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Editorial

Advanced Research on Energy Storage Materials and Devices

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With the continuous consumption of global fossil energy and the prevalence of serious environmental problems, renewable and clean energy has attracted increasingly more attention. For that reason, it is urgent to develop new energy storage technologies and realize the efficient utilization of energy. Among various energy storage technologies, electrochemical energy storage is of great interest for its potential applications in renewable energy-related fields. There are various types of electrochemical energy storage devices, such as secondary batteries, flow batteries, super capacitors, fuel cells, etc. Lithium-ion batteries are currently the most used electrochemical devices [1,2]. However, the low theoretical energy density of current lithium-ion batteries limits their future applications. Using Li metal as the anode and developing specific electrolytes can yield an extremely high energy density thus, this field is a current research hotspot.

Lithium metal has a theoretical capacity of 3860 mAh g^{-1} and a low electrochemical potential of −3.04 V [3]. However, there are still several key problems that need to be solved, such as the dendritic problem [4], volume change [5], etc. The current research mainly focuses on designing key electrode materials and battery structures. Regarding the research of Li metal anodes, the current research can be roughly divided into two categories. One category entails the lithium metal anode itself, and comprises topics such as designing 3D structures, constructing artificial SEI, etc. Chang et al. [6] used polycyclic aromatic hydrocarbons to construct in situ π-π stacked organic–inorganic hybrid layers as artificial SEI and achieved a high coulombic efficiency of 99.8%. Liu et al. [7] constructed LMC-Li metal electrodes with a fast Li transport by the electrochemical lithiation of α-MnO_2 materials, thus realizing dendrite-free Li deposition. The other category involves research into the electrolyte. The formation of SEI and acquirement of uniform Li deposition is controlled by adjusting the solvation structure. Oh B. Chae et al. [8] reported a novel electrolyte additive lithium cyanotris(2,2,2trifluoroethyl)borate, and introduced it into a carbonate-based electrolyte, which significantly improved the electrochemical performance of symmetrical batteries and full Li metal batteries. On the cathode side of research, Yang et al. [9] first proposed a rapid internal conversion (RIC) mechanism to accelerate the liquid–solid conversion in sulfur reduction reaction (SRR) kinetics. Furthermore, solid electrolytes are safer than traditional organic electrolytes. For example, Chen et al. [10] used the amidation reaction between maleic anhydride groups and amino groups to prepare a novel cross-linked solid polymer electrolyte with alternating lithium-ion conductive segments.

Except for Li-based batteries, other metals can also display broad application prospects in electrochemical energy storage, such as zinc. Zn exhibits a high theoretical capacity of 820 mAh g^{-1} [11] because of its unique two-electron transfer reactions (Zn^0 to Zn^{2+}). Its high electroconductivity and excellent extensibility endow it with wide applications to electrode materials. Aqueous electrolytes are favored for their inherent safety. However, similar to Li metal batteries, dendritic growth, self-corrosion, and passivation have long restrained further development of zinc-ion batteries due to the use of thermodynamically

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active zinc metal as the anode [12]. To solve these problems, researchers have proposed relevant strategies including electrolyte additives, surface modification, and the construction of artificial SEI layers. Zhang et al. [13] introduced an ion-electronic hybrid conductive scaffold into zinc powder, thereby realizing a corrosion-resistant, soft, and dendrite-free Zn anode. Yang et al. [14] also realized dendrite-free zinc-ion batteries by adding hexaoxacyclooctadecane into a typical zinc sulfate dielectric, which promoted the deposition of zinc ions and reduced the participation of water. In addition, a severe hydrogen evolution reaction occurred between the zinc anode and the aqueous electrolyte [15]. Wang et al. [16] achieved the effective inhibition of the hydrogen evolution and dendritic growth of a Zn metal anode through Sn alloying. In addition to the zinc anode, the performance of the cathode material cannot be ignored either. Gou et al. [17] polymerized in situ a hydrophobic poly(3,4-ethylenedioxythiophene) (PEDOT) conducting polymer film on α-MnO_2 using a biomimetic design, which enhanced the reaction kinetics and stability of the cathode interface.

Solid electrolyte has been shown to act as a mechanical barrier to suppress dendritic growth. Ma et al. [18] further prepared PVDF-HFP/PEO all-solid-state polymer electrolyte based on ionic liquid zinc salt electrolyte, which highly adequately suppressed deep hydrogen evolution and dendritic growth. However, due to the poor diffusion kinetics of Zn^{2+} ions and the low ionic conductivity, the application of all-solid electrolytes in zinc-ion batteries is greatly limited. By contrast, gel electrolyte can improve these two aspects; thus, it is a popular research direction for zinc-ion batteries. For example, Wei et al. [19] achieved wide temperature performance at −20–60 °C and cycle stability (3000 h) for zinc-ion batteries through a composite gel electrolyte (ZS/GL/AN gel).

In addition to the traditional experimental methods, increasingly more research is being assisted by simulation methods, including first-principle calculations, molecular dynamics calculations, and ab-initio molecular dynamics. Through simulation and calculation methods, we can understand many physical and chemical changes inside the battery that cannot be directly observed through experiments. Recently, our group used first-principle calculations and ab-initio molecular dynamics to reveal the phase transition induced by the defect chain reaction mechanism in nickel-rich cathode materials [20].

In summary, the issues raised in this editorial are conducive to interpreting the findings of the present advanced research on energy storage materials and devices. It is the authors' intention to generate questions about the material and approach for the future energy.

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