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Advancing next-generation batteries towards 4S: Stable, safe, smart, sustainable

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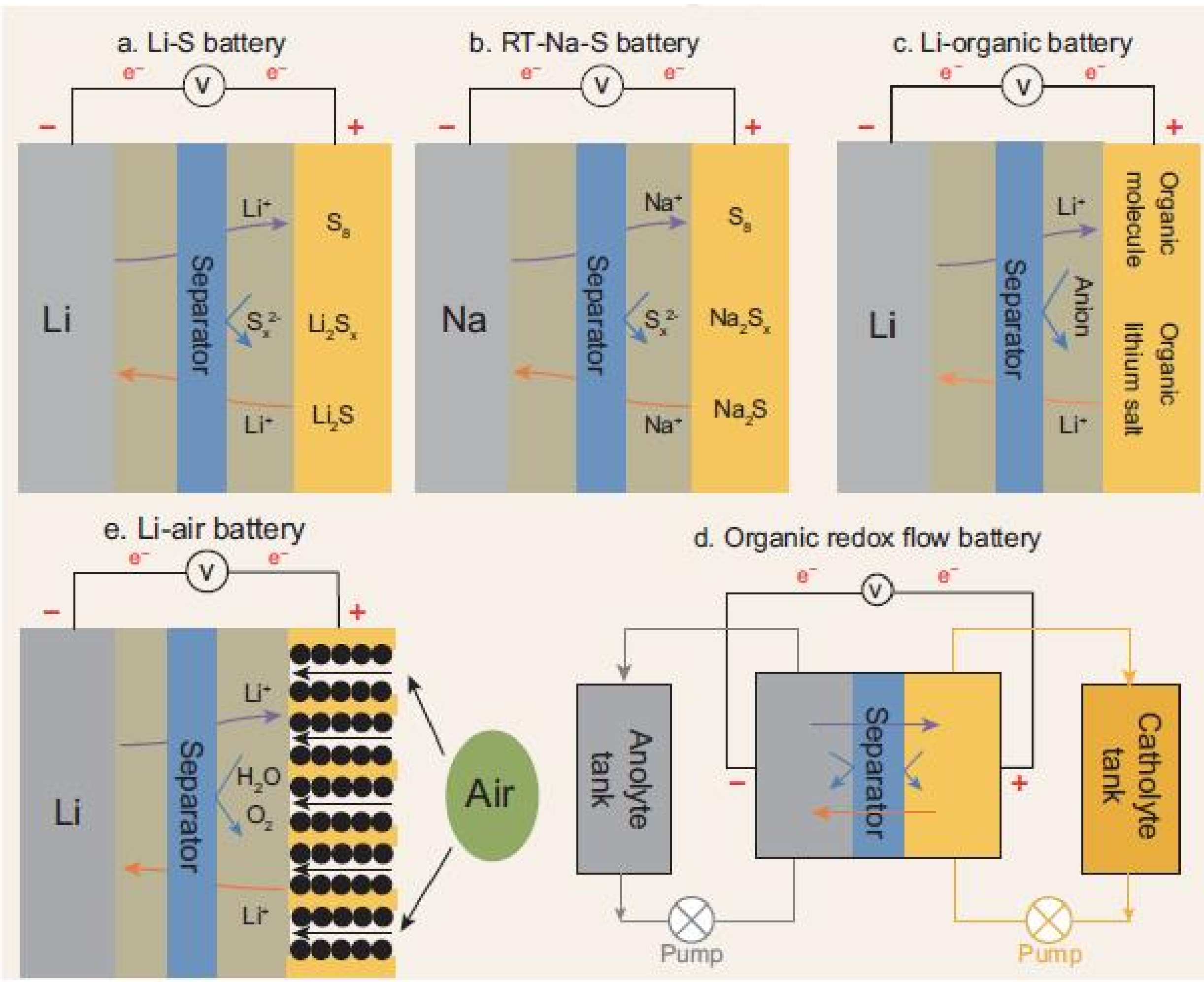

(a) Li-S, (b) room-temperature Na-S, (c) Li-organic, (d) organic-based redox-flow, and (e) Li-air batteries. Credit: ©Science China Press

Next-generation rechargeable batteries are promising candidates for state-of-the-art lithium-ion batteries, owing to their high energy density and preferred cost efficiency. For instance, lithium-sulfur batteries theoretically offer 10 times higher capacity and five times higher energy density. Shu Lei Chou and colleagues from the University of Wollongong have published a review article in *National Science Review* proposing a new concept of 4S (stable, safe, smart, sustainable) batteries. They reviewed the development of functional membrane separators in liquid-electrolyte next-generation batteries, based on which they report four important criteria for guiding the advancement of novel battery systems.

Compared to conventional lithium-ion batteries capable of thousands of cycles, next-generation batteries are plagued by the poor cycling behavior, which is normally caused by active material loss and electrode degradation. Functional membrane separators provide an effective approach to extend the cycling stability of several important battery systems. As can be seen in the figure, this work breaks the boundaries of five types of next-generation batteries: Li-S, room-temperature Na-, Li-organic, organic-based redox-flow and Li-air batteries. Ion-selective materials are applied as the separator to retard the unwanted shuttling of some specific species, e.g., polysulfide diffusion in Li-S batteries. The applied functional membrane materials are nafion (protonated, lithiated or sodiated), polymer of intrinsic microporosity (PIM), polyurethane (PU), metal organic frameworks (MOF), graphene oxide and lithium superionic conductors (LISICON). All these materials, whether polymers or inorganics, possess characteristic pore structures for the transport of the component ions but reject others, therefore preventing side reactions and greatly enhancing cycling stability.

The performance of batteries closely relates to safety concerns, another key criterion for battery development. Separators with important properties of high thermal/dimensional stability, good wetting performance and excellent thermal conductivity can improve battery safety. With regard to the notorious lithium dendrite problem, separator approaches that create a homogeneous environment for lithium deposition enhance battery safety. Additionally, this article reviews the latest works of smart and sustainable separators. For instance, a voltage-responsive smart membrane system was constructed using a doped polypyrrole. When the applied electric field is zero, the membrane allows no ionic current. Otherwise, when a certain reducing electric field is applied, the transport of positive ions is facilitated because the polymer is negatively charged and provides hopping pathways for cations. The pore size is expanded and the polymer turns from hydrophobic to hydrophilic. In addition, renewable polymers like cellulose are studied as promising candidates for fossil-based polyolefin materials to enable sustainable separators. The paper concludes that functional separators need further investigation and are expected to play a key role in advancing next-generation batteries towards the goal of 4S batteries.

More information: Yuede Pan et al, Functional membrane separators for next-generation high-energy rechargeable batteries, *National Science Review* (2017). DOI: 10.1093/nsr/nwx037

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