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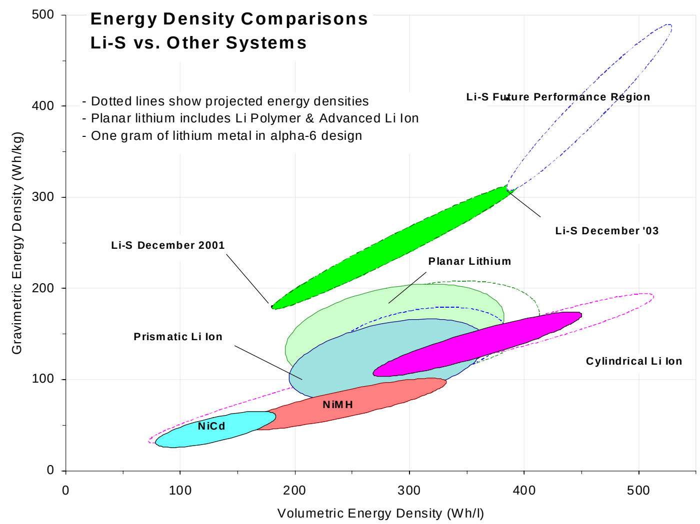
Lithium Sulfur Rechargeable Battery Safety

James Robert Akridge, Ph.D.

Moltech Corporation dba Sion Power Corporation

Lithium batteries have become prevalent in modern electronic devices. The performance improvement brought by lithium chemistry to portable batteries was possible only through advances in understanding the chemistry, assembly precision and heightened quality control of the final battery products beyond the norm for contemporary commercial battery systems. These advances lead to the reliable and safe product that is so prevalent today.



Lithium Sulfur (Li-S) batteries will provide the consumer a quantum leap in performance, ultimately delivering up to 500 Wh/kg and 600 WH/liter. It is mandatory, as it was with lithium ion, that the battery is designed to be safe and that the manufacturing processes and controls necessary to insure reliable, repeatable performance are strictly maintained. Moltech's experiences with Lithium Ion technology will help to facilitate commercialization of the Li-S technology.

Li-S secondary batteries have demonstrated safe performance consistent with the technology's current state of development. Failures of early prototypes have been experienced, but they are of a magnitude and type that will yield to improvements in cell chemistry, packaging and electronic controls for cell charge/discharge management. The research and development areas specifically targeted to enhance Li-S battery safety are electrode stabilization, electrolyte composition, electronic controls and packaging designs internal and external to the cell.

The lithium electrode stabilization concept is an engineered layer on the electrode's surface designed to minimize shape change and dendrite formation. These are the primary modes of lithium electrode and therefore, are the key causes of cell degradation if not prevented. The stabilization layer serves as a barrier to all ions except lithium, allowing cycling of the lithium electrode without loss of capacity while maintaining a pristine surface. This concept has been proven. Lithium secondary batteries having 100 percent depth of discharge (DoD) cycling for many thousands of cycles have been demonstrated (ref 1). However, these systems are solid state. By creating the semblance of a solid-state interface in a liquid electrolyte system, the problems noted above are solved. Efficient use of lithium is a direct and desirable consequence yielding lower weight, volume and cost.

Cell chemistry, especially in the formulation of the electrolyte, is also important for safe performance. The electrolyte, being in intimate contact with the lithium and sulfur electrodes, must be stable under the oxidizing and reducing conditions experienced during the charging and discharging of the cell. It must also be stable upon exposure to elevated temperatures and with aging. The electrolyte formulation has been designed to react to over discharge with an accompanying rise in impedance to signal the need to shut the cell down, thus preventing damage. The cell returns to normal operation once the over discharge condition is removed. This internal chemistry protection is invaluable for safe use, should the electronic controls for over-discharge fail or if the cell is exposed to a large over voltage discharge condition.

Quality control of raw materials to produce the lithium sulfur cell is critical to eliminate safety defects. To prevent undesired reaction, impurities in separator or electrode materials must not be introduced into the cell. To attain these goals, and thus a defect free product, state-of-the-art quality control with strict control practices and procedures is mandatory.

Production engineering for the assembly of batteries is another key to safety. A poorly developed process and improperly designed equipment will not achieve the specification. In addition, it is important to understand the critical elements in the production process to ensure control is maintained as materials and equipment evolve with time.

Li-S cells can accommodate over-charge. The cell creates a chemical shuttle between the lithium and sulfur electrodes thereby shunting over charge currents. This permits the cell to tolerate up to three times the specified C rate charging, and this is accomplished without electronic controls. Continued improvements in electrolyte compositions are expected to bring electrical abuse under full control without the reliance on electronics. This does not mean electronic controls will be eliminated entirely but it does mean that the chemistry itself can provide its own inherent safe response to extreme charges or discharges.

Electronic controls will need to be tailored for this specific chemistry. The end user must not be able to damage the battery through normal use conditions and the packaging should resist as much abuse as possible. Unlike Nickel Metal Hydride, Nickel Cadmium, or Lithium Ion batteries, there is currently no off-the-shelf commercially available safety or charger electronics. Due to the cell chemistry differences compared to conventional Lithium Ion based technologies, the existing electronics are not directly applicable. Therefore new electronics have to be designed to provide optimal safety and charging. However, in comparison to Lithium Ion at the same state of development, the electronics required are not as complicated and therefore less costly.

Electronics to complement the cell chemistry are being intensively explored. The safety electronics are based on double redundancy digital and analog modules. Combining these electronics features with a thermistor (i.e., PTC) and a hard fuse will insure the safety of the battery.

For charging purposes, a micro-controller is used in conjunction with the safety circuit to permit high rate charging while not degrading cycle life. Proprietary charging algorithms tailored specifically for the Li-S chemistry will be used. In addition, an internal smart bus may be employed to differentiate various cell models and adjust charging protocols accordingly. The final production unit will include a single chip, power management solution delivering safety and optimum performance.

Perhaps the two most valued attributes of a battery are outstanding performance and unconstrained safety. Both must be delivered to the consumer simultaneously. Actions should be put into effect at the very beginning of the planning stages to help implement state-of-the-art performance and safety. Everything from product design to the capability of the engineering line to the product package design determines the commercial success of the battery. By implementing these and by providing continuing advancements in the technology, Li-S will offer consumers the type of battery they want, along with outstanding performance and safety.

Reference

1: "A Microfabricated Solid State Secondary Li Battery," S.D. Jones & J.R. Akridge, Solid State, Ionics, 86-88, pp. 1291-1294, 1996.

James Akridge currently serves as the Vice President of Technology for Moltech Corporation doing business as SION POWER CORPORATION where he is leading the development of the company's cutting-edge rechargeable battery technology, Lithium Sulfur. Jim began his career with Eveready Battery Company as an Electrochemist. Jim has B.A. and M.S degrees in Chemistry from California State University, Fresno and a Ph.D. degree in Electrochemistry from the University of California, Santa Barbara.