

A High Rate Lithium Sulfur Positive Electrode Using A Quasi Solid State Mechanism

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The Lithium-sulfur (Li-S) battery offers high theoretical energy density but faces challenges like poor cycling performance. Quasi-solid-state (QSS) Li-S batteries, which prevent Li-polysulfide production, present a solution. This study introduces an improved electrode design for QSS Li-S cells by incorporating the solid-state electrolyte $\text{Li}_{10}\text{GeP}_2\text{S}_{12}$ (LGPS) into the positive electrode slurry, where ethyl acetate (EA) is used as solvent, hexyl butyrate (HB) as co-solvent, ketjen black (KB) as carbon and poly(vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP) as binder. The addition of LGPS improved lithium-ion transport, reduced internal resistance, and enhanced reaction kinetics, leading to a high and stable capacity at high current densities.

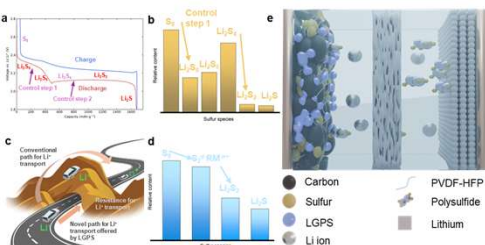


Figure 1: a) A typical 2-plateau charge/discharge profile of lithium-sulfur batteries with two control steps; b) The relative contents of sulfur species in typical 2-plateau charge/discharge process of lithium-sulfur batteries; c) Schematic of the electrochemical reaction in lithium-sulfur batteries with stable sulfur positive electrode; d) The relative contents of sulfur species in lithium-sulfur batteries with a single control step; e) Structure schematic of KB+LGPS battery

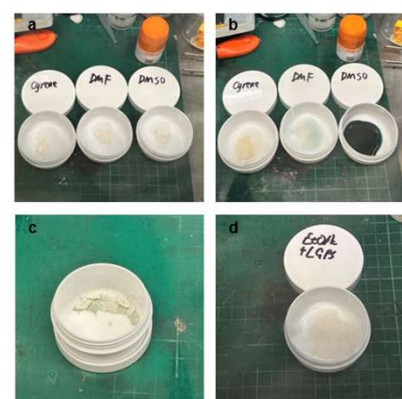


Figure 2: Photographs of LGPS with different solvents: a) LGPS; b) LGPS with dihydrolevoglucosone (Cyrene), dimethylformamide (DMF), dimethyl Sulfoxide (DMSO); c) LGPS with NMP after drying; d) LGPS with ethyl acetate (EA) and hexyl butyrate (HB)

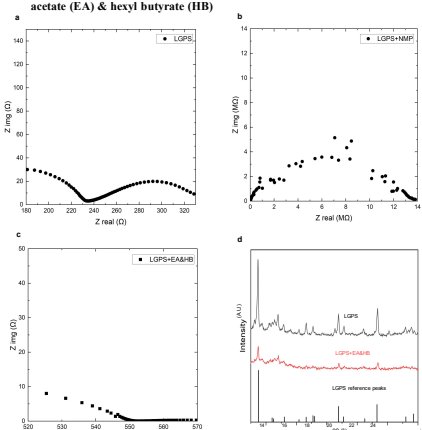


Figure 3: EIS and XRD of LGPS with different solvents: a) LGPS; b) LGPS with NMP; c) LGPS with EA+HB; d) XRD of LGPS, LGPS+EA+HB and LGPS reference peaks



Figure 4: Photographs of coating of PVDF-HFP with EA+HB: a) Coating before drying; b) Coating after drying; c) Coating after cutting and folding

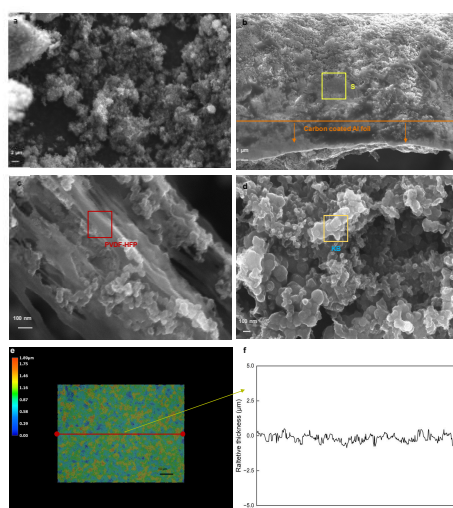


Figure 5: Scanning electron microscope (a-d) and optical microscopy measurements (e-f) of the positive electrode incorporating sulfur, LGPS, ketjen black, and PVDF-HFP binder. The images highlight the presence of a) KB powder; b) a side profile of the electrode highlighting the strong adhesion to the Al foil and dispersion of sulfur in the electrode; c) the binder connectivity between the particles in the electrode; d) KB with good morphology in the electrode; e) surface topography of the electrode obtained using optical microscopy; f) cross-surface profile of the electrode highlighting the uniform thickness observed following manufacture.

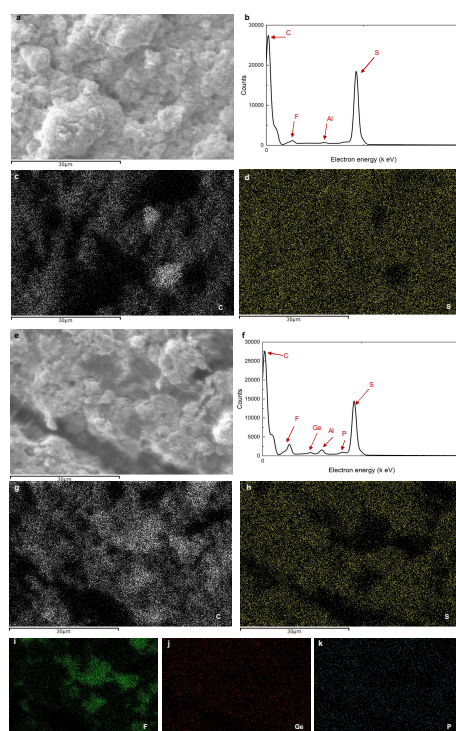


Figure 6: a) EDS raw image of KB positive electrode; b) EDS analysis of KB positive electrode; c) EDS mapping image of C of KB positive electrode; d) EDS mapping image of S of KB positive electrode; e) EDS raw image of KB+LGPS positive electrode; f) EDS analysis of KB+LGPS positive electrode; g) EDS mapping image of C of KB+LGPS positive electrode; h) EDS mapping image of S of KB+LGPS positive electrode; i) EDS mapping image of F of KB+LGPS positive electrode; j) EDS mapping image of Ge of KB+LGPS positive electrode

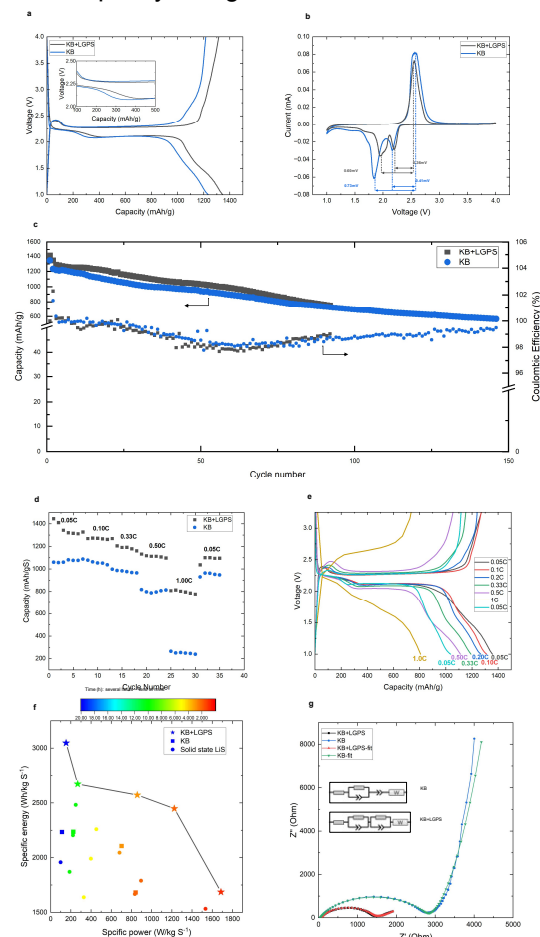


Figure 7: Electrochemical performance of KB and KB-LGPS: during a) 2nd charge and discharge at 0.1C; b) 1st cycle CV; c) long term cycle performance; d) rate performance; e) KB+LGPS rate performance; f) specific power and capacity of this work and solid-state Li-S coin cells reported by different groups; g) EIS of fresh coin cells

- This study developed a new system for deploying a Li-ion conducting component (LGPS) into Li-S electrodes.
- The addition of LGPS altered the main electrode reaction, significantly increasing the reaction kinetics and decreasing the electrode polarisation during the reduction of lithium polysulphide to Li_2S .
- The results confirm that the integration of LGPS into the sulfur positive electrode enhances the performance of quasi-solid-state Li-S batteries, providing new pathways for Li-ion transport and facilitating Li-ion diffusion.
- Offering potential for future improvements based on the optimisation of Li-ion conducting pathways in the positive electrode.

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Reference:
Pang, Boyi, et al. "A quasi-solid-state high-rate lithium sulfur positive electrode incorporating $\text{Li}_{10}\text{GeP}_2\text{S}_{12}$." *Communications Materials* 6.1 (2025): 175.



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