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High-Power Li-ion Cells for Passive Thermal Management and Failsafe Operation

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Li-ion battery safety is a priority of most commercial applications. Heat dissipation becomes a special concern for high power batteries. Especially to be cost competitive for the hybrid vehicle application, the battery design requires inherent reliability and safety. InvenTek's rolled–ribbon (1) is undergoing tests to demonstrate these requirements.

The unique disc-shape of InvenTek rolled-ribbon Li-ion cell (7.5Ah) enables creation of a compact, high power density, stacked-cell battery. The specific energy of a high-performance battery (90-135 Wh/kg) is coupled with the specific power of an ultracapacitor (2.5kW/kg). The battery can be passively-cooled for high pulse power applications where conventional design would require active cooling. Electrode ribbons act as cooling fins to remove heat from the Celgard separator interface. Heat is transferred to the heat-conducting metal cell hardware that acts as heat sink. Heat removal is further augmented by large area contact between electrode and cell hardware and also by the short path length from electrode interface and cell hardware. An inherent thermal management feature of rolled-ribbon cells is that no heat must exit the cell by crossing a Celgard separator layer. The rolled-ribbon battery can be continuously discharged to full capacity at 15C and not overheat. The cell has a pressure regulating, "burping" seal. Only modest temperature rise result. Power pulses gave a temporary 2-3 ^{o}C rise and high rate discharge gave a 10 ^{o}C rise. The temperature differential from center to the edge of cell never exceeded more than 1 ^{o}C.

To enhance safety, addition of flame retardant (FR) electrolyte additive (eg., hexaethoxy-triaza-phosphazene) is used to suppress thermal runaway and for self extinguishing cell incineration (2). Addition of FR cannot reduce cell performance relative to cell operating temperature. The effect of temperature on the lithium–ion cells performance is evident especially when the battery is operating at low temperature (<10^{o}C). At such low temperatures a considerable loss of the cell capacity is observed mainly due to the decrease of ionic conductivity, electrochemical reaction rates, electrical conductivity, and solid lithium diffusion at low temperature (3,4). On the other hand, although a better performance is expected at higher temperature, most lithium-ion cell manufacturers recommend operation below 65^{o}C to avoid thermal runaway and hence cell rupture (5). Due to the interdependence of temperature, performance, and safety, the thermal behavior of batteries is of paramount importance in selecting the electrode materials, operating conditions and extending the safety and life of the battery.

Exothermic reactions of electrodes with the electrolyte can cause the Li-ion cells to undergo thermal runaway (6-8) at relatively low temperatures especially at increasing state of charge. The electrochemical and thermal runaway behavior of high-power InvenTek cells were evaluated using galvanostatic techniques (constant current charge-discharge and HPPC profile) and Accelerated Calorimetry (ARC). The thermal studies of the carbonaceous anode and $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$ cathode at various state-of-charge were carried out using Differential scanning calorimetry (DSC) and ARC in an effort to explain the full cell thermal runaway. FR addition studies will be discussed in detail.

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