Simulation of External Short Circuit, an On-Field Relevant Battery Safety Event, with AutoLion-1D™

Introduction

Li-ion battery safety in the field and battery system cost are the two paramount challenges for mass-scale adoption of Li-ion battery-based systems for vehicle electrification and for energy storage units. Replicating on-field safety events such as internal short or external shorts due to bad connections or leakage of coolant that might be slightly electronically conductive are not always easy to replicate in the lab. In addition, development of high capacity cells (more energy in the cell conventionally means more prone to hazardous safety events) is posing a challenge to cell manufacturers to manufacture inherently safe high energy density cells.

Challenge

Investigate external short circuit of 18650 cells using AutoLion-1D™. Three different 18650 cells designed for high power (1.2Ah, 100 Wh/kg), medium energy (e.g. PHEV cell) (2.2Ah, 150 Wh/kg) and high energy (2.8Ah, 200 Wh/kg) are chosen.

Technology Used

AutoLion-1D™

Setup

- All cells have NMC cathode and graphite anode
- 2.8Ah cell design follows the latest industrial strategy in 18650 cell development for consumer electronics where the volume of active materials is maximized and the pore volume for electrolyte transport is reduced to ~20% (1.2 Ah power cell simulated here has 58% cathode porosity, 2.2Ah PHEV cell has 29% porosity, 2.8Ah energy cell has 18% porosity)
- CR (constant resistance) load profile is chosen with a short resistance of 100mΩ
- All cells start with 100% SOC and an ambient temperature of 25°C
Benefits

- AutoLion-1D™ with its intuitive and user-friendly user interface, fast and robust simulation capabilities enables users to evaluate cell design and its impact on on-field relevant safety incidents.
- Counterintuitive to conventional wisdom, the 2.8Ah cell reach the cut-off voltage of 2.2V prematurely, resulting in a relatively benign cell temperature rise.
- If the criterion of 100°C as the safety threshold is used, clearly both the high power (1.2Ah) and high energy (2.8Ah) cells are safe, while the medium-energy (2.2Ah) cell is unsafe.
- This surprising result of safe 2.8Ah cell can be explained by the electrolyte distribution across the cell; due to low electrolyte volume involved in the high-density electrode cell, after only 40s short-circuit discharge, the electrolyte in the anode and cathode reaches 3M and nearly 0M, respectively, both leading to nearly zero ion conductivity.
- AutoLion-1D™ simulation results clearly show that the limiting current for high-density electrode cells, with minimal pore volume for electrolyte, is dictated no longer by the electrode active material but rather by electrolyte amount and transport properties.
- Such a paradigm shift in the cell current-limiting controlling mechanisms is of paramount importance to the performance and safety optimization of high-density electrode cells prevalent in the consumer electronics industry.