1 Is Lithium-Sulfur Promising?

Introduction Lithium-ion batteries associated with the modern world for the collection of electricity. The lithium-ion cells have many advantages including: high specific energy and load capacity, long cycles and extended shelf life, high capacity, low internal resistance, good coulombic efficiency, simple charging alogrithm and relatively short charging time, low self-discharge.

However, the current lithium-ion battery used as electrical energy storage system (EES) technology does not meet high energy and power requirements for large applications such as electric vehicles with comparable driving range to internal combustion engines (ICEs). In addition, they also are not suitable for use in fixed power networks, which require a higher capacity, lower cost, and greater safety. The main disadvantage of lithium-ion batteries lies in the fundamental chemistry of the cell, which uses transition metal compounds to store electricity through topotactic reactions (inside crystal lattices) on both electrodes.

Lithium-Sulfur Batteries As the conventional Li-ion batteries (LIBs) are already facing their energy density limit, many research studies have been aimed at developing a new energy-storage systems using the lithium-sulfur with high theoretical specific energy. Early limitation of Li-S batteries is the low sulfur utilization and poor cycle life, which results from the poor conductivity of sulfur and its discharge product Li_2S, the shuttling of the soluble intermediates ($Li_2S_n, 4 < n < 8$) between the two electrodes, and the large volumetric change ($\sim 80\%$) between sulfur and Li_2S.

How It Works? The typical Li-S cell uses composite carbon-sulfur as a cathode and metallic lithium as the anode with a liquid organic electrolyte between them. During discharging, the sulfur is electrochemically reduced to Li_2S on the electrode through a complex process with a series of intermediate poly-sulfides. The lithium-sulfur system uses conversion chemistry instead of the topotactic reaction:

$$S_8 + 16Li \longleftrightarrow 8Li_2S$$

With this reaction, each sulfur atom accepts two lithium atoms without the need for additional atoms to preserve the crystalline structure that is required for lithium-ion batteries using transition metal oxides or phosphates as cathode materials.

Difficulties of Li-S batteries Sulfur litigation can be briefly described in the following processes:

$$S_8 + 2e^- \longrightarrow S_8^{2-}$$
$$S_8^{2-} + 2e^- \longrightarrow 2S_4^{2-}$$

These two processes cause a rapid increase in the viscosity of the electrolyte due to an increase in the concentration of poly-silicon anions (PS) and result in a steep drop in voltage up to the lower peak observed when the solution reaches the maximum viscosity.

$$(2x + 2y)Li^+ + 0.25(2x + y)S_4^{2-} + 0.5(2x + 3y)e^- \longrightarrow xLi_2S_2 + yLi_2S$$
$$2Li^+ + Li_2S_2 + 2e^- \longrightarrow 2Li_2S$$

These processes have problems with weak kinetics and high polarization due to the slowdown of solid state ion diffusion and the nature of electronic isolation of Li_2S_2 and Li_2S.

Overall, despite the significant benefits mentioned previously, Li-S batteries continue to face difficulties in their practical application:

(i) the nature of the electronic and ionic sulfur and its discharge products deteriorate the use of sulfur;

(ii) the dissolution of poly-sulfides mediators for the cathodic reaction in a conventional liquid organic electrolytes leads to a so-called "shuttle effect" and leads to significant loss of active cathode material and lithium corrosion on the anode;

(iii) a noticeable 76% change in volume from S to Li_2S leads to destabilization of the cathode structure;

(iv) adoption of a metallic lithium anode results in a weakening of potential safety due to the formation of lithium dendrites and flammability in the liquid organic electrolyte.

Conclusion The Li-S cell has safety and protection needs that exceed those of lithium-ion batteries, as well as requiring a robust housing structure, reducing the energy density of the battery pack. The Li-S cell holds promise for the future, but the current state of the cell's degradation characteristics prevents it from competing with lithium-ion cells. Retrieved from *Next-Generation Batteries with Sulfur Cathodes* by Krzysztof Jan Siczek.