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Blended Cathode Design for High Energy and Power Density with AutoLion-1D™

Introduction

PHEVs and EVs require not only high energy density but also moderate rate power capability and pulse power capability over the full range of state of charge (SOC). The widely used $Li(NiMnCo)_{1/3}O_2$ (NMC) cathode material delivers limited power at low SOC level due to the increased impedance, which is an inherent nature of layered oxides. On the other hand, $LiFePO_4$ (LFP), an olivine material, has been shown to have excellent rate capability by using nano-size particles with good conductive agent. However, the energy density of LFP is relatively low due to its low equilibrium potential (~3.4V vs. Li/Li^+). Blended NMC-LFP provides a good solution that achieves both the energy and power capability.

In this case study we demonstrate the use AutoLion-1D™ to rapidly evaluate the energy and power capabilities of a 2Ah 18650 cell using graphite as the anode and blended NMC-LFP as the cathode.

Challenge

Design a cell with blended cathode for PHEV/EV applications and rapidly asses its energy and power capabilities over a full range of SOC and a wide range of temperatures using AutoLion-1D™.

Technology Used

AutoLion-1D™

Setup

- Two 18650 cells are designed: One uses NMC as the cathode, the other one use NMC-LFP as the cathode (75:25 wt.). Graphite anodes are used in both cells. Cathode loading of $3.2 mAh/cm^2$ and electrode thickness of 0.17mm (double-sided costing) are used for both cells to achieve the same design capacity.
- A 10 second current pulse at 3C was applied to the cell to characterize its power capability at different cell voltages/SOCs. Area specific impedance (ASI) is defined in equation (1) and is calculated to evaluate cell's power capability:

$$R = \frac{OCV - V_{cell}}{I} A \qquad (1)$$

- As shown in Figure 1, the ASI of pure NMC cell increases sharply when cell voltage drops below 3.5V. However, the ASI at low voltage is significantly lowered by incorporating the LFP into the cathode. Low ASI implies smaller voltage loss. Thus the blended cathode is able to deliver more power at low SOC.
- Figure 2 displays the discharge performance of the 18650 cell with blended chemistry. The plateau of LFP is clearly reflected in low SOC region, indicating that NMC is discharged first. Therefore, the high power of LFP can be used to increase cell's power capability at low SOC.

Results

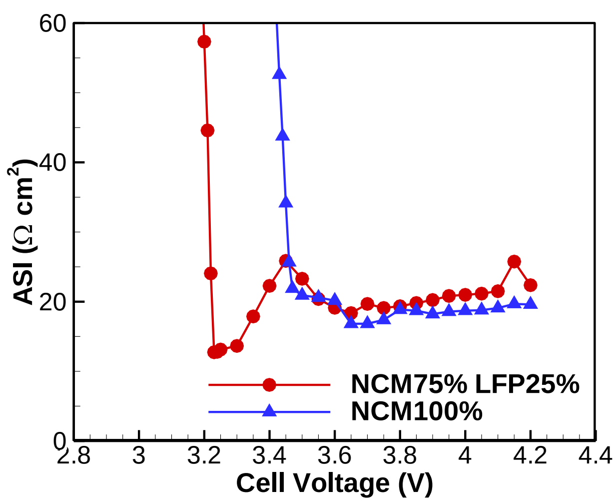

Figure 1: Simulated electrochemical impedance for NMC-LFP blended cathode (red line) and NMC cathode (blue line)

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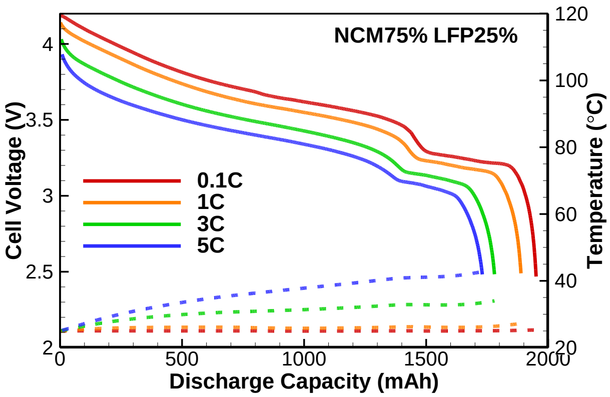

Figure 2 Discharge performance of Li-ion cell using blended NMC-LFP cathode

Benefits

- With its user-friendly user interface, AutoLion-1D™ enables users to design Li-ion cells with blended active materials and evaluate the power and energy capabilities.
- Blended material composition for a given application and performance requirement can be rapidly optimized using AutoLion-1D™