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Performance and Safety of Commercial Li-ion Cells

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Motivation & Objectives

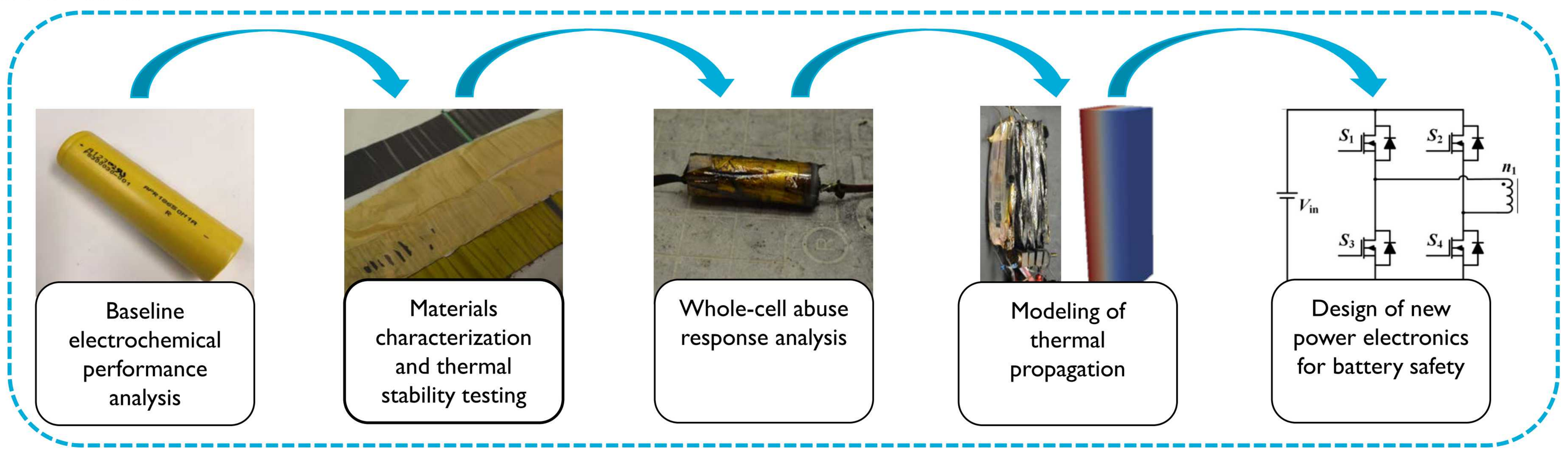
Experimentally quantify Li-ion battery failure at the materials level during abusive and non-abusive conditions to enable:

…informed decision making about preferred operating conditions for different batteries

…modeling of battery degradation and thermal propagation

…translation of failure understanding to technologies for intervention

…safe and reliable energy storage for a resilient grid

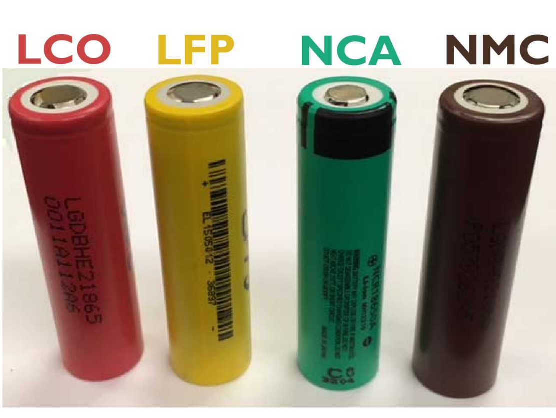


Performance

Goal: Understand difference in aging behavior as a function of chemistry, environment, and use case for popular commercial Li-ion chemistries

Design of experiment approach with two cells at each set of conditions, all within manufacturer specifications

Commercial cell specifications



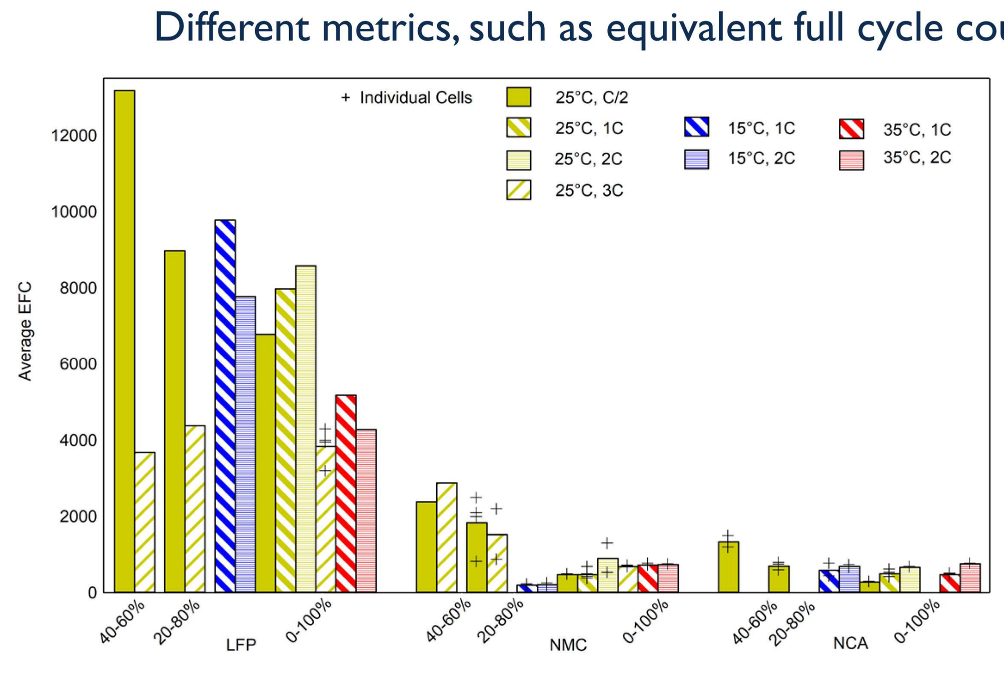
Battery	LFP (A123)	NCA (Panasonic)	NMC (LG Chem)
Capacity	1.1 Ah	3.2 Ah	3.0 Ah
Voltage	3.3 V	3.6 V	3.6 V
Max Discharge Current	30 A	6 A	20 A
Operating T	-30 to 60°C	0 to 45°C	0 to 50°C

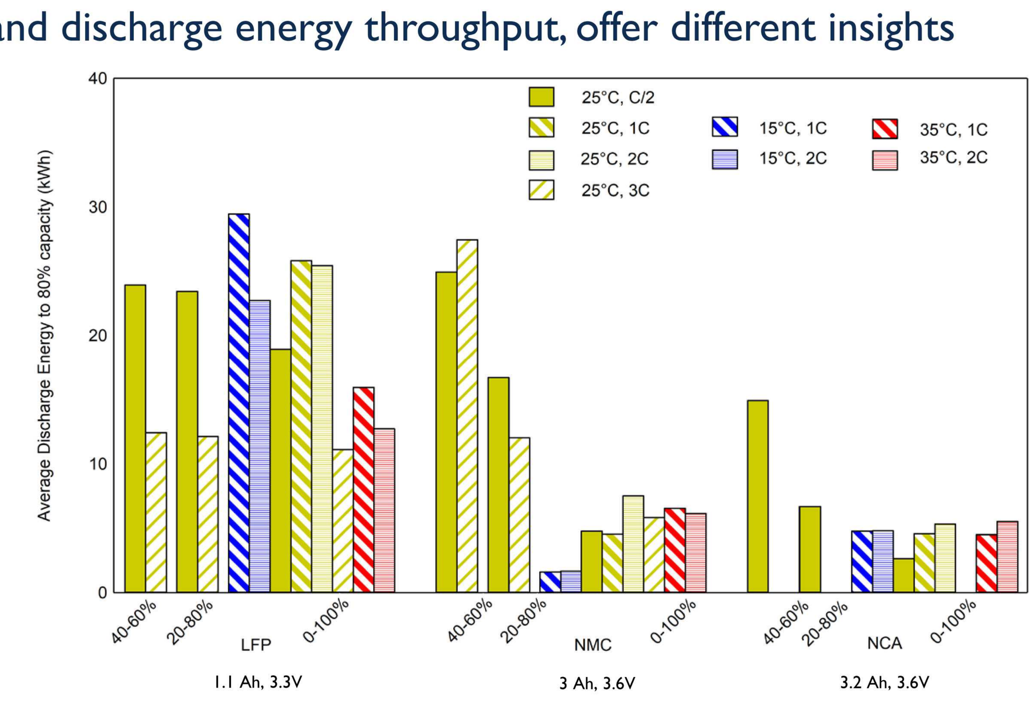
Cycling conditions for all cells

DOD, Temperature, Discharge Rate*			
40-60%, 25°C, 0.5C	0-100%, 15°C, 1C	0-100%, 15°C, 2C	40-60%, 25°C, 3C
20-80%, 25°C, 0.5C	0-100%, 25°C, 1C	0-100%, 25°C, 2C	20-80%, 25°C, 3C
0-100%, 25°C, 0.5C	0-100%, 35°C, 1C	0-100%, 35°C, 2C	0-100%, 25°C, 3C

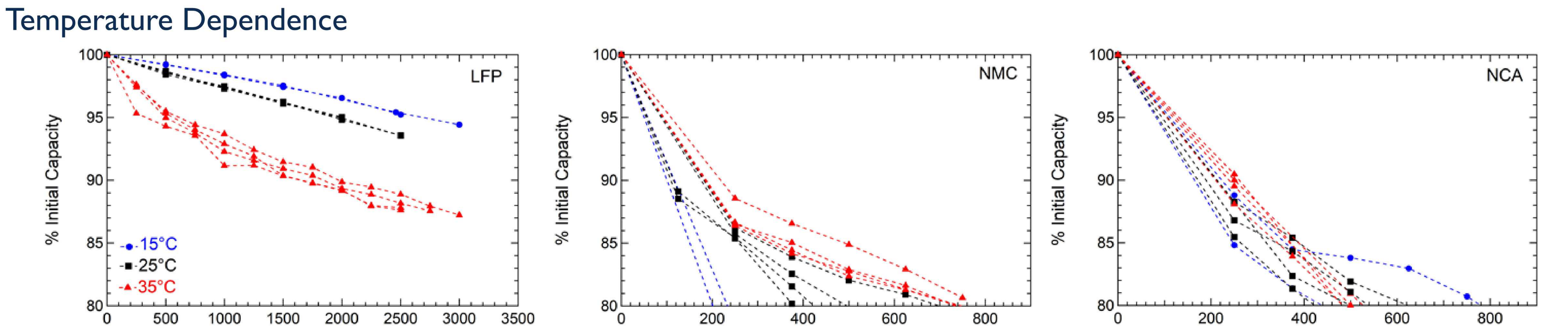
*Charge rate always C/2

Different metrics, such as equivalent full cycle count and discharge energy throughput, offer different insights

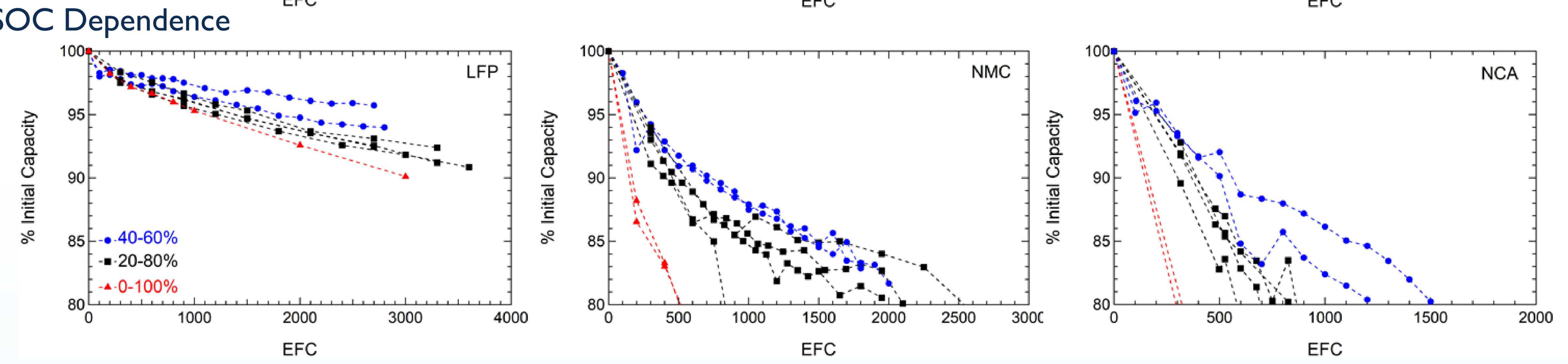




Temperature Dependence



SOC Dependence



Safety

Goal: Relate component to whole cell failure for popular commercial Li-ion chemistries

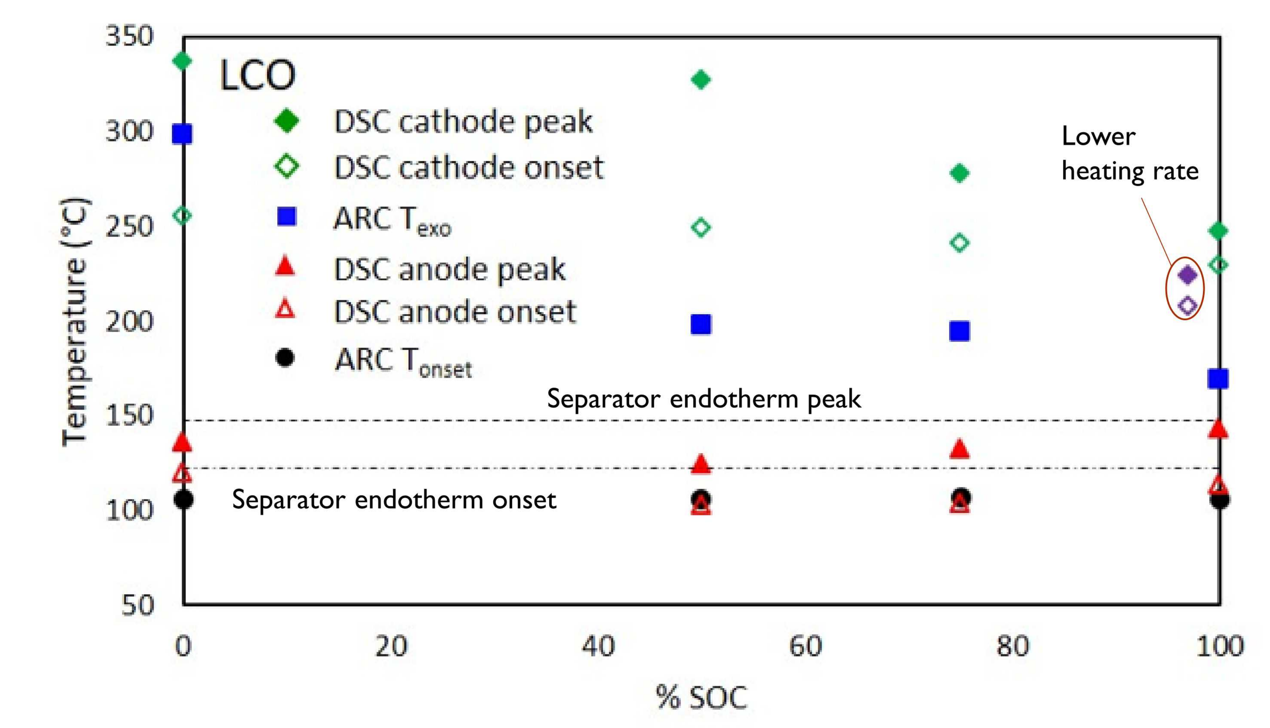
Completed multi-scale comparison using:

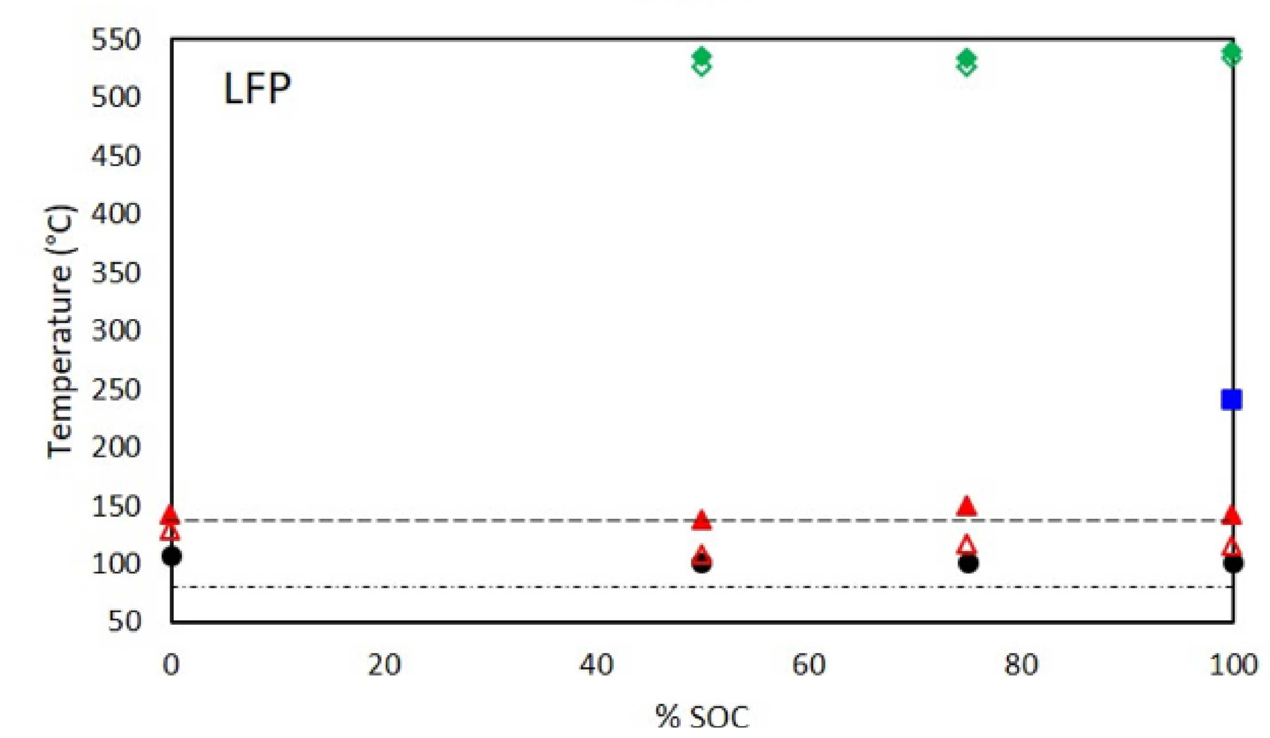
•Whole cell calorimetry for LCO, LFP, NCA at 0, 50, 75, and 100% SOC

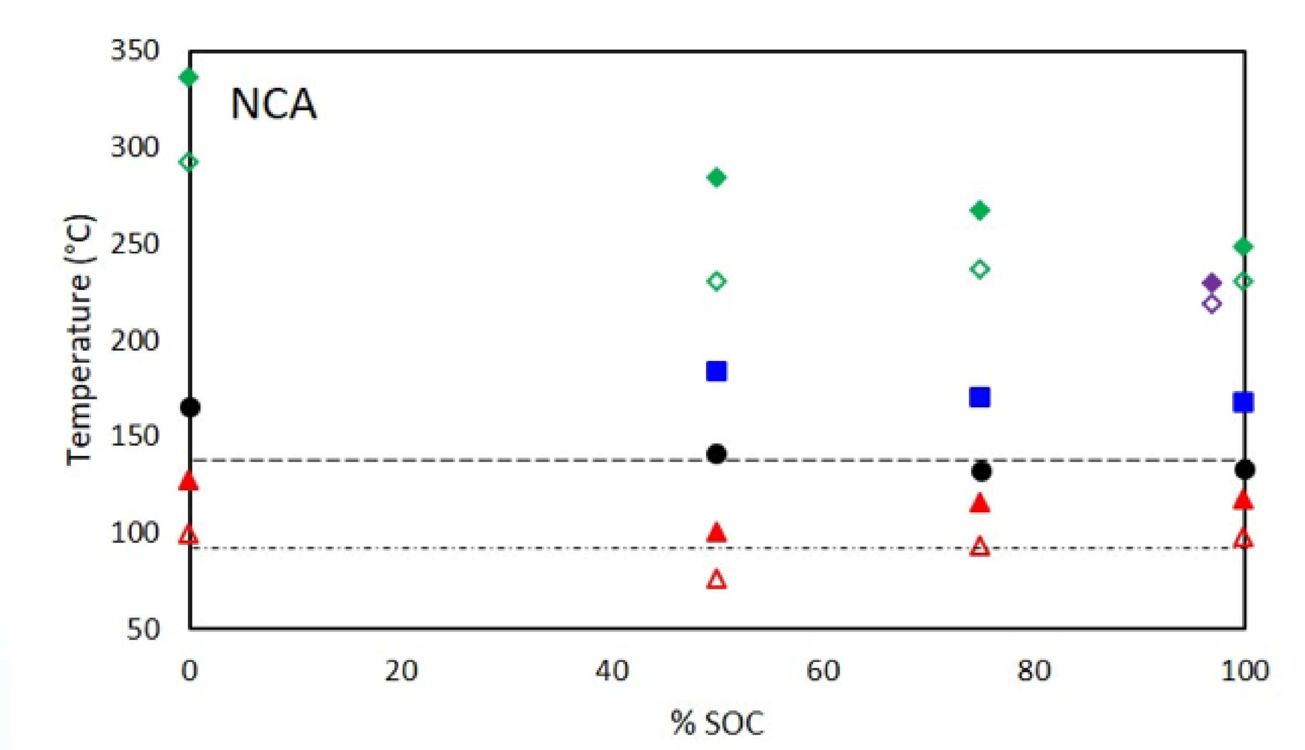
•Calorimetry of separator, anode, and cathode components at 0, 50, 75, and 100% SOC

• Temperature-resolved X-ray diffraction of cathode and anode at 0 and 100% SOC

Onset temperatures show progression of failure across SOC







Conclusions

- Equivalent full cycle count is the most common literature metric, but other metrics such as discharge energy are more useful for application
- Dependence on different variables is highly chemistry-specific (especially temperature)
- Variability in onset temperatures can be traced back to cell chemistry and SOC
- SEI decomposition is typically the onset of thermal runaway and does not vary with SOC
- LFP cathode does not contribute to runaway; metal oxides contribute only in combination with solvent

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