EPSRC DTP PhD Research Project

Project Title: Sustainable all-solid-state Li-S battery

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Location: Penryn campus

PhD Programme: PhD in Renewable Energy

Project Description:

Battery technologies are crucial for advancing the widespread adoption of electric vehicles (EVs) and portable electronic devices, playing a significant role in achieving the UK's 2035 net-zero electricity target. Lithium-sulfur (Li-S) battery is one of the most promising ''beyond Li-ion'' technologies for a lightweight, earth-abundant, and cost-effective next-generation energy storage device. Owing to a substantially high specific capacity of sulfur and lithium metal, the energy density of Li−S batteries can go far beyond that the conventional Li-ion batteries. However, due to the polysulfide shuttle and nonuniform Li plating and stripping issues, the commercialization of sulfur cathode has been hindered by the resulted in low cycle life.[1]

Replacing the liquid electrolyte with a solid electrolyte is the most promising way to address the above issues. The ability of solid electrolytes to prevent polysulfide dissolution endows Li-S battery with potential for achieving higher specific energy, safe and a longer lifespan than conventional batteries.[2] Various inorganic/organic materials have been investigated for use as solid state electrolyte, and they all have unique pros and cons. Among these, polymers are cheaper and easier to process, provide good interfacial contact with the active materials, particularly through the incorporation of additives and fillers. Cellulose is such a renewable and abundant organic polymer material due to their favourable mechanical, thermal, electrical, and chemical properties.

Albeit broad research has been conducted in this area, there are still challenges specific to practical solid-state Li-S batteries, beyond the typical challenges inherent to solid-state batteries in general.[3] First, finding the right sustainable polymer/composite solid electrolyte materials with high ionic conductivity is critical for enhanced battery performance with low fabrication cost. In the meantime, the solid electrolyte materials should also be satisfied with the mechanical strength and flexibility requirements. Second, the compatibility of solid-state electrolyte materials and sulfur electrode still needs thorough investigation, which requires bulk materials degradation and interfacial deteriorates study. Third, the design of sulfur cathode, such as enhanced ionically and electronically conductivity, should be adapted to the properties of electrolyte materials. For example, during the conversion reaction of sulfur, the associated significant volume change can result in contact loss, chemo-mechanical failure and thus decreased capacity.[4]

Through this project, significant research outcomes are anticipated, including the development of sustainable low-density and high room temperature ionic conductivity electrolyte materials, design of optimized positive electrodes with high sulfur content, practical easy fabrication of all-solid-state Li-S battery devices with great safety, energy-dense (theoretically 2600 Wh kg^{-1}), lightweight with sustainable materials. This research will provide new insights into mechanistic studies and material synthesis, supporting the long-term growth of the UK's EV and energy storage industries. In the meantime, the successful PhD student will benefit from rewarding research experience across material science, electrochemistry, and sustainable energy.

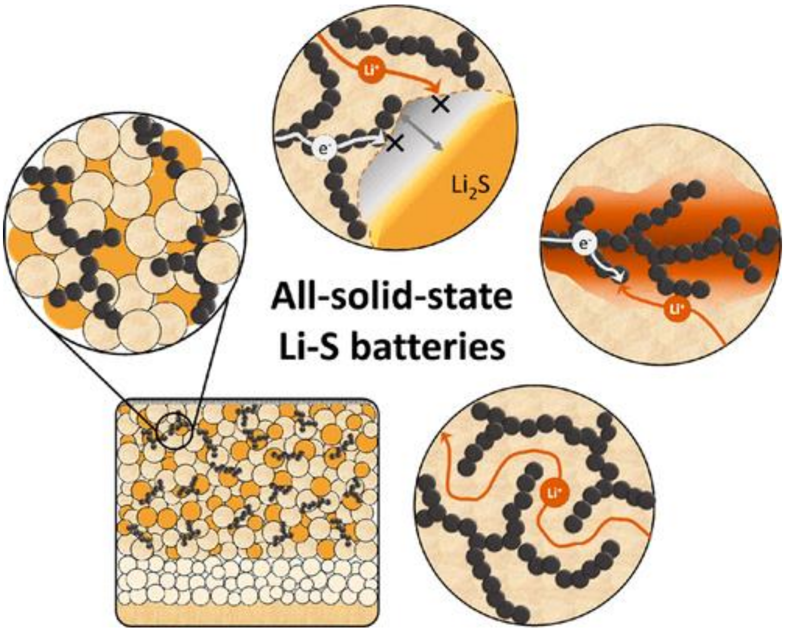

Figure. Significant challenges to solve for solid-state Li−S batteries.[3]

References:

[1] S. Kim et al, Thin Solid Electrolyte Separators for Solid-State Lithium-Sulfur Batteries, Nano Lett. 2022, 22, 10176-10183.

[2] C. Xian et al, Solid-State Electrolytes in Lithium-Sulfur Batteries: Latest Progress and Prospects, Small 2023, 19, 2208164.

[3] S. Ohno et al, Toward Practical Solid-State Lithium-Sulfur Batteries: Challenges and Perspectives, Acc. Mater. Res. 2021, 2, 869-880.

[4] D. Wang et al, Realizing High-Capacity All-Solid-State Lithium-Sulfur Batteries Using a Low-Density Inorganic Solid-State Electrolyte, Nat. Common. 2023, 14, 1895.

Entry Requirements:
Bachelor's degree in chemistry, chemical engineering, physics / materials, energy storage

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