Safety of Lithium Ion (Li-Ion) Batteries

The dense packing of energy makes Li-ion batteries susceptible to safety hazards when abused. Of particular concern are conditions that dramatically increase the internal temperature of the cell. Two conditions that are potentially unsafe are short circuit and severe overcharge.

Short Circuit of Li-Ion Batteries: It is obvious that short-circuiting an energy dense battery cell will increase its internal temperature to high values in a relatively short time. Manufacturers of small 18650 Li-ion cells have been able to overcome safety hazards from short circuit through several design features of the cell. The key to the design of a safe cell is to incorporate features that would prevent the buildup of excessive heat that can vaporize the organic solvents in the cell, resulting in internal pressure build-up, cell rupture and venting. Generally this problem is mostly attributed to large Li-ion cells rather than 18650 cells, since the large cells are unable to quickly dissipate the internally generated heat and prevent pressure buildup.

Small cells such as the 18650 Li-ion cells with a capacity of about 2 ampere-hours have several layers of protection against hazards from short circuit. First of all, the small size of the 18650 cell enables the heat generated during a short circuit to be dissipated fast enough from the inside to the outside to prevent buildup. In addition, the cell incorporates a current limiting device, referred to as a PTC (positive temperature coefficient), that erves as a reversible thermal fuse and over-temperature protection device. As a back-up to the PTC, shut-down separators and/or current interrupting devices (CID) can permanently limit current flow during internal short circuit and prevent excessive pressure build-up and cell rupture. If all of these safety features fail the cell incorporates a pressure relief disc to safely vent the gases generated. The gases generated are non-toxic organic compounds, hydrocarbons and carbon dioxide.

Overcharge of Li-Ion Batteries: A Li-ion cell is usually charged to a potential of about 4.2 V. The cell generates very little heat during this normal charging process. Experiments have revealed that it can be safely charged to a potential of at least 4.5 V without excessive heat buildup. Excessive heating of and pressure buildup and heating in the cell can occur if the voltage exceeds 4.5 V and hovers around 5 V. Such a severe overcharge of Li-ion cell leads to the plating of elemental Li on the carbon anode and the formation of chemically unstable cobalt oxide. Our work indicates that the safety hazard upon overcharge does not originate from the plated Li but from the unstable cobalt oxide cathode although the plated Li on the anode may have a role in exacerbating the ensuing runaway reaction. A cell would encounter this situation if the charger fails and the electronic circuitry in the cell fails. In a battery built with cells connected in series, overcharge can occur if each of the cells is not electronically protected against this condition.

The 18650 cells are safeguarded against excessive heat buildup from the rare event of an overcharge by means of all of the above features that are also used to protect it against short circuit. When these cells are combined to form batteries, each cell is further protected against overcharge with electronic circuitry. Large Li-ion batteries may not contain all the necessary safety features, and also suffer from the basic problem of using large monolithic cells for which adequate internal protection mechanisms have not yet been developed. When such large batteries experience a safety hazard, there is a tendency to blame Li-ion batteries as a whole.

There is no question that Li-ion batteries can be unsafe if they are abused. The majority of incidents occurred in the early days of portable equipment. This was because the early cells did not have all of the safety features of today's cells. Other problems may occur in battery packs that incorporate poor electronic protection circuitry, or if the pack is exposed to mechanical abuse, such as puncturing a cell with an electric drill or fork lift truck.

For additional discussion and consulting on the safety pf Li-ion batteries consult Dr. K. M. Abraham at E-KEM Sciences

References:

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