



NEW ELECTROLYTE SYSTEMS FOR LITHIUM-SULFUR BATTERY CELLS

THE TASK

Lithium-sulfur (Li-S) battery cells are characterized by high specific energy and low material costs in comparison with traditional lithium-ion batteries. This cell chemistry is highly attractive for future lightweight storage, mainly to extend the range of electric vehicles.

However low battery life is a tremendous challenge: although current Li-S prototype cells can achieve a specific energy value of 350 Wh kg^{-1} , they degrade substantially within the first 50 charging/discharging cycles. As a result, their range of application is still mainly limited to aerospace industry. At present it is not feasible to use these cells for electric mobility. In future, however, an increase in cycle stability or another increase in the specific energy to more than 400 Wh kg^{-1} can significantly extend the real application potential of the cell type.

OUR SOLUTION

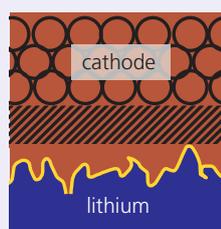
The electrolyte system is a key component for a refinement of the Li-S technology and significantly affects the following cell properties:

- Energy- and power density: In previous prototypes, the electrolyte has represented at least 40 - 50 percent of the cell weight. Since the electrolyte is involved in both dissolution and conversion reactions in the cathode, the kinetics and the completeness of sulfur conversion (specific capacity) immediately depend on the electrolyte share. Values less than 3 ml electrolyte per gram sulfur cannot be achieved by classical approaches.

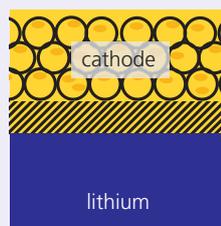
- Cycle stability: decomposing reactions of the electrolytes on the lithium anode surfaces are the main reason for drying out and degrading.
- Self-discharging and energy-efficiency: Highly soluble reaction intermediary products (lithium polysulfides) result in accelerated self-discharging and low charging efficiency (polysulfide shuttle).
- Temperature and safety: Electrolyte solvents significantly define the thermal range of Li-S cell application and the resistance of the cell against misuse and inflammability.

*Electrolyte concepts for Li-S battery cells
left: Principle; right: Electrolyte*

E1: Intermediary complete solubility of lithium polysulfides



E2: IWS electrolyte system, low lithium polysulfide solubility

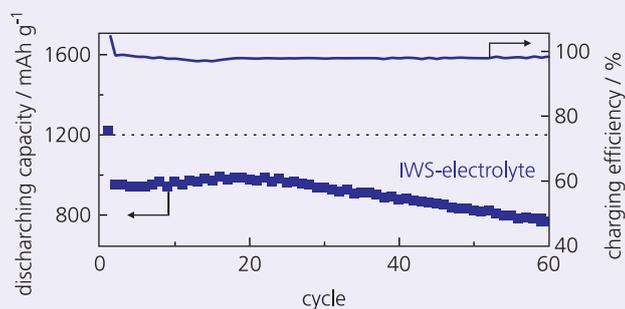


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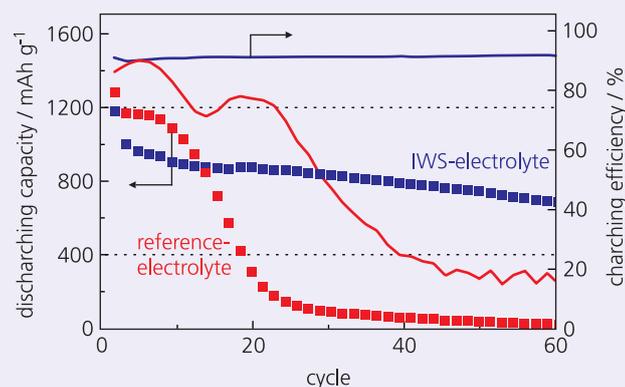
At Fraunhofer IWS, innovative approaches that make it possible to overcome the limitations of these properties are being developed. For this purpose, reducing the polysulfide solubility in the electrolyte system through modified solvent formulations is very promising. This reduction not only restricts the polysulfide shuttles, but also compresses the cathode structure to a wider extent. Stable protective coatings can be formed on the lithium anode and be adapted by electrolyte additives or co-solvents (Fig. 1).

Galvanostatic measurements with IWS electrolyte (5.0 ml g^{-1} -sulfur) in CR2016 button cell indicates high charging efficiency and stable capacity.



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Galvanostatic measurement in IWS prototype cell confirms clear increase in cycle stability and charging efficiency by IWS electrolyte (2.7 ml g^{-1} -sulfur) in comparison with reference electrolyte (3.0 ml g^{-1} -sulfur).



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RESULTS

The non-combustible electrolyte with low polysulfide solubility developed at Fraunhofer IWS causes sulfur to be converted on the cathode's carbon surface in a quasi solid material-solid material conversion. Unlike in the ether based reference electrolyte system, in this approach, the active material is efficiently held back in the cathode. Due to the restricted polysulfide shuttles, the charging efficiency is high, as is confirmed by button cell experiments and tests in multilayer lithium-sulfur prototype cells (Fig. 3).

Corrosion of the lithium anode is prevented by a consistent, in-situ deposited surface coating (solid-electrolyte interphase). For this reason the morphology of the deposited lithium remains smooth and fine-grained for more than 100 cycles. Using the IWS electrolyte, a cell expansion induced by unintentional degradation processes is excluded (Fig. 2). Based on these advantages, the cycles can be made significantly more stable for 40 – 60 cycles. At the first time, the sulfur can be widely utilized even at low electrolyte percentages of 2.7 ml g^{-1} -sulfur (< 40 percent cell weight) or less.

- 2 Left: No gas formation to be detected at prototype cell after cell test with new electrolyte; Right: Expansion of the cell with traditional electrolyte by gas formation after cell test

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