Advanced Materials for Li-S Batteries

Chengdu Liang,[1] Wujun Fu,[1] Zhan Lin,[1] Zengcai Liu,[1] Nancy Dudney,[2] and Jane Howe[2]
Center for Nanophase Materials Sciences,[1] and Materials Science and Technology Division,[2] Oak Ridge National Laboratory, Oak Ridge, TN USA 37831

The lithium sulfur (Li-S) battery system uses the conversion chemistry instead of the topotactic reactions that are widely used in lithium-ion batteries. With a theoretic capacity of 1675 $mAhg^{-1}$ elemental sulfur has been considered as one of the most promising alternative cathode materials for high capacity energy storage. Nevertheless, Li-S batteries have a short cycle-life resulting from a combination of a few scientific barriers: extremely low electronic conductivity of sulfur and its discharge products, dissolution of sulfur in liquid electrolytes, corrosion of lithium anode, and irreversible deposition of lithium sulfide. This research tackles the challenges for achieving the longevity of Li-S batteries by engineering the cathode structures of sulfur-carbon composites.

Bimodal porous carbon materials have been studied as the host materials for the construction of sulfur cathodes. Compositing sulfur with these high surface area carbon materials confers a high electronic conductivity to the sulfur cathode through intimate. The porous structure of the carbon host is specifically tuned for retaining soluble sulfur species through absorption whilst conducting lithium ions through diffusion. The migration of sulfur species in the liquid electrolytes results in the polysulfide shuttle phenomenon that causes “chemical short” of the Li-S cell. Therefore, Li-S cells often have low coulombic efficiency and high self-discharge rates. This research will discuss in details on how the nanostructures of the cathode materials sequestrate the soluble sulfur species on the cathode and hence mitigate the undesirable parasitic reactions. Cell life and performance significantly improved in a well-designed cathode structure.

Irreversible deposition of lithium sulfide is account for the rapid capacity decay of Li-S batteries. To overcome the irreversible deposition of Lithium sulfide, we use lithium bromide as the electrolyte additive that facilitates the reversible formation of lithium sulfide. In the electrochemical cycling, lithium bromide is electrochemically oxidized to bromine at the charging cycle. The resulting bromine reacts with lithium sulfide to form polysulfides and restore the capacity of the cathode by overcharging the cell. Lithium bromide is regenerated at the chemical reaction with lithium sulfide and the discharge cycle. Proof-of-principle experiment for 1000 deep cycles was demonstrated. Advantages and disadvantages of lithium bromide additives will be discussed.

Reference:

Liang, C. D.; Dudney, N. J.; Howe, J. Y., Hierarchically Structured Sulfur/Carbon Nanocomposite Material for High-Energy Lithium Battery, *Chem. Mat.* **2009**, *21*, 4724-4730.
Liu, Z. C., Fu, W. J., Liang, C. D., “Lithium Sulfur Batteries”. In “Handbook of Battery Materials” John Wiley & Sons, Ltd (2011)
Liang, C. D.; Dudney, N. J.; Howe, J. Y., Sulfur-Carbon Composites and Their Application as Cathode Materials in Lithium-Sulfur Batteries, U.S. Provisional Patent Application No. 61/239,132

Acknowledgment:

This work was sponsored by the Division of Materials Science and Engineering, Office of Basic Energy Sciences (synthesis and characterization of electrode materials), and the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Vehicle Technologies of the U.S. Department of Energy through the Batteries for Advanced Transportation Technologies (BATT) Program (Li-S battery assembly and evaluation). The synthesis of carbon materials was conducted at the Center for Nanophase Materials Sciences, which is sponsored at Oak Ridge National Laboratory by the Division of Scientific User Facilities, U.S. Department of Energy.