fundamental mechanisms, scientific challenges, characterization techniques, theoretical investigations and advanced strategies is systematically presented. First, the basic working principles of Li metal-based batteries are introduced. Specific attention is then paid to the fundamental understanding of and challenges facing Li metal anodes. Accordingly, advanced characterization approaches and theoretical computations are introduced to understand the fundamental mechanisms of dendrite growth and parasitic reactions. Recent key progress in Li anode protection is then comprehensively summarized and categorized to generate an overview of the respective superiorities and limitations of the various strategies. Furthermore, this review concludes the remaining obstacles and potential research directions for inspiring the innovation of Li metal anodes and endeavors to accomplish the practical application of next-generation Li-based batteries.

Keywords: Next-generation batteries, Li metal anodes, high energy density, advanced protection strategy, practical application

4. Enhanced all-temperature sodium-ion batteries performance in a low-defect and Na-enriched Prussian blue analogue cathode by nickel substitution

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Abstract

Cobalt hexacyanoferrate (CoHCF) is one of the most promising cathode materials for all-temperature sodium-ion batteries (SIBs) due to its open three-dimensional (3D) framework structures, high theoretical specific capacity, good voltage platform and almost no Jahn-Teller effects. However, CoHCF still suffers from poor cycling stability and bad rate capability, which is closely related to the huge distortion of frame structure and poor conductivity. In this study, by choosing nickel (Ni) to partially replace cobalt (Co) in the CoHCF lattice, we successfully prepared low-defect and Na-enriched $\text{Na}_2\text{Co}_{0.7}\text{Ni}_{0.3}[\text{Fe}(\text{CN})_6]$ ($\text{Co}_{0.7}\text{Ni}_{0.3}\text{HCF}$) in chelate and sodium salt-assisted coprecipitation method. Both experiments and first-principles calculations demonstrate that Ni substitution can effectively suppress the lattice distortion during the charging and discharging process of CoHCF. Furthermore, the introduction of Ni increases ion mobility by reducing the ion migration barrier (0.31 eV versus 0.17 eV) and improves the electronic conductivity by reducing the bandgap. It is found that $\text{Co}_{0.7}\text{Ni}_{0.3}\text{HCF}$ exhibits superior electrochemical performance compared with that of CoHCF in a wide temperature range (-30 to 60 °C). At 25 °C, $\text{Co}_{0.7}\text{Ni}_{0.3}\text{HCF}$ delivers a high specific capacity of 142.2 mAh g⁻¹ at 0.2 C, an ultrahigh rate capability with 126.2 mAh g⁻¹ at 5 C and excellent cycling stability with 80.9% capacity retention after 500 cycles at 5 C. Even at -30 °C, $\text{Co}_{0.7}\text{Ni}_{0.3}\text{HCF}$ can provide a high capacity of 109 mAh g⁻¹ without an activation process. This work reveals the great application prospect of PBAs for all-

climate SIBs, especially at low temperatures.

Keywords: Prussian blue analogues, all-climate, sodium-ion batteries, CoHCF, Ni substitution

5. C₆₀ and ZIF-67 synergistically modified gelatin-based nanofibrous separators for Li-S batteries

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Abstract

The lithium-sulfur (Li-S) battery has been attracting much more attention in recent years due to its high theoretical capacity and low cost, although various issues, such as the “shuttle effect” and the low use ratio of active materials, have been hindering the development and application of Li-S batteries. The separator is an important part of Li-S batteries, and its modification is a simple and effective strategy to improve the electrochemical performance of Li-S batteries. In this work, we explore separators with different functions on their two sides that have been produced by a step-by-step electrospinning method. The multifunctional separator on one side is pure gelatin, and the other side is zeolitic imidazolate framework-67 (ZIF-67)-C₆₀-gelatin. The ZIF-67-C₆₀-gelatin layer on the cathode side is of great importance. The chemisorption sites on it are provided by ZIF-67, and the transformation sites of lithium polysulfide are provided by C₆₀. Gelatin, which is on the anode side, as an admirable separator material, makes the lithium flux uniform and thus prevents the generation of lithium dendrites. This type of multifunctional nanofiber separator based on double gelatin layers plays an important role in the adsorption and conversion of polysulfides, and it improves the overall performance of the Li-S battery. As a result, the Li-S batteries assembled with the prepared separator can still maintain the capacity of 888 mAh g⁻¹ after 100 cycles at 0.2 C, and the capacity retention rate of the Li-S batteries is 72.9% after 400 cycles at 2 C. This simple preparation method and high-performance bilayer membrane structure provide a new route for commercial application.

Keywords: Gelatin-based, electrostatic spinning, modified separator, Li-S battery

6. Organic-inorganic hybrid quasi-2D perovskites incorporated with fluorinated additives for efficient and stable four-terminal tandem solar cells

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Abstract

Quasi-two-dimensional (2D) lead halide perovskites have emerged as promising candidates for improving the environmental stability of perovskite solar cells (PSCs). Herein, we report the preparation of a new quasi-2D perovskite by introducing a fluorine-containing additive [3-(trifluoromethyl)benzylammonium iodide (3-TFMBAI)] into Cs_{0.17}FA_{0.83}Pb(I_{0.83}Br_{0.17})₃. The moderate doping of 3-TFMBAI effectively induces the formation of the Ruddlesden-Popper perovskite phase, which can passivate the trap states and restrain the ionic motion in the perovskite lattice. The constructed 3-(trifluoromethyl)benzylamine molecular planes with strong

hydrophobicity favorably suppress the decomposition and collapse of the perovskite phase against humidity. Moreover, the introduction of Cs⁺ and Br⁻ ions tune the bandgap and improve the absorption, crystallinity and thermal stability of the perovskite films. As a result, a champion photoelectric conversion efficiency (PCE) of 20.89% is achieved, along with an improved open-circuit voltage reaching 1.22 V. The quasi-2D PSCs without encapsulation maintain 90.7% of the initial PCE after 1000 h under continuous heating at 60 °C and simultaneous exposure to humid air with a relative humidity of 60%. Four-terminal tandem solar cells are fabricated by combining top semi-transparent quasi-2D PSCs with bottom monocrystalline silicon solar cells, achieving an overall PCE of 23.53% and favorable performance stability.

Keywords: Perovskite/silicon tandem solar cells, organic-inorganic hybrid lead halide perovskites, quasi-2D structure, fluorinated additive, high stability

7. Design of highly conductive iongel soft solid electrolytes for Li-O₂ batteries

Article [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Li-O₂ batteries show high energy storage potential, but there remain many material challenges that must be solved to fully develop them into a robust technology. The reactivity of the electrolyte against lithium metal as the anode or with oxygen superoxide radicals in the cathode is the main problem that may be alleviated by the use of ionic liquids and solid electrolytes. In this work, iongel solid flexible electrolytes with facile preparation are designed based on five variations of the successful N,N-diethyl-N-methyl-N-(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide ionic liquid. These iongels show an outstanding ionic conductivity of $7.8 \times 10^{-3} \text{ S} \cdot \text{cm}^{-1}$ at 25 °C, excellent performance against lithium metal and reduced dendritic growth, even at a high current density rate of $2 \text{ mA} \cdot \text{cm}^{-2}$. Tests on Li-O₂ cells show a 100% capacity retention for 25 cycles with limited capacity. Hence, this work provides a plausible pathway to tackle the design of effective lithium protection methods and efficient solid electrolytes for Li-O₂ batteries.

Keywords: Polymer electrolytes, iongels, ionic liquids, Li-O₂ batteries, lithium metal batteries, solid-state batteries

8. Accelerating redox kinetics by ZIF-67 derived amorphous cobalt phosphide electrocatalyst for high-performance lithium-sulfur batteries

Article [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

The feasibility of the commercialization of lithium-sulfur (Li-S) batteries is troubled by sluggish redox conversion kinetics and the shuttle effect of polysulfides. Herein, a zeolitic imidazolate framework derived amorphous CoP combined with carbon nanotubes conductive network composites (aCoP@CNTs) has been synthesized as an

effective dual-electrocatalyst for accelerating the redox kinetics of polysulfides to prolong the lifespan of Li-S batteries. Compared with crystalline CoP, unsaturated Co atoms of aCoP@CNTs exhibit stronger chemical adsorption capacity for polysulfides and serve as catalytic centers to accelerate the conversion from soluble polysulfides to solid-state lithium sulfide. Meanwhile, the 3D porous conductive network not only facilitates ion/electron transportation but also forms a physical barrier to limit the migration of polysulfides. Benefiting from the above preponderances, the batteries with aCoP@CNTs modified interlayer exhibited excellent cycle stability (initial discharge capacity of 1227.9 mAh g⁻¹ at 0.2 C), rate performance (795.9 mAh g⁻¹ at 2.5 C), long-term cycle reliability (decay rate of 0.049% per cycle at 1 C over 1000 cycles), and superior high-loading performance (high initial discharge capacity of 886 mAh g⁻¹ and 753.6 mAh g⁻¹ at 1 C under high S loading of 3 mg cm⁻² and 4 mg cm⁻²).

Keywords: CoP, amorphous, electrocatalyst, redox kinetics, lithium-sulfur batteries

9. Ionic conductivity and mechanical properties of the solid electrolyte interphase in lithium metal batteries

Mini Review [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

With the fullness of time, metallic lithium (Li) as an anode could become highly promising for high-energy-density batteries. Theoretically, using Li metal as the negative electrode can result in higher theoretical capacity and lower oxidation voltage and density than in current commercially available batteries. During the charge/discharge process, however, metallic Li shows unavoidable drawbacks, such as dendritic growth, causing capacity degradation and a solid electrolyte interphase (SEI) layer derived from the side reactions between the Li metal anode and the electrolyte, resulting in depletion of the electrolyte. The formation of a suitable SEI is crucial to avoid the side reactions at the interface by circumventing direct contact. Unavoidable dendritic growth at the Li metal anode can be controlled by its ionic conductivity. Furthermore, the SEI is also required as a mechanical reinforcement for withstanding the volume change and suppressing dendritic growth in the Li metal anode. A limiting factor due to complex SEI formation must be considered from the perspectives of chemical and mechanical properties. To further enhance the cycling performance of Li metal batteries, an in-depth understanding of the SEI needs to be achieved to clarify these issues. In this mini review, we focus on the SEI, which consists of various deposited components, and discuss its ionic conductivity and mechanical strength for applications in electric vehicles.

Keywords: Electrolyte additive, ionic conductivity, lithium dendrite, lithium metal battery, solid electrolyte interphase (SEI), solid electrolyte

10. Quasi-solid-state electrolytes - strategy towards stabilising Li|inorganic solid electrolyte interfaces in solid-state Li metal batteries

Review [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Solid-state batteries (SSBs) based on inorganic solid electrolytes (ISEs) are considered promising candidates for enhancing the energy density and the safety of next-generation rechargeable lithium batteries. However, their practical application is frequently hampered by the high resistance arising at the Li metal anode/ISE interface. Herein, a review of the conventional solid-state electrolytes (SSEs) the recent research on quasi-solid-state battery (QSSB) approaches to overcome the issues of the state-of-the-art SSBs is reported. The feasibility of ionic liquid (IL)-based interlayers to improve ISE/Li metal wetting and enhance charge transfer at solid electrolyte interfaces with both positive and lithium metal electrodes is presented together with a novel generation of IL-containing quasi-solid-state-electrolytes (QSSEs), offering favourable features. The opportunities and challenges of QSSE for the development of high energy and high safety quasi-solid-state lithium metal batteries (QSSLMBs) are also discussed.

Keywords: All solid-state batteries, lithium metal anode, inorganic solid-state electrolytes, interfacial issues, quasi-solid-state batteries

11. Heterogeneous single-atom catalysts for energy process: recent progress, applications and challenges

Review [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Single-atom catalysts (SACs) with high activity, unique selectivity, and nearly 100% atom utilization efficiency are promising for broad applications in many fields. This review aims to provide a summary of the current development of SACs and point out their challenges and opportunities for commercial applications in the energy process. The discussion starts with an introduction of various types of SACs materials, followed by typical SACs synthetic methods with concrete examples and commonly used characterization methods. The state-of-the-art synthesis methods, whereby SACs with stabilized single metal atoms on the substrate without migration and agglomeration could be obtained, are emphasized. Next, we give an overview of different types of substrates and discuss the effects of substrate species on the structure and properties of SACs. Then we highlight the typical applications of SACs and the remaining challenges. Finally, a perspective on the opportunities for the development of SACs for future commercial applications is provided.

Keywords: Single-atom catalysts, synthesis method, substrates, structure and properties, applications

12. Recent strategies for improving the performances of rechargeable lithium batteries with sulfur- and oxygen-based conversion cathodes

Review [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

The energy density of lithium-ion batteries based on intercalated electrode materials has reached its upper limit, which makes it challenging to meet the growing demand

for high-energy storage systems. Electrode materials based on conversion reactions such as sulfur, organosulfides, and oxygen involving breakage and reformation of chemical bonds can provide higher specific capacity and energy density. In addition, they usually consist of abundant elements, making them renewable. Although they have the aforementioned benefits, they face numerous challenges for practical applications. For example, the cycled products of sulfur and molecular organosulfides could be soluble in a liquid electrolyte, resulting in the shuttle effect and significant capacity loss. The discharged product of oxygen is Li_2O_2 , which could result in high charge overpotential and decomposition of the electrolyte. In this review, we present an overview of the current strategies for improving the performances of lithium-sulfur, lithium-organosulfide, and lithium-oxygen batteries. First, we summarize the efforts to overcome the issues facing sulfur and organosulfide cathodes, as well as the strategies to increase the capacity of organosulfides. Then, we introduce the latest research progress on catalysts in lithium-oxygen batteries. Finally, we summarize and provide outlooks for the conversion of electrode materials.

Keywords: Electrode material, conversion reaction, sulfur, organosulfide, oxygen, lithium battery

13. Insights into the design of mildly acidic aqueous electrolytes for improved stability of Zn anode performance in zinc-ion batteries

Review [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Mildly acidic aqueous zinc (Zn) batteries are promising for large-energy storage but suffer from the irreversibility of Zn metal anodes due to parasitic H_2 evolution, Zn corrosion, and dendrite growth. In recent years, increasing efforts have been devoted to overcoming these obstacles by regulating electrolyte structures. In this review, we investigate progress towards mildly acidic aqueous electrolytes for Zn batteries, with special emphasis on how the microstructures (in the bulk phase and on the surface of Zn anodes) affect the performance of Zn anodes. Moreover, effective computational simulations and characterization measurements for the structures of bulk electrolytes and Zn/electrolyte interfaces are discussed, along with perspectives for the direction of further investigations.

Keywords: Mildly acidic aqueous electrolytes, Zn metal anodes, electrolyte design, Zn/electrolyte interfaces, Zn plating/stripping processes

14. Progress in the high-temperature synthesis of atomically dispersed metal on carbon and understanding of their formation mechanism

Review [Full-Text](#) [PDF](#) [RIS](#)

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<http://dx.doi.org/10.20517/energymater.2022.77>

Abstract

The development of various high-performance electrochemical devices is crucial for mitigating the global climate crisis, and thus the design and fabrication of advanced electrode materials is highly significant. Currently, atomically dispersed metal on

catalysts (ADMCs) have shown great potential in boosting the performance of various energy storage/conversion devices involving aqueous and aprotic catalytic processes, including fuel cells, water electrolyzers, CO₂ electrolyzers, metal-air batteries, and metal-sulfur batteries, as well as systems involving noncatalytic deposition/adsorption of metals. To date, several reliable fabrication methodologies that can ensure the formation of ADCMs have been demonstrated, and continuous optimization is still being performed. To further reinforce the basic scientific research and promote possible practical applications of these materials, we have analyzed, compared, and summarized progress in the fabrication methodology and formation mechanism of ADCMs in this review. This review aims to draw a comprehensive picture of the current methodology and underlying mechanism in the field of material fabrication to serve as guidance for future material design.

Keywords: Atomically dispersed metal, catalysis, energy conversion, carbon-based materials, formation mechanism

15. Two-dimensional nitrogen and phosphorus co-doped mesoporous carbon-graphene nanosheets anode for high-performance potassium-ion capacitor

Article [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Heteroatom-doped carbon materials have high gravimetric potassium-ion storage capability because of their abundant active sites and defects. However, their practical applications toward potassium storage are limited by sluggish reaction kinetics and short cycling life owing to the large ionic radius of K⁺ and undesirable parasitic reactions. Herein, we report a new strategy that allows for bottom-up patterning of thin N/P co-doped carbon layers with a uniform mesoporous structure on two-dimensional graphene sheets. The highly porous architecture and N/P co-doping properties provide abundant active sites for K⁺, and the graphene sheets promote charge/electron transfer. This synergistic structure enables excellent K⁺ storage performance in terms of specific capacity (387.6 mAh g⁻¹ at 0.05 A g⁻¹), rate capability (over 5 A g⁻¹), and cycling stability (70% after 3,000 cycles). As a proof of concept, a potassium-ion capacitor assembled using this carbon anode yields a high energy density of 107 Wh kg⁻¹, a maximum power density of 18.3 kW kg⁻¹, and ultra-long cycling stability over 40,000 cycles.

Keywords: Potassium-ion capacitor, graphene, nanosheet, heteroatom doping, mesoporous carbon

16. Polyurethane/Li₁₀GeP₂S₁₂ composite electrolyte with high ions transfer number and ions capture for all-solid-state lithium batteries

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Abstract

Polymer/ceramic composite electrolytes have recently received a lot of attention

because they combine the advantages of high ionic conductivity of inorganic ceramics and the inherent elasticity of polymer constituents. Nonetheless, the interaction between the ceramic particles and the polar functional groups on the polymer molecules would affect the ion transport rate, which is an important factor to consider when developing a polymer/ceramic composite electrolyte. We present a composite elastic electrolyte based on polyurethane (PU) with high ionic conductivity of 10^{-3} S/cm and excellent mechanical properties (stress-strain) of 4.5 MPa by incorporating ceramic particles into the ion conduction chains on PU. This method improves the interaction between PU/LGPS and Li^+ ions and the conduction of Li^+ ions at the bi-phase interface, yielding a high Li^+ transfer number of 0.56. After 2,000 cycles, the capacity retention rates of the batteries assembled by [LFP|(PU-LGPS)/ $\text{Li}^+|\text{Li}$] are 95.7% (0.2 C) and 87.8% (5 C), respectively. The Li symmetric battery test demonstrates the PU/LGPS composite electrolyte's high stability over 50 days. The current study presents a novel approach to developing high-performance ceramic/polymer composite electrolytes.

Keywords: Polymer/ceramic composite electrolytes, ions transfer number

17. Revealing energy storage mechanism of CsPbBr_3 perovskite for ultra-stable symmetric supercapacitors

Article [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Pang L, Hoang MT, O'Mullane AP, Wang H. Revealing energy storage mechanism of CsPbBr_3 perovskite for ultra-stable symmetric supercapacitors. *Energy Mater* 2023;3:300012.

<http://dx.doi.org/10.20517/energymater.2022.81>

Abstract

Inorganic metal halide perovskites such as CsPbX_3 ($\text{X} = \text{I}, \text{Br}$) have been intensively studied in optoelectrical applications such as solar cells and light-emitting diodes due to better thermal and structural stability compared to the organic-inorganic hybrid perovskite counterparts. Limited studies have shown that inorganic perovskites could potentially be promising electrode materials in energy storage devices like supercapacitors. Nevertheless, there is some controversy regarding their electrochemical properties and energy storage mechanism. Furthermore, the stability of the inorganic perovskites in electrochemical energy storage systems is a big concern. In this work, we studied the electrochemical properties of CsPbBr_3 electrodes composed of pure CsPbBr_3 nanocrystals without any additives to reveal their intrinsic electrochemical characteristics. We carefully selected the electrolyte solution composed of tetrabutylammonium hexafluorophosphate in dichloromethane and the electrode substrate based on FTO glass to ensure they do not cause damage to the perovskite material or introduce side reactions during the charge-discharge process. The results showed that the CsPbBr_3 perovskite demonstrates electrical double-layer capacitive behaviour, and the specific capacitance of the electrode can reach 528 mF g^{-1} . A symmetrical supercapacitor based on this perovskite demonstrated exceptional cycling stability with a capacitance retention of 90% after 10,000 charge and discharge cycles at a discharge current density of 100 mA g^{-1} . The device also exhibited a constant power density of 25.0 mW kg^{-1} with increasing energy density up to 33.3 mWh kg^{-1} . Further characterizations have revealed the important role of the large cations and anions of tetrabutylammonium hexafluorophosphate in the electrolyte in stabilizing the perovskite electrode material.

Keywords: CsPbBr_3 perovskite nanocrystals, energy storage mechanism, supercapacitors, stability, long cycling lifetime

18. Rational design of Ru/TiO₂/CNTs as cathode: promotion of cycling performance for aprotic lithium-oxygen battery

Article [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Liu L, Zhou C, Fang W, Hou Y, Wu Y. Rational design of Ru/TiO₂/CNTs as cathode: promotion of cycling performance for aprotic lithium-oxygen battery. *Energy Mater* 2023;3:300011. <http://dx.doi.org/10.20517/energymater.2022.68>

Abstract

Realizing long-life cycling is the biggest challenge in the research field of Li-O₂ batteries in the current stage. The main reasons for poor cycling performance are the sluggish Li₂O₂ formation and decomposition process, as well as the side reaction of carbon cathode. In order to accurately address the problems above, a TiO₂/CNTs cathode was rationally designed for long-life Li-O₂ batteries. The CNTs skeleton offers multiple three-dimensional channels for the rapid transportation of oxygen, Li⁺ and electrons. A thin-film and discontinuous layer of TiO₂ is coated on the CNTs surface to effectively inhibit the carbon corrosion but still could let mass transfer smoothly. Ultrafine Ru nanoparticles decorating the TiO₂/CNTs serve as efficient catalytic active sites. Benefiting from the unique structure design, Li-O₂ batteries with the cathode of TiO₂/CNTs achieve a cycling life of 110 with a fixed capacity of 500 mAh g⁻¹ at a current density of 100 mA g⁻¹. Our research generates new ideas for designing long-cycling Li-O₂ battery cathodes.

Keywords: Lithium-oxygen battery, rational design cathode, side reaction, Li₂O₂, cycling performance

19. Recent commentaries on the expected performance, advantages and applications of sodium-ion batteries

Research Highlight [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Glushenkov AM. Recent commentaries on the expected performance, advantages and applications of sodium-ion batteries. *Energy Mater* 2023;3:300010. <http://dx.doi.org/10.20517/energymater.2022.70>

Keywords: Sodium-ion batteries, lithium-ion batteries, performance, industrial developments

20. Self-terminated electrodeposition of Pt group metal: principles, synthetic strategies, and applications

Article [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Cui Y, Ding Y, Guo L, Guo C, Liu Y, Bai Y, Li G, Wang K. Ultra-long Zn₃(OH)₂V₂O₇·2H₂O nanowires grown on carbon cloth as cathode material for aqueous zinc-ion batteries. *Energy Mater* 2023;3:300023. <http://dx.doi.org/10.20517/energymater.2022.90>

Abstract

Enhancing the performance of the cathode materials is one of the key issues for aqueous zinc-ion batteries (AZIBs). Layered vanadium-based compounds are considered to be a candidate cathode material for AZIBs owing to their advantages of variable crystal structures and high-theoretical capacity. Nevertheless, the inherent low conductivity of V-based compounds leads to their sluggish kinetics and serious capacity degradation of AZIBs. Here, we proposed a strategy that combined morphology regulation with self-supporting electrodes to build an efficient electron/ion transport network and prepared Zn₃(OH)₂V₂O₇·2H₂O (ZVO) nanowires (ZVNW) on carbon cloth (CC) by a

hydrothermal method. As expected, the ZVNW-CC electrode showed excellent electrochemical performances of a high specific capacity of 361.8 mAh g⁻¹ (50 mA g⁻¹), high-rate capability (145.9 mAh g⁻¹ discharge capacity at 1,000 mA g⁻¹), and long cycling life (96.7% capacity retention after 1,010 cycles at 1,000 mA g⁻¹). The Zn²⁺/H₂O co-intercalation mechanism for ZVNW-CC electrodes was demonstrated by ex-situ XPS and ex-situ TGA.

Keywords: Aqueous zinc-ion batteries, cathode material, Zn₃(OH)₂V₂O₇·2H₂O, carbon cloth, zinc storage mechanism

21. Iron phthalocyanine coupled with nickel-iron selenide layered hydroxide derivative as dual-functional oxygen electrocatalyst for rechargeable zinc-air batteries

Article [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Li G, Sheng K, Lei Y, Zhang F, Yang J, Chang B, Zheng L, Wang X. Iron phthalocyanine coupled with nickel-iron selenide layered hydroxide derivative as dual-functional oxygen electrocatalyst for rechargeable zinc-air batteries. *Energy Mater* 2023;3:300021. <http://dx.doi.org/10.20517/energymater.2023.09>

Abstract

The oxygen reduction reaction (ORR) and oxygen evolution reaction (OER) for dual-functional non-precious metal electrocatalysts are promising alternatives for Pt/Ru-based materials in rechargeable zinc-air batteries (ZABs). However, how to achieve dual-functional oxygen electrocatalytic activity on single-component catalysts and identify the sites responsible for ORR and OER still face many challenges. Herein, an efficient and stable dual-functional electrocatalyst is fabricated by a two-step hydrothermal method with iron phthalocyanine (FePc) π - π stacking on nickel-iron selenide layered hydroxide derivatives (Se/Ni₃Se₄/Fe₃O₄). The as-prepared multi-component catalyst (named as FePc/Se@NiFe) exhibits better oxygen electrocatalytic properties than Pt/Ru-based catalysts, with a half-wave potential ($E_{1/2}$) of 0.90 V and an overpotential of 10 mA cm⁻² (E_{j10}) of 320 mV. More importantly, chronoamperometry (I-T) and accelerated durability tests (ADT) show the unordinary stability of the catalyst. Both physical characterization and experimental results verify that the Fe-N₄ moieties and Ni₃Se₄ crystalline phase are the main active sites for ORR and OER activities, respectively. The small potential gap ($\Delta E = E_{j10} - E_{1/2} = 0.622$ V) represents superior dual-functional activities of the FePc/Se@NiFe catalyst. Subsequently, the ZABs assembled using FePc/Se@NiFe exhibit excellent performances. This study offers a promising design concept for promoting further development of high-performance ORR and OER electrocatalysts and their application in ZAB.

Keywords: Multi-component, layered double hydroxide, iron (II) phthalocyanine, dual-functional electrocatalyst, rechargeable zinc-air battery

22. Impact of *in coin cell* atmosphere on lithium metal battery performance

Article [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Kühn SP, Weiling M, Diddens D, Baghernejad M, Winter M, Cekic-Laskovic I. Impact of *in coin cell* atmosphere on lithium metal battery performance. *Energy Mater* 2023;3:300020. <http://dx.doi.org/10.20517/energymater.2023.07>

Abstract

Research on lithium metal as a high-capacity anode for future lithium metal batteries (LMBs) is currently at an all-time high. To date, the different influences of a highly

pure argon glovebox (GB) and an industry-relevant ambient dry room (DR) atmosphere have received little attention in the scientific community. In this paper, we report on the impact of *in coin cell* atmosphere (ICCA) on the performance of an LMB as well as its interphase characteristics and properties in combination with three organic carbonate-based electrolytes with and without two well-known interphase-forming additives, namely fluoroethylene carbonate (FEC) and vinylene carbonate (VC). The results obtained from this carefully executed systematic study show a substantial impact of the ICCA on solid electrolyte interphase (SEI) resistance (R_{SEI}) and lithium stripping/plating homogeneity. In a transition metal cathode (NMC811) containing LMBs, a DR ICCA results in an up to 50% increase in lifetime due to the improved chemical composition of the cathode electrolyte interphase (CEI). Furthermore, different impacts on electrode characteristics and cell performance were observed depending on the utilized functional additive. Since this study focuses on a largely overlooked influential factor of LMB performance, it highlights the importance of comparability and transparency in published research and the importance of taking differences between research and industrial environments into consideration in the aim of establishing and commercializing LMB cell components.

Keywords: Lithium metal battery, *in coin cell* atmosphere, liquid electrolyte, film-forming additive, solid electrolyte interphase, cathode electrolyte interphase

23. Recent advances in the type, synthesis and electrochemical application of defective metal-organic frameworks

Review [Full-Text PDF RIS](#)

Copy here to cite this article: Zhang Y, Li Q, Zhang G, Lv T, Geng P, Chen Y, Pang H. Recent advances in the type, synthesis and electrochemical application of defective metal-organic frameworks. *Energy Mater* 2023;3:300022. <http://dx.doi.org/10.20517/energymater.2023.06>

Abstract

Metal-organic frameworks (MOFs) have attracted increasing attention in electrochemistry due to their inherent characteristics, such as large specific surface area, high porosity, and structural flexibility. Defects can be designed and generated during the synthesis of MOFs, and their presence gives MOF materials excellent properties in terms of electrochemical energy conversion and storage. This review focuses on the types of defects in MOFs and presents recent and important advances in the methods for introducing defects into MOFs and the effects of defects on the physicochemical properties of MOFs, with emphasis on the application of defective MOFs as catalysts for electrochemical energy conversion and storage. On this basis, the current advantages and disadvantages of defective MOFs in electrochemical energy conversion and storage are presented and future research directions for defective MOFs construction in electrochemical applications are proposed.

Keywords: Metal-organic framework, defects, vacancy, catalyst, electrochemical

24. Recent advances in lithiophilic materials: material design and prospects for lithium metal anode application

Review [Full-Text PDF RIS](#)

Copy here to cite this article: Liu J, Pei N, Yang X, Li R, Hua H, Zhang P, Zhao J. Recent advances in lithiophilic materials: material design and prospects for lithium metal anode application. *Energy Mater* 2023;3:300024. <http://dx.doi.org/10.20517/energymater.2023.08>

Abstract

The rapid development of electronic technology and energy industry promotes the increasing desire for energy storage systems with high energy density, thus calling for the exploration of lithium metal anode. However, the enormous challenges, such as uncontrollable lithium deposition, side reaction, infinite volume change and dendrite generation, hinders its application. To address these problems, the deposition behavior of lithium must be exactly controlled and the anode/electrolyte interface must be stabilized. The deposition of lithium is a multi-step process influenced by multi-physical fields, where nucleation is the key to final morphology. Hence, increasing investigations have focused on the employment of lithiophilic materials that can regulate lithium nucleation in recent years. The lithiophilic materials introduced into the deposition hosts or solid electrolyte interphases can regulate the nucleation overpotential and facilitate uniform deposition. However, the concept of lithiophilicity is still undefined and the mechanism is still unrevealed. In this review, the recent advances in the regulation mechanisms of lithiophilicity are discussed, and the applications of lithiophilic materials in hosts and protective interphases are summarized. The in-depth exploration of lithiophilic materials can enhance our understanding of the deposition behavior of lithium and pave the way for practical lithium metal batteries.

Keywords: Lithium metal anode, lithiophilic materials, lithium deposition, host, solid-state electrolyte interphase

25. Phase change materials microcapsules reinforced with graphene oxide for energy storage technology

Review [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Du B, Wang M, Zhao Q, Hu X, Ding S. Phase change materials microcapsules reinforced with graphene oxide for energy storage technology. *Energy Mater* 2023;3:300026. <http://dx.doi.org/10.20517/energymater.2023.04>

Abstract

Phase change materials (PCMs) are considered one of the most promising energy storage methods owing to their beneficial effects on a larger latent heat, smaller volume change, and easier controlling than other materials. PCMs are widely used in solar energy heating, industrial waste heat utilization, energy conservation in the construction industry, and other fields. To avoid leakage, phase separation, and volatile problems of PCMs, the encapsulation technique typically uses organic polymer materials as shell structures of microcapsules. Furthermore, using inorganic materials to enhance the thermal property of phase change microcapsules is a popular approach in recent research. Especially, graphene oxide (GO) with high thermal conductivity was used as a common thermal conducting additive to improve the thermal performance of phase change microcapsules. Due to its amphiphilic property, GO combined with PCM microcapsules can achieve a variety of nanostructures for thermal energy storage. In this paper, four aspects have been summarized: configuration of PCMs, methods of combining GO with phase change microcapsules, position and content of GO, and applications of PCM/GO microcapsules. This work attempts to discuss preparation methods and heat-conducting properties of the PCM/GO microcapsules, which helps to

better promote the application-targeted design and greatly improve the thermal properties of PCM microcapsules for various applications.

Keywords: Phase change materials, microcapsules, graphene oxide, thermal energy storage, thermal properties

26. Recent progress and prospect of Li-Se batteries: a comprehensive review

Review [Full-Text PDF RIS](#)

Copy here to cite this article: Yang Z, Lu Y, Wang Z, Dong H, Lin J, Wang Y, Qiu M, Ye Z, Lu J. Recent progress and prospect of Li-Se batteries: a comprehensive review. *Energy Mater* 2023;3:27. <http://dx.doi.org/10.20517/energymater.2022.91>

Abstract

Developing high specific capacity electrode materials is definitely critical. Selenium (Se), with competitive electronic conductivity and high volumetric capacity, is regarded as one of the promising cathodes for next-generation lithium (Li) batteries. But the volume change and shuttle effect, together with loss of active material, result in poor lifetime and limited capacity. To alleviate these issues, various efforts have been made to optimize the performances of Li-Se batteries. This review summarizes the recent progress of the Li-Se system, especially the development of cathodes, with preparations, structures, electrochemical performances, and their relationships between structures and performances. The corresponding components are mentioned as well. We expect that Li-Se batteries will have a bright perspective in the energy storage area.

Keywords: Li-Se battery, Se cathode, lithium storage, energy storage systems

27. Scissor g-C₃N₄ for high-density loading of catalyst domains in mesoporous thin-layer conductive network for durable Li-S batteries

Article [Full-Text PDF RIS](#)

Copy here to cite this article: Lai C, Zhou X, Lei M, Liu W, Mu X, Li C. Scissor g-C₃N₄ for high-density loading of catalyst domains in mesoporous thin-layer conductive network for durable Li-S batteries. *Energy Mater* 2023;3:300025. <http://dx.doi.org/10.20517/energymater.2023.02>

Abstract

The application of Li-S batteries (LSBs) is hindered by the undesired shuttle effect that leads to the fast consumption of active materials. The separator modification by using the carbon matrix with embedded metal nitride as catalyst can ease the problem. However, the previous synthesis processes of metal nitride catalysts are difficult to achieve a balance between their high-density production, homogenous distribution and excellent electronic contact with conductive substrates. Herein, we propose a bond scissoring strategy based on g-C₃N₄ to prepare NbN catalyst domains with high-density loading uniformly embedded in mesoporous thin-layer conductive carbon network (NbN/C) for durable LSBs. The molten salt reaction process is favorable for the diffusion of Nb cations into a porous g-C₃N₄ precursor to break the C-N bond and immobilize the N element. The residual monolithic carbon framework with space confinement effect limits the irregular growth and stacking of NbN precipitates. The NbN catalytic domains exhibit a strong adsorption effect on lithium polysulfides (LiPSs) and accelerate their liquid-solid conversion reactions. The LSBs utilizing an NbN/C-modified separator show superior cycling and rate performance, with a high-capacity

retention of 72.7% after 1,000 cycles under 2 C and a high areal capacity of $\sim 7.08 \text{ mA h cm}^{-2}$ under a high sulfur loading of 6.6 mg cm^{-2} . This g-C₃N₄-assisted strategy opens a new gate for the design of an integrated catalysis-conduction network for high-performance LSBs.

Keywords: g-C₃N₄, NbN catalyst domains, conductive network, separator modification, Li-S batteries

28. Recent processing of interaction mechanisms of single metallic atom/clusters in energy electrocatalysis

Review [Full-Text PDF RIS](#)

Copy here to cite this article: Wei Y, Xia H, Yan W, Zhang J. Recent processing of interaction mechanisms of single metallic atom/clusters in energy electrocatalysis

Energy Mater 2023;3:300033. <http://dx.doi.org/10.20517/energymater.2023.13>

Abstract

Understanding the interactions between single metallic atom/clusters (SMACs) has been taken to an unprecedented level, due to the delicate conditions required to produce exotic phenomena in electrode materials, such as thermocatalysis, electrocatalysis, and energy storage devices. Recently, state-of-the-art synthesis methods, such as one-step pyrolysis and multistep pyrolysis, have been developed for SMACs. Herein the interactions between SMACs such as synergetic, charge redistribution effects, and mutual assistance effects, are studied. SMACs have the advantage of maximum utilization of atoms and scattered active sites compared to single metal atoms, and they also have flexible and tunable atom clusters. SMACs have been widely developed and have shown excellent catalytic performance in electrocatalysis. Herein, the self-interaction between SMACs and their catalytic mechanisms are systematically described. The challenges in current synthesis strategies, catalytic mechanisms, and industrial applications of SMACs are analyzed, and a possible synthesis method for SMACs is proposed.

Keywords: Single metallic atom/clusters, interactions, mechanism, synthetic strategy, energy electrocatalysis

29. The application of *in situ* liquid cell TEM in advanced battery research

Review [Full-Text PDF RIS](#)

Copy here to cite this article: Yuan Y, Pu S, Gao X, Robertson A. The application of *in situ* liquid cell TEM in advanced battery research. *Energy Mater* 2023;3:300032.

<http://dx.doi.org/10.20517/energymater.2023.14>

Abstract

The fast development of modern battery research highly relies on advanced characterisation methods to unveil the fundamental mechanisms of their electrochemical processes. The continued development of *in situ* characterisation techniques allows the study of dynamic changes during battery cycling rather than just the initial and the final phase. Among these, *in situ* transmission electron microscopy (TEM) is able to provide direct observation of the structural and morphological evolution in batteries at the nanoscale. Using a compact liquid cell configuration, which allows a fluid to be safely imaged in the high vacuum of the TEM, permits the study of a wide range of candidate liquid electrolytes. In this review, the experimental setup is outlined and the important points for reliable operation are summarised, which are critical to the safety and reproducibility of experiments. Furthermore, the application

of in situ liquid cell TEM in understanding various aspects, including dendrite growth, the solid electrolyte interface (SEI) formation, and the electrode structural evolution in different battery systems, is systematically presented. Finally, challenges in the current application and perspectives of the future development of the *in situ* liquid cell TEM technique are briefly addressed.

Keywords: *In situ* TEM, liquid cell electrochemical TEM, rechargeable batteries, dendrite growth, SEI formation

30. Research advances in earth-abundant-element-based electrocatalysts for oxygen evolution reaction and oxygen reduction reaction

Review [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

The oxygen evolution reaction (OER) and oxygen reduction reaction (ORR) are crucial half-reactions of green electrochemical energy storage and conversion technologies, such as electrochemical water-splitting devices and regenerative fuel cells. Researchers always committed to synthesizing earth-abundant-element-based nanomaterials as high-efficiency electrocatalysts for realizing their industrial applications. In this review, we briefly elaborate on the underlying mechanisms of OER and ORR during the electrochemical process. Then, we systematically sum up the recent research progress in representative metal-free carbon (C)-based electrocatalysts; metal-nitrogen-C electrocatalysts; and nonprecious-metal OER/ORR electrocatalysts, including transition-metal oxides, phosphides, nitrides/oxy-nitrides, chalcogenides, and carbides. Among these, some representative bifunctional electrocatalysts for the OER/ORR are mentioned. In particular, we discuss the effects of physicochemical properties-morphology, phases, crystallinity, composition, defects, heteroatom doping, and strain engineering-on the comprehensive performance of the abovementioned electrocatalysts, with the aim of establishing the nanostructure-function relationships of the electrocatalysts. In addition, the development directions of OER and ORR electrocatalysts are determined and highlighted. The generic approach in this review expands the frontiers of and provides inspiration for developing high-efficiency OER/ORR electrocatalysts.

Keywords: Electrocatalysts, OER, ORR, nanomaterials, nanostructure-function

31. Challenges and design strategies for alloy-based anode materials toward high-performance future-generation potassium-ion batteries

Review [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Potassium-ion batteries (PIBs) are a promising candidate for low-cost and large-scale energy storage due to their abundant potassium resources. However, the potassiation-depotassiation of K^+ presents a significant challenge due to its large ionic radius, which

results in the pulverization of active materials and poor cyclability. Thus, researchers are exploring anode materials with a high specific capacity, long cyclability, and excellent rate capability. In this context, alloy-type anode materials are exceptional candidates due to their high theoretical capacity and low working potential. Nonetheless, the large volume expansion of active materials limits their practical application. This review discusses various strategies for overcoming these challenges, including nanostructure design, heterostructure design, alloy engineering, and compositing. The review provides a comprehensive overview of the current state of research on alloy-based anodes for PIBs and offers insights into promising directions for future work toward commercializing PIBs.

Keywords: Alloy anode, high-performance anode, potassium-ion batteries

32. Advanced 3D-structured electrode for potassium metal anodes

Review [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Liu D, Shen J, Jian Z, Cai X. Advanced 3D-structured electrode for potassium metal anodes. *Energy Mater* 2023;3:300028. <http://dx.doi.org/10.20517/energymater.2023.05>

Abstract

The potassium (K) metal anode, following the "Holy Grail" Li metal anode, is one of the most promising anode materials for next-generation batteries. In comparison with Li, K exhibits even more pronounced energy storage properties. However, it suffers from similar challenges as most alkali metal anodes, such as safety and cyclability issues. Borrowing strategies from Li/Na metal anodes, the three-dimensional (3D)-structured current collector has proven to be a universal and effective strategy. This study examines the recent research progress of 3D-structured electrodes for K metal anodes, focusing on the most commonly used host materials, including carbon-, metal-, and MXene-related electrode materials. Finally, existing challenges, various perspectives on the rational design of K metal anodes, and the future development of K batteries are presented.

Keywords: Potassium metal anode, 3D-structured electrode, metal batteries, current collectors

33. Nanostructured block copolymer single-ion conductors for low-temperature, high-voltage and fast charging lithium-metal batteries

Article [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Shi J, Nguyen H, Chen Z, Wang R, Steinle D, Barnsley L, Li J, Frielinghaus H, Bresser D, Iojoiu C, Paillard E. Nanostructured block copolymer single-ion conductors for low-temperature, high-voltage and fast charging lithium-metal batteries. *Energy Mater* 2023;3:300036. <http://dx.doi.org/10.20517/energymater.2023.27>

Abstract

Herein, a single-ion polymer electrolyte is reported for high-voltage and low-temperature lithium-metal batteries that enables suppressing the growth of dendrites, even at high current densities of 2 mA cm⁻². The nanostructured electrolyte was introduced into the cell by mechanically processing the polymer powder via an easily scalable process. Important for the potential application in commercial battery cells is the finding that it does not induce aluminum corrosion at high voltages and leads to low interfacial resistance with lithium metal. These beneficial characteristics, in

combination with its high single-ion conductivity and its high anodic stability, allow for the stable cycling of state-of-the-art lithium-ion cathodes, such as NMC₁₁₁ and NMC₆₂₂, in combination with a lithium metal anode at 20 °C and even 0 °C for several hundred cycles.

Keywords: Polymer electrolyte, single-ion conductor, lithium metal, NMC, battery

34. Pore filled solid electrolytes with high ionic conduction and electrochemical stability for lithium sulfur battery

Article [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Mong A, Ahn Y, Puttaswamy R, Kim D. Pore filled solid electrolytes with high ionic conduction and electrochemical stability for lithium sulfur battery. *Energy Mater* 2023;3:300035. <http://dx.doi.org/10.20517/energymater.2023.20>

Abstract

High lithium (Li)-ion conductive solid electrolytes with mechanical stability are quite important in the development of long-term safe and high-performance solid-state Li-sulfur batteries (LSBs). Accordingly, we prepared a pore-filling solid electrolyte (PFSE) by introducing poly(ethylene glycol) double-grafted (poly(arylene ether sulfone) (PAES-g-2PEG), ionic liquid (IL), and ethylene carbonate (EC) into a porous polypropylene/polyethylene/polypropylene (PP/PE/PP) substrate. While the PP/PE/PP substrate provides the membrane with the mechanical strength, the PAES-g-2PEG filler provides high Li-ion conductivity due to the facile ion conduction pathway formation via percolation in the presence of IL and EC. This synergistic effect allowed the prepared PFSE membranes to exhibit both high mechanical strength of 200 MPa, thermal stability above 150 °C, and high ion conductivity of 0.604 mS cm⁻¹ with a Li-transfer number of 0.41. Moreover, PFSE membranes also achieved a large electrochemical potential window of 4.60 V and high cyclic stability after 500 h of Li-stripping/plating. The LSB cell based on a PFSE membrane showed excellent electrochemical performance with preserving 95% of initial capacity after 200 cycles at a 0.2 C-rate.

Keywords: Sulfur battery, solid electrolyte, pore-filling, ion conductivity, electrochemical stability

35. Achieving fast and stable Li⁺ transport in lithium-sulfur battery via a high ionic conduction and high adhesion solid polymer electrolyte

Article [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Cui X, Wang X, Pan Q. Achieving fast and stable Li⁺ transport in lithium-sulfur battery via a high ionic conduction and high adhesion solid polymer electrolyte. *Energy Mater* 2023;3:300034. <http://dx.doi.org/10.20517/energymater.2023.19>

Abstract

Solid-state lithium (Li)-sulfur (S) batteries are promising secondary batteries because of their high energy density and high safety, but their practical application is severely hindered by poor Li-ions (Li⁺) transport in batteries due to low ionic conduction of the electrolyte and unstable electrode/electrolyte interface. Here, we address the issue by using a polyurethane (PU)-based electrolyte. The polar urethane/urea groups of PU reduce the hopping energy barrier of Li⁺, which results in high ionic conductivity of 1.8 × 10⁻⁴ S cm⁻¹ (25 °C), high ion transference number of 0.54, and low activation energy of 0.39 eV. In addition, the polar urethane/urea groups endow the electrolyte with high

adhesion, which allows the electrode/electrolyte interfaces to self-heal timely after being damaged during cycling. Benefiting from these merits, a symmetric Li||Li cell using the polyolefin-PU-bis(trifluoromethane)sulfonimide lithium salt electrolyte can cycle for approximately 800 h with a stable overpotential (approximately 40 mV), and a solid-state Li-S battery using the electrolyte delivers a specific capacity of approximately 610 mAh g⁻¹ after testing for 125 cycles at a S loading of about 4 mg cm⁻². Self-healing of the electrode/electrolyte interfaces during cycling was observed in situ by a laser confocal microscope. This study demonstrates the importance of polar groups in electrolytes in maintaining a fast and stable Li⁺ transport, which can be applied to other solid-state batteries.

Keywords: Solid-state Li-S battery, urethane/urea groups, low energy barrier, self-healing electrode/electrolyte interface, *in-situ* observation

36. Understanding of working mechanism of lithium difluoro(oxalato) borate in Li||NCM85 battery with enhanced cyclic stability

Article [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Yang X, Huang Y, Li J, Huang W, Yang W, Wu C, Tang S, Ren F, Gong Z, Zhou N, Yang Y. Understanding of working mechanism of lithium difluoro(oxalato) borate in Li||NCM85 battery with enhanced cyclic stability. *Energy Mater* 2023;3:300029. <http://dx.doi.org/10.20517/energymater.2023.10>

Abstract

Despite the significant advances achieved in recent years, the development of efficient electrolyte additives to mitigate the performance degradation during long-term cycling of high-energy density lithium||nickel-rich (Li||Ni-rich) batteries remains a significant challenge. To achieve a rational design of electrolytes and avoid unnecessary waste of resources due to trial and error, it is crucial to have a comprehensive understanding of the underlying mechanism of key electrolyte components, including salts, solvents, and additives. Herein, we present the utilization of lithium difluoro(oxalato) borate (B) (LiDFOB), a B-containing lithium salt, as a functional additive for Li||LiNi_{0.85}Co_{0.1}Mn_{0.05}O₂ (NCM85) batteries, and comprehensively investigate its mechanism of action towards enhancing the stability of both anode and cathode interfaces. The preferential reduction and oxidation decomposition of DFOB⁻ leads to the formation of a robust and highly electronically insulating boron-rich interfacial film on the surface of both the Li anode and NCM85 cathode. This film effectively suppresses the consumption of active lithium and the severe decomposition of the electrolyte. Furthermore, the presence of B elements in the cathode-electrolyte interfacial film, such as BF₃, BF₂OH, and BF₂OBF₂ compounds, can coordinate with the lattice oxygen of the cathode, forming strong coordination bonds. This can significantly alleviate lattice oxygen loss and mitigate detrimental structural degradation of the Ni-rich cathode. Consequently, the Li||NCM85 battery cycled in LiDFOB-containing electrolyte displays superior capacity retention of 74% after 300 cycles, even at a high charge cut-off voltage of 4.6 V. The comprehensive analysis of the working mechanisms of LiDFOB offers valuable insights for the rational design of electrolytes featuring multifunctional lithium salts or additives for high energy density lithium metal batteries.

Keywords: Lithium metal battery, lithium difluoro(oxalato) borate, Li anode, Ni-rich cathode, SEI/CEI film

37. Research on carbon-based and metal-based negative electrode materials via DFT calculation for high potassium storage performance: a review

Review [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Chen Y, Sun H, Guo J, Zhao Y, Yang H, Li H, Li W, Chou S, Jiang Y, Zhang Z. Research on carbon-based and metal-based negative electrode materials via DFT calculation for high potassium storage performance: a review. *Energy Mater* 2023;3:300045. <http://dx.doi.org/10.20517/energymater.2023.35>

Abstract

The key R&D concern in the domain of new energy in recent years has been the large-scale development of electrochemical energy storage. However, the steep increase in pricing has constrained the further expansion of lithium-ion batteries, primarily due to the ongoing depletion of their scarce lithium supplies. A potential candidate material at the moment is the potassium-ion battery (KIB), which has an anode made of carbon and/or an alloy and rich reserves, offering an excellent theoretical capacity and ideal working voltage. More significant advancements are still required to achieve long life and high energy density, despite the fact that some significant breakthroughs have been reported. The most recent findings from research on carbon-based [graphite, hard carbon (HC), and nanoporous carbon] and alloy-based (mainly including Sb, Sn, P, and its compounds) anodes for KIBs are compiled in this document. Numerous simulations at the atomic level based on particular chemical interactions, phase transitions, ion/electron transport dynamics, and conduction band spin utilizing density functional theory (DFT) calculations have been conducted to thoroughly investigate the storage mechanism of K^+ on various electrode materials. Moreover, this paper examined contemporary structural modification techniques used in carbon- and alloy-based anode electrode materials and applied DFT calculations to confirm the advancement of its thorough tests. To promote the manufacturing of rechargeable KIBs, the challenges and potential of KIBs were also explored in future research.

Keywords: Carbon-based anode, alloy-based anode, electronic structure, DFT theory, potassium-ion battery

38. Toward safer lithium metal batteries: a review

Review [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Kang S, Cheng J, Gao W, Cui L. Toward safer lithium metal batteries: a review. *Energy Mater* 2023;3:300043. <http://dx.doi.org/10.20517/energymater.2023.24>

Abstract

The energy density of conventional graphite anode batteries is insufficient to meet the requirement for portable devices, electric cars, and smart grids. As a result, researchers have diverted to lithium metal anode batteries. Lithium metal has a theoretical specific capacity ($3,860 \text{ mAh} \cdot \text{g}^{-1}$) significantly higher than that of graphite. Additionally, it has a lower redox potential of -3.04 V compared to standard hydrogen electrodes. These properties make high-energy lithium metal batteries a promising candidate for next-generation energy storage devices, which have garnered significant interest for several years. However, the high activity of lithium metal anodes poses safety risks (e.g., short circuits and thermal runaway) that hinder their commercial growth. Currently, modification of reversible lithium anodes is the primary focus of lithium metal batteries. This article presents conceptual models and numerical simulations that address failure processes and offer specific techniques to mitigate the challenges of lithium metal

anodes, including electrolyte design, interface engineering, and electrode modification. It is expected that lithium metal batteries will recover and become a feasible energy storage solution.

Keywords: Lithium metal anodes, safety hazards, modification technology

39. Recent progress on metal-organic framework derived carbon and their composites as anode materials for potassium-ion batteries

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Abstract

Potassium-ion batteries (PIBs) are considered as promising alternatives to lithium-ion batteries (LIBs) due to their abundant potassium resources, cost-effectiveness, and comparable electrochemical performance to LIBs. However, the practical application of PIBs is hindered by the slow dynamics and large volume expansion of anode materials. Owing to their unique morphology, rich pores, abundant active sites, and tunable composition, metal-organic framework (MOF)-derived carbon and its composites have been widely studied and developed as PIB anodes. In this review, the basic configuration, performance evaluation indicators, and energy storage mechanisms of PIBs were first introduced, followed by a comprehensive summary of the research progress in MOF-derived carbon and its composites, especially the design strategies and different types of composites. Moreover, the advances of in situ characterization techniques to understand the electrochemical mechanism during potassiation/depotassiation were also highlighted, which is crucial for the directional optimization of the electrochemical performance of PIBs. Finally, the challenges and development prospects of MOF-derived carbon and its composites for PIBs are prospected. It is envisioned that this review will guide and inspire more research efforts toward advanced MOF-derived PIB anode materials in the future.

Keywords: Metal-organic framework-derived carbon, carbon composites, *in situ* characterization, potassium-ion batteries

40. Fundamentals and perspectives of electrolyte additives for non-aqueous Na-ion batteries

Review [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Despite extensive research efforts to develop non-aqueous sodium-ion batteries (SIBs) as alternatives to lithium-based energy storage battery systems, their performance is still hindered by electrode-electrolyte side reactions. As a feasible strategy, the engineering of electrolyte additives has been regarded as one of the effective ways to address these critical problems. In this review, we provide a comprehensive overview of recent progress in electrolyte additives for non-aqueous SIBs. We classify the additives based on their effects on specific electrode materials and discuss the functions

and mechanisms of each additive category. Finally, we propose future directions for electrolyte additive research, including studies on additives for improving cell performance under extreme conditions, optimizing electrolyte additive combinations, understanding the effect of additives on cathode-anode interactions, and understanding the characteristics of electrolyte additives.

Keywords: Non-aqueous Na-ion batteries, electrolyte additives, solid electrolyte interphase, cathode electrolyte interphase, cell lifetime

41. Advanced and sustainable functional materials for potassium-ion batteries

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Copy here to cite this article: Salado M, Amores M, Pozo-Gonzalo C, Forsyth M, Lanceros-Méndez S. *Energy Mater* 2023;3:300037. <http://dx.doi.org/10.20517/energymater.2023.36>

Abstract

Rechargeable potassium-ion batteries (PIBs) have gained attention as sustainable, environmentally friendly, and cost-effective large-scale stationary energy storage technology. However, although this technology was assumed to perform in a manner similar to that of its monovalent counterparts, huge anode volume expansion and sluggish kinetics are posing challenges in up-scaling it. Apart from the efforts to develop and optimise electrode materials, recent research endeavours have also focussed on the essential role of sustainability. These attempts have often relied on bio-derived and bio-inspired materials to mimic the effectiveness of nature. Furthermore, the use of materials with self-healing properties can alleviate electrode degradation after cycling and augment its electrochemical performance. This review summarises the development of smart materials with self-healing properties that aid in overcoming the present issues of PIBs and highlights the relevance of the interphases. In addition, state-of-the-art design strategies for bio-derived and bio-inspired materials are presented and discussed. The incorporation of recycled and sustainable materials into the manufacturing of PIBs is expected to contribute towards the ultimate goal of achieving truly circular economy ecosystems. Finally, perspectives for further advancements are provided to kindle new ideas and open questions regarding the use of new-generation materials in the development of PIBs.

Keywords: Potassium batteries, self-healing, polymers, sustainable, bio-inspired, circular economy

42. Protective behavior of phosphonate-functionalized imidazolium ionic liquid and its impact on the Li-ion battery performance

Article [Full-Text](#) [PDF](#) [RIS](#)

Copy here to cite this article: Liao K, Song J, Ge J, Si J, Cai X, Luo Z, Zhou M, Liang H, Cheng Y, Milanovic M, Inoishi A, Okada S. Protective behavior of phosphonate-functionalized imidazolium ionic liquid and its impact on the Li-ion battery performance. *Energy Mater* 2023;3:300044. <http://dx.doi.org/10.20517/energymater.2023.33>

Abstract

The commercial lithium-ion batteries (LIBs) rely on lithium hexafluorophosphate (LiPF₆), which is extremely sensitive to moisture and liable to thermal decomposition. Lithium bis (trifluoro methane sulfonyl) imide (LiTFSI), as a promising electrolyte salt, possesses high thermal stability and excellent moisture tolerance. However, LiTFSI is

closely related to severe corrosion of the aluminum (Al) current collector at high voltage. Herein, phosphonate-functionalized imidazolium ionic liquid (PFIL) is developed and utilized as an electrolyte co-solvent to inhibit the oxidative dissolution of the Al current collector. PFIL can suppress Al corrosion by participating in the interface reaction and forming a stable and reliable protective film on the surface of Al foils, as confirmed by X-ray photoelectron spectroscopy. Thanks to the corrosion suppression of the Al current collector, the Li||LiNi_{0.8}Mn_{0.1}Co_{0.1}O₂ (NCM811) cells with PFIL-containing electrolytes exhibit better cycling performance and improved capacity retention. This work proposes an effective strategy for the advancement of high-voltage LIBs and contributes to promoting the widespread use of the sulfone imide-based lithium salts.

Keywords: Electrolyte, aluminum corrosion, ionic liquid, lithium-ion battery, lithium bis (trifluoro methane sulfonyl) imide

43. Highly fluorinated co-solvent enabling ether electrolyte for high-voltage lithium ion batteries with graphite anode

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Copy here to cite this article: Wang R, Wang H, Zhao H, Yuan M, Liu Z, Zhang G, Zhang T, Qian Y, Wang J, Lynch I, Deng Y. Highly fluorinated co-solvent enabling ether electrolyte for high-voltage lithium ion batteries with graphite anode. *Energy Mater* 2023;3:300040. <http://dx.doi.org/10.20517/energymater.2023.28>

Abstract

Conventional ether electrolytes are generally considered unsuitable for use with graphite anodes and high-voltage cathodes due to their co-intercalation with graphite and poor oxidation stability, respectively. In this work, a highly fluorinated ether molecule, 1,1,1-trifluoro-2-[(2,2,2-trifluoroethoxy) methoxy] ethane (TTME), is introduced as a co-solvent into the conventional ether system to construct a fluorinated ether electrolyte, which not only avoids the co-intercalation with graphite but also is compatible with high-voltage cathodes. Li||graphite half-cells using the fluorinated ether electrolyte deliver stable cycling with a capacity retention of 91.7% for 300 cycles. Moreover, LiNi_{0.8}Co_{0.1}Mn_{0.1}O₂ (NCM811)||graphite and LiCoO₂ (LCO)||graphite full-cells (cathode loadings are ≈ 3 mAh/cm²) with the fluorinated ether electrolyte show capacity retentions of > 90% over 200 cycles with a charge cut-off voltage of 4.4 V and > 97% for 100 cycles with a charge cut-off voltage of 4.5 V, respectively. The dense and firm solid electrolyte interphase (SEI) and cathode electrolyte interphase (CEI) formed by the fluorinated ether electrolyte on the anode and cathode, respectively, are key to excellent cell performance. These results have significance for the subsequent application of ether electrolytes for high-voltage lithium ion batteries (up to 4.5 V) with graphite anodes.

Keywords: Lithium ion batteries, fluorinated ether, high-voltage layered oxides, graphite, solid electrolyte interphase, cathode electrolyte interphase

44. Room temperature ionic liquids viscosity prediction from deep-learning models

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Copy here to cite this article: Acar Z, Nguyen P, Cui X, Lau K. Room temperature ionic liquids viscosity prediction from deep-learning models. *Energy Mater* 2023;3:300039. <http://dx.doi.org/10.20517/energymater.2023.38>

Abstract

Ionic liquids (ILs) are a new group of novel solvents with great potential in design-synthesis. They are promising electrolyte candidates in energy storage applications, especially in rechargeable batteries. However, in practice, their usage remains limited due to the unfavorable high-viscosity (η) property at ambient conditions. To optimize the design synthesis of ILs, a systematic fundamental study of their structure-property relationship is deemed necessary. In this study, we employed a deep-learning (DL) model to predict the room-temperature viscosity of a wide range of ILs that consist of various cationic and anionic families. Based on this DL model, accurate prediction of IL viscosity can be realized, reaching an R^2 score of 0.99 with a root mean square error of ~ 45 mPa·s. To further help identify low- and high- η ILs, a low/high- η binary classification model with an overall accuracy of 93% for test prediction is obtained based on the DL model. From the important structure-property relationship analysis governed by the top-rank molecular descriptors of this model, a list of very low- η ILs (i.e., $\eta < 30$ mPa·s) that could be potentially useful in battery electrolytes is identified. Based on the finding of the DL model, it suggests that in order to achieve low- η , grafting IL cations into smaller sizes (e.g., smaller head rings) and short alkyl chains and reducing ionization potentials/energies will help. Meanwhile, for the same cations, further reducing anions in sizes, chain lengths, and hydrogen bonds might be useful to further reduce the viscosity. Thus, with a fine selection and molecular grafting of anionic and cationic species in ILs, we believe fine-tuning IL viscosities can be achieved through the proper design synthesis of functional groups in ILs.

Keywords: Machine learning, deep learning, ionic liquids, batteries, viscosity

45. Stretchable microbatteries and microsupercapacitors for next-generation wearable electronics

Perspective [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Stretchable energy-storage devices are required to power next-generation wearable electronics intimately integrated with the human body. The microbatteries and microsupercapacitors represent promising candidates featuring small footprints and facile system integration. This perspective reviews common strategies to convert conventional rigid devices into stretchable forms. Several prototype soft electronic systems are presented utilizing microbatteries and microsupercapacitors as power sources. We discuss the current challenges and perspectives of the stretchable microbattery and microsupercapacitor. Stretchable forms of miniaturized energy-storage devices often show a significant trade-off between mechanical deformability and electrochemical performances, which present attractive opportunities for the material and engineering community.

Keywords: Microbattery, microsupercapacitor, stretchable electronics, wearable electronics, energy-storage devices

46. Cathode materials in microbial electrosynthesis systems for carbon dioxide reduction: recent progress and perspectives

Review [Full-Text](#) [PDF](#) [RIS](#)

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Zhu J. Cathode materials in microbial electrosynthesis systems for carbon dioxide reduction: recent progress and perspectives. *Energy Mater* 2023;3:300055. <http://dx.doi.org/10.20517/energymater.2023.60>

Abstract

Microbial electrosynthesis (MES) is an emerging technology that enables the synthesis of value-added chemicals from carbon dioxide (CO₂) or inorganic carbon compounds by coupling renewable electricity to microbial metabolism. However, MES still faces challenges in achieving high production of value-added chemicals due to the limited extracellular electron transfer efficiency at the biotic-abiotic interfaces. To overcome this bottleneck, it is crucial to develop novel cathodes and modified materials. This review systematically summarizes recent advancements in cathode materials in the field of electrocatalyst-assisted and photocatalyst-assisted MES. The effects of various material types are further investigated by comparing metal-free and metal materials and photocatalyst materials of different semiconductor types. Additionally, the review introduces the maximum production rate of value-added chemicals and conversion efficiency achieved by these cathode materials while highlighting the advantages and disadvantages of different material types. To the best of our knowledge, in electrocatalyst-assisted systems, the maximum CH₄ yield on graphene aerogel/polypyrrole cathode achieved 1,672 mmol m⁻² d⁻¹, and the maximum Faraday efficiency (FE) of CH₄ reached up to 97.5% on graphite plate. Meanwhile, the maximum acetate yield achieved 1,330 g m⁻² d⁻¹ with CO₂ conversion efficiency into acetate close to 100% on carbon nanotube cathodes. In photocatalyst-assisted systems, the maximum acetate yield could reach 0.51 g L⁻¹ d⁻¹ with the coulombic efficiency of 96% on the MnFe₂O₄/g-C₃N₄ photocathode. Finally, prospects for future development and practical applications of MES are discussed, offering theoretical guidance for the fabrication of cathode materials that can improve production efficiency and reduce energy input.

Keywords: Microbial electrosynthesis, cathode materials, electrochemically active microorganisms, extracellular electron transfer, photocatalyst

47. Fluorine chemistry in lithium-ion and sodium-ion batteries

Review [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

As the peculiar element in the Periodic Table of Elements, fluorine gas owns the highest standard electrode potential of 2.87 V vs. F⁻, and a fluorine atom has the maximum electronegativity. Benefiting from the prominent property, fluorine plays an important role in the development of lithium-ion batteries (LIBs) and sodium-ion batteries (SIBs) in terms of cathode materials (transition metal fluorides, fluorinated polyanionic compounds), electrolytes, and interfaces. In cathode materials, the highly electronegative renders enhanced ionic character of transition metal fluorine bonds and correspondingly high working potential in electrolytes; fluorinated electrolytes possess good antioxidant ability and flame retardance, which can significantly improve the thermal safety of a battery. On an electrode-electrolyte interface, the fluorine-rich inorganic component (such as LiF and NaF) is essential for the formation of a robust and stable solid electrolyte interface on anodes. Despite the remarkable advances achieved in fluorinated cathodes, electrolytes, and interfaces, there is still a lack of

comprehensive understanding of the function of fluorides in LIBs and SIBs. Accordingly, this review briefly summarized the recent progress of fluorine-based electrodes, electrolytes, and interfaces and highlighted the correlation between the composition, property, and function to reveal the fluorine chemistry in LIBs and SIBs. This review will provide guidance for the rational design and targeted regulation of fluorine-dominated high-performance electrode materials, functionalized electrolytes, and consolidated interfaces.

Keywords: Fluorine chemistry, lithium/sodium ion batteries, cathode materials, electrolytes, interfaces

48. Strategies towards inhibition of aluminum current collector corrosion in lithium batteries

Review [Full-Text PDF RIS](#)

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Abstract

Aluminum (Al) foil, serving as the predominant current collector for cathode materials in lithium batteries, is still unsatisfactory in meeting the increasing energy density demand of rechargeable energy storage systems due to its severe corrosion under high voltages. Such Al corrosion may cause delamination of cathodes, increasement of internal resistance, and catalysis of electrolyte decomposition, thus leading to premature failure of batteries. Hence, a systematic understanding of the corrosion mechanisms and effective anticorrosion strategies are necessary to enhance overall performance of lithium batteries. In this review, the corrosive mechanisms related to Al current collectors are systematically summarized and clarified. In addition, an overview on recent progress and advancement of strategies toward inhibiting Al corrosion is presented. In the end, we also provide a perspective with motivation to stimulate new ideas and research directions to further inhibit Al corrosion to achieve high energy density, long cycle life, and high safety of lithium batteries.

Keywords: Al corrosion, corrosive mechanisms, inhibition strategies, lithium batteries

49. PGM-free carbon-based catalysts for the electrocatalytic oxygen reduction reaction: active sites and activity enhancement

Review [Full-Text PDF RIS](#)

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Abstract

Exploring high-activity, low-cost platinum group metal-free (PGM-free) oxygen reduction reaction (ORR) electrocatalysts to replace precious metal Pt is critical for large-scale fuel cell applications. Owing to their wide source, controllable composition, low price, and excellent performance, the PGM-free carbon-based electrocatalysts have attracted great interest in academia and are expected to be an ideal replacement for precious metal electrocatalysts. In this review, we mainly focus on PGM-free carbon-based electrocatalysts and first introduce the ORR mechanisms and the active site classification of PGM-free carbon-based electrocatalysts. Then, we propose four

strategies to enhance the ORR activity of electrocatalysts from the active site perspective based on the relationship between the structure and function of active sites. Finally, we present the current challenges and prospects for developing ORR electrocatalysts exhibiting high performance and stability.

Keywords: Carbon-based electrocatalysts, oxygen reduction reaction mechanisms, active sites, activity enhancement strategy

50. Ionic liquids and their derivatives for lithium batteries: role, design strategy, and perspectives

Review [Full-Text PDF RIS](#)

Copy here to cite this article: Palluzzi M, Tsurumaki A, Adenusi H, Navarra M, Passerini S. Ionic liquids and their derivatives for lithium batteries: role, design strategy, and perspectives. *Energy Mater* 2023;3:300049. <http://dx.doi.org/10.20517/energymater.2023.48>

Abstract

Lithium-ion batteries (LIBs) are the predominant power source for portable electronic devices, and in recent years, their use has extended to higher-energy and larger devices. However, to satisfy the stringent requirements of safety and energy density, further material advancements are required. Due to the inherent flammability and incompatibility of organic solvent-based liquid electrolytes with materials utilized in high energy devices, it is necessary to transition to alternative conductive mediums. The focus is shifting from molecular materials to a class of materials based on ions, including ionic liquids (ILs) and their derivatives such as zwitterionic ILs, polymerized ILs, and solvated ILs, which possess high levels of safety, stability, compatibility, and the ability to rationally design ILs for specific applications. Ion design is crucial to achieve superior control of electrode/electrolyte interphases (EIs) both on anode and cathode surfaces to realize safer and higher-energy lithium-metal batteries (LMBs). This review summarizes the different uses of ILs in electrolytes (both liquid and solids) for LMBs, reporting the most promising results obtained during the last years and highlighting their role in the formation of suitable EIs. Furthermore, a discussion on the use of deep-eutectic solvents is also provided, which is a class of material with similar properties to ILs and an important alternative from the viewpoint of sustainability. Lastly, future prospects for the optimization of IL-based electrolytes are summarized, ranging from the functional design of ionic structures to the realization of nanophases with specific features.

Keywords: Ionic liquids, deep eutectic solvents, lithium batteries, safety, electrode/electrolyte interphases

51. Efficient separation and selective Li recycling of spent LiFePO₄ cathode

Article [Full-Text PDF RIS](#)

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Abstract

Given the fast-growing demand for lithium-ion batteries (LIBs) and the upcoming climax of LIB retirement, efficient recycling of spent LIBs has shown increasing importance in both economic benefit and environmental conservation. The LIBs with LiFePO₄ (LFP) cathodes account for half of the LIB market, so developing an

appropriate recycling way for spent LFP (SLFP) batteries is imperative. In this work, a closed-loop regeneration of SLFP cathodes is proposed, in which a facile cold stimulation route is invented to peel the SLFP layer from Al foil, and then Li and Fe elements are selectively and efficiently extracted from the peeling SLFP layer under mild conditions based on an oxidant of NaClO. The leaching rate of elemental Li could reach 98.3%, and the regenerated LFP synthesized by recovered Li_2CO_3 and FePO_4 shows exceptional performance with a discharge capacity of 162.6 mAh g^{-1} at 0.5 C. This regeneration route has greatly reduced the use of chemical reagents, shortened the process of impurity removal, and, therefore, realized the closed-loop regeneration of SLFP batteries.

Keywords: Spent lithium iron phosphate batteries, cold stimulation, separation, NaClO, selective Li recycling

52. Ion transport, mechanical properties and relaxation dynamics in structural battery electrolytes consisting of an imidazolium protic ionic liquid confined into a methacrylate polymer

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<http://dx.doi.org/10.20517/energymater.2023.49>

Abstract

The effect of confining a liquid electrolyte into a polymer matrix was studied by means of Raman spectroscopy, differential scanning calorimetry, temperature-modulated differential scanning calorimetry, dielectric spectroscopy, and rheology. The polymer matrix was obtained from thermal curing ethoxylated bisphenol A dimethacrylate while the liquid electrolyte consisted of a protic ionic liquid based on the ethyl-imidazolium cation [C_2HIm] and the bis(trifluoromethanesulfonyl)imide [TFSI] anion, doped with LiTFSI salt. We report that the confined liquid phase exhibits the following characteristics: (i) a distinctly reduced degree of crystallinity; (ii) a broader distribution of relaxation times; (iii) reduced dielectric strength; (iv) a reduced cooperativity length scale at the liquid-to-glass transition temperature (T_g); and (v) up-speeded local T_g -related ion dynamics. The latter is indicative of weak interfacial interactions between the two nanophases and a strong geometrical confinement effect, which dictates both the ion dynamics and the coupled structural relaxation, hence lowering T_g by about 4 K. We also find that at room temperature, the ionic conductivity of the structural electrolyte achieves a value of 0.13 mS/cm , one decade lower than the corresponding bulk electrolyte. Three mobile ions (Im^+ , TFSI $^-$, and Li^+) contribute to the measured ionic conductivity, implicitly reducing the Li^+ transference number. In addition, we report that the investigated solid polymer electrolytes exhibit the shear modulus needed for transferring the mechanical load to the carbon fibers in a structural battery. Based on these findings, we conclude that optimized microphase-separated polymer electrolytes, including a protic ionic liquid, are promising for the development of novel multifunctional electrolytes for use in future structural batteries.

Keywords: Structural battery electrolyte, protic ionic liquid, ionic conductivity, relaxation dynamics, confinement

53. Theoretical evidence of self-intercalated 2D materials for battery and electrocatalytic applications

Article [Full-Text](#) [PDF](#) [RIS](#)

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Abstract

Covalently bonded two-dimensional (2D) self-intercalated transition metal chalcogenides (i.e., ic-2Ds) have been recently fabricated experimentally, and their properties are highly tunable by stoichiometry and composition. Inspired by this progress, we focus on the applications of ic-2Ds in the field of electrochemistry and systematically investigate their performance in lithium-ion batteries (LIBs) and electrocatalytic hydrogen evolution reactions (HER). By means of density functional theory calculations, seven 3d-metal ic-2Ds are confirmed to be thermodynamically, mechanically, and thermally stable. The metallicity and abundant active sites endow these ic-2Ds with the potential as excellent electrode materials and HER catalysts. Among them, Ti_7S_{12} and V_7S_{12} exhibit the potential as anode materials for LIBs, showing low Li diffusion energy barriers, suitable open-circuit voltages, and ultrahigh capacity of 745.6 and 723.9 mA hg^{-1} , respectively; Cr_7S_{12} and Co_7S_{12} show promises for HER with moderate hydrogen adsorption strengths. This theoretical study provides a new avenue for the application of newly reported ic-2Ds in various electrochemical energy conversion and storage applications.

Keywords: Self-intercalated 2D materials, transition metal chalcogenides, lithium-ion batteries, hydrogen evolution reaction

54. High-stability room temperature ionic liquids: enabling efficient charge transfer in solid-state batteries by minimizing interfacial resistance

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Abstract

Currently, intensive research is underway to develop stable electrolyte systems that can significantly enhance the performance of rechargeable batteries. Recent advances in solid electrolytes have led to new types of promising systems owing to their high conductivity. This has generated considerable interest in the practical applications of safe batteries. Considering the safety concerns associated with rechargeable batteries, solid electrolytes have become indispensable for the advancement of next-generation battery technologies. However, the increased interfacial resistance at solid-solid interfaces has become a critical challenge. To address this problem, room-temperature ionic liquids (RTILs) have been investigated as functional materials for mitigating the interfacial resistance in solid-state batteries (SSBs). The special properties of RTILs, such as their non-volatility, non-flammability, and high safety characteristics, make them highly promising candidates for safe batteries. Various approaches have been explored for the effective utilization of ionic liquids in SSBs. This review provides a comprehensive discussion on the application of RTILs as electrolytes, considering their electrochemical properties and incorporation into composites to minimize resistance in

SSBs.

Keywords: Room temperature ionic liquid, room temperature molten salt, all-solid battery, solid-liquid interface, solid electrolyte

55. Could potassium-ion batteries become a competitive technology?

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Abstract

Potassium-ion batteries (PIBs) have attracted significant attention as a complement to lithium-ion and sodium-ion batteries (SIBs). PIBs can theoretically provide higher specific energy and power density than SIBs due to lower standard electrode potential of K/K^+ and faster K^+ ion diffusion, maintaining the benefits of low-cost and sustainability. However, research on PIBs is in its infancy; therefore, further efforts are necessary to enhance their performance and position them as a competitive technology. In this perspective, the remaining challenges and possible strategies to advance the development of PIBs are presented.

Keywords: Sustainability, energy storage, potassium-ion batteries, electrolyte, cathode, anode