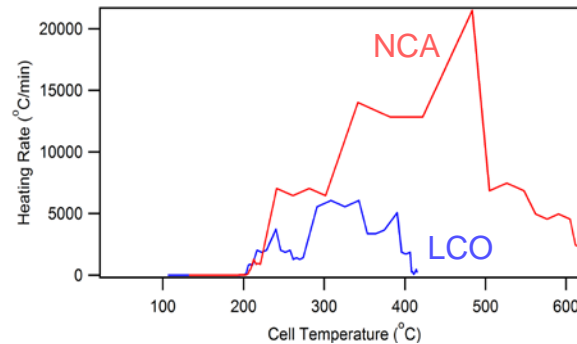


Exceptional service in the national interest



Baseline Electrochemical Performance of Commercial Lithium-Ion Cells

Heather Barkholtz, Armando Fresquez, Babu Chalamala, and Summer Ferreira



Sandia National Laboratories is a multi-mission laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2017-1676 C

System selection fraught with uncertainty

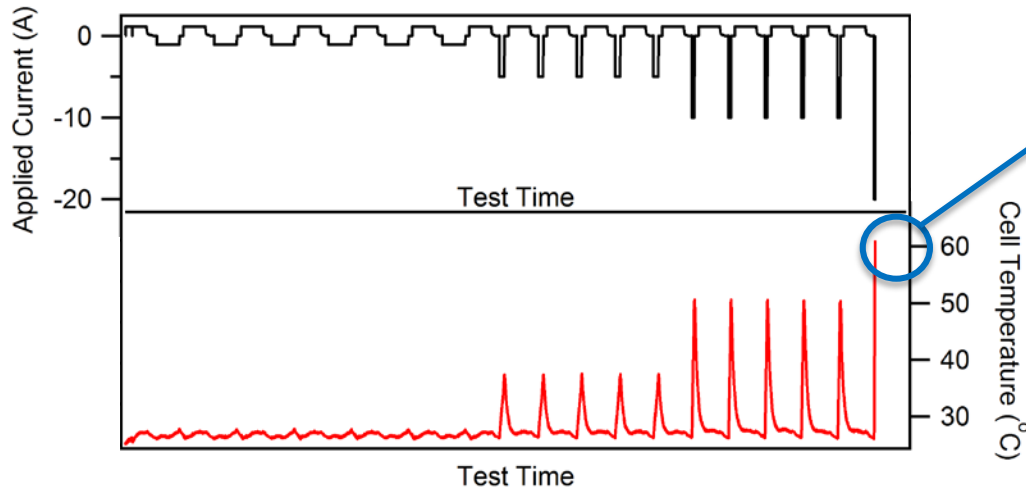
Problem:

- Performance and safety data
 - Primarily manufacturer-provided data
- Chemistry Selection for an ESS installation must consider
 - Cost
 - Size
 - Safety
 - Application
 - Reliability
 - Oversizing
 - Manufacturer reputation
 - Performance
 - Pack management

Approach:

- Quantify performance with uniform methodology
- Evaluate fundamentals of material stability
- Determine battery failure scenarios and mechanisms
- Validate battery fire suppression techniques

Avoiding accelerated aging or abuse



Current = 20 A (max = 30 A)
Environment = 25 °C
Cell skin Temp = 60 °C

Most packs don't monitor
individual cell skin
temperatures.

Unintended abuse condition
under 'normal' operation.

Pristine Cell



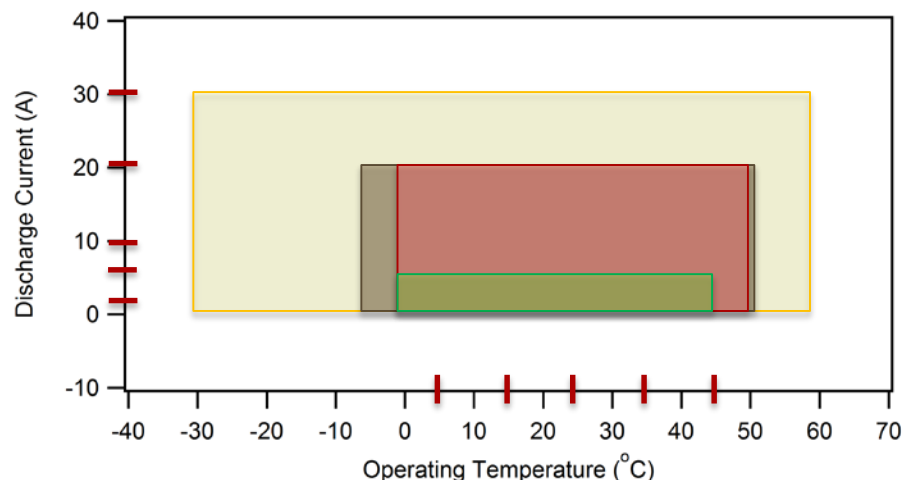
Abused Cell



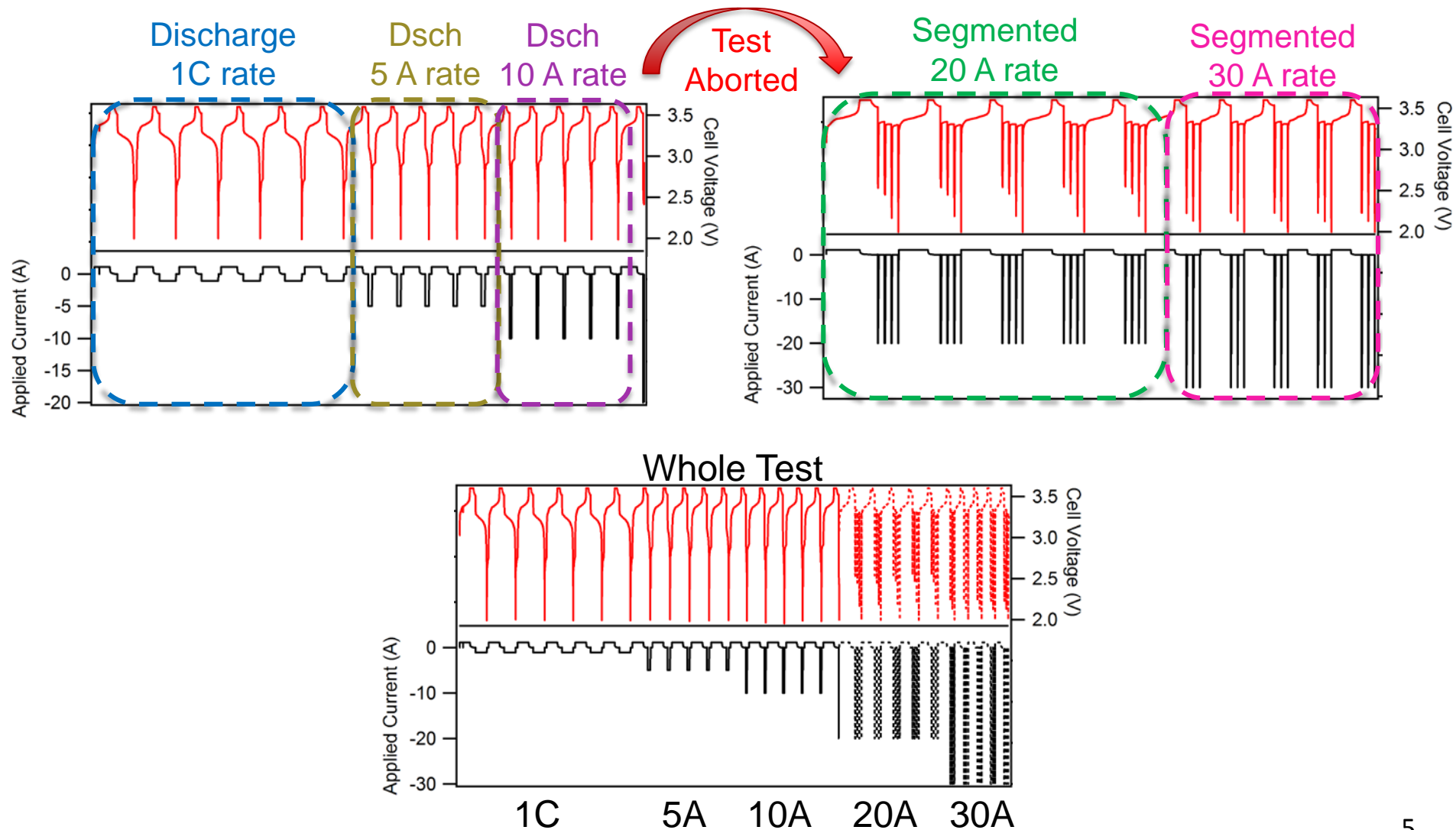
Cells and Manufacturer Specs.

Cathode Chemistry	AKA	Specific Capacity (Ah)	Average Potential (V vs Li ⁰ /Li ⁺)	Max Discharge Current	Acceptable Temperature (°C)
LiCoO ₂	LCO	2.5	3.6	20	0 to 50
LiFePO ₄	LFP	1.1	3.3	30	-30 to 60
LiNi _x Co _y Al _{1-x-y} O ₂	NCA	2.9	3.6	6	0 to 45
LiNi _{0.80} Mn _{0.15} Co _{0.05} O ₂	NMC	3.0	3.6	20	-5 to 50

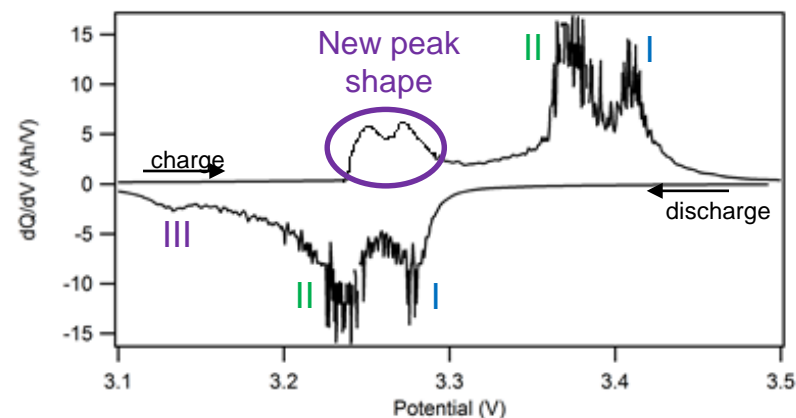
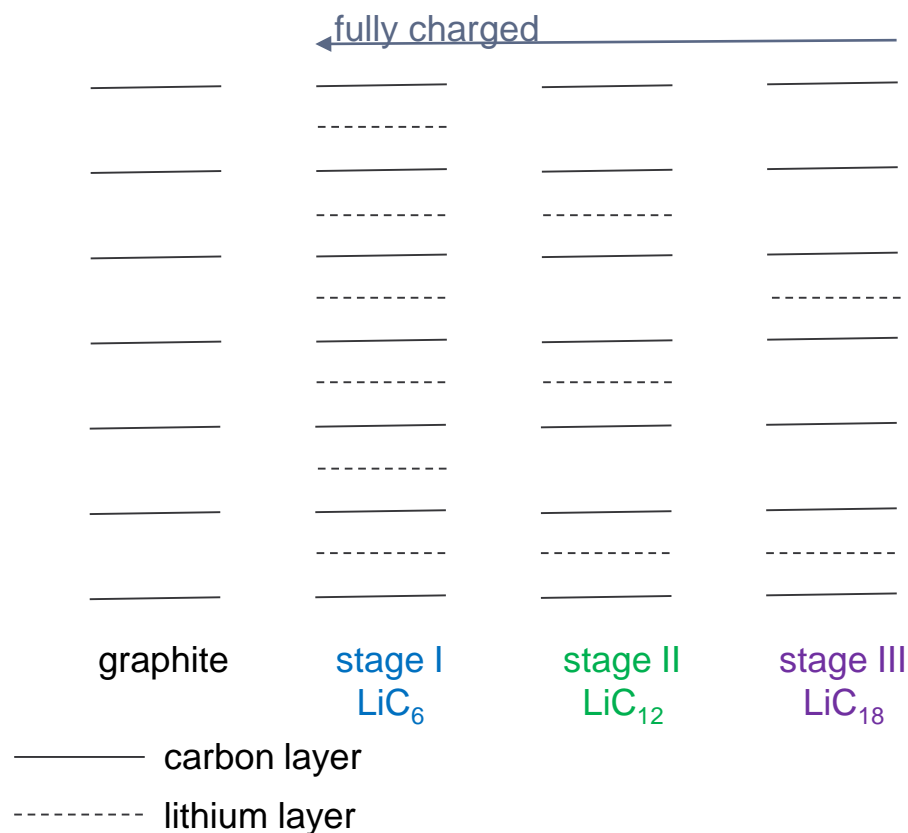
LCO **LFP** **NCA** **NMC**



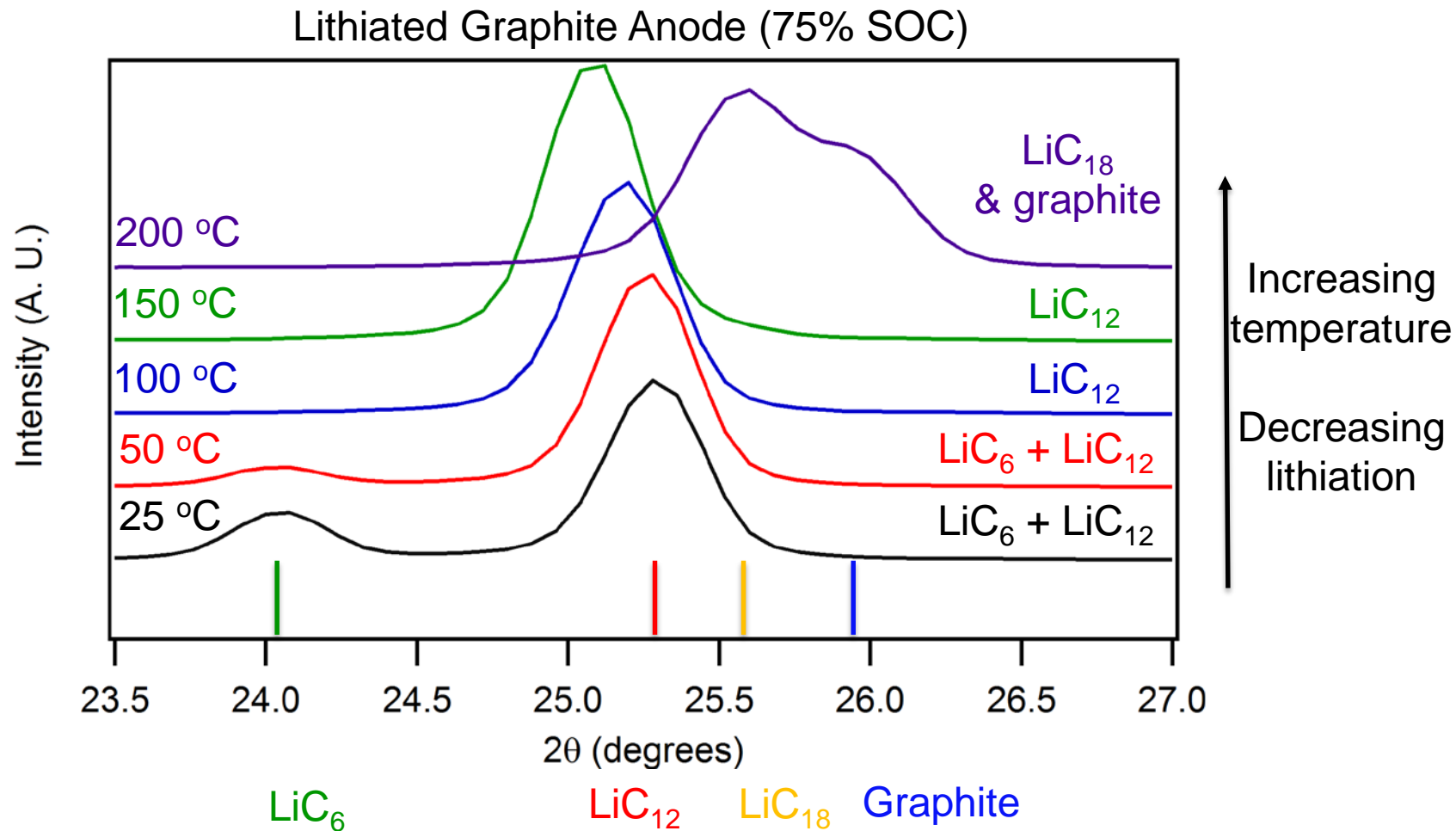
Evaluating cell chemistries uniformly



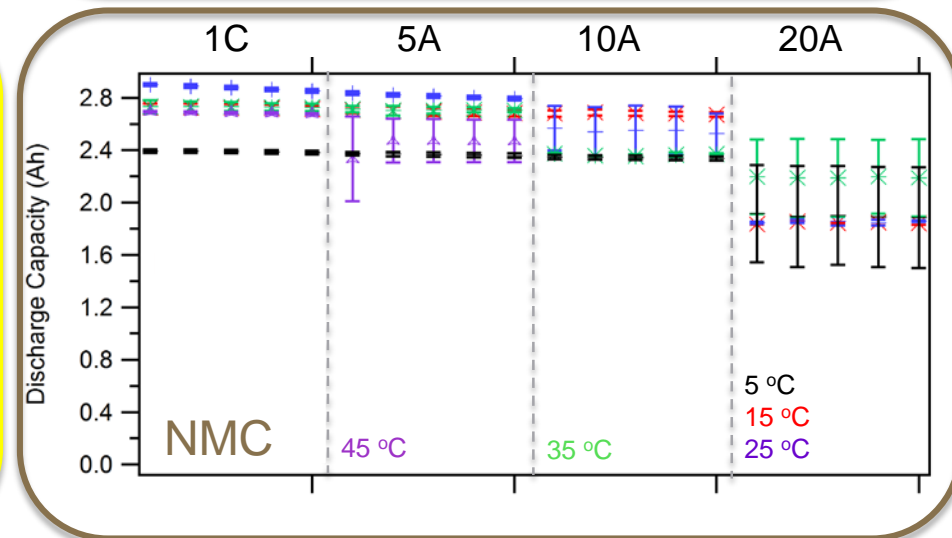
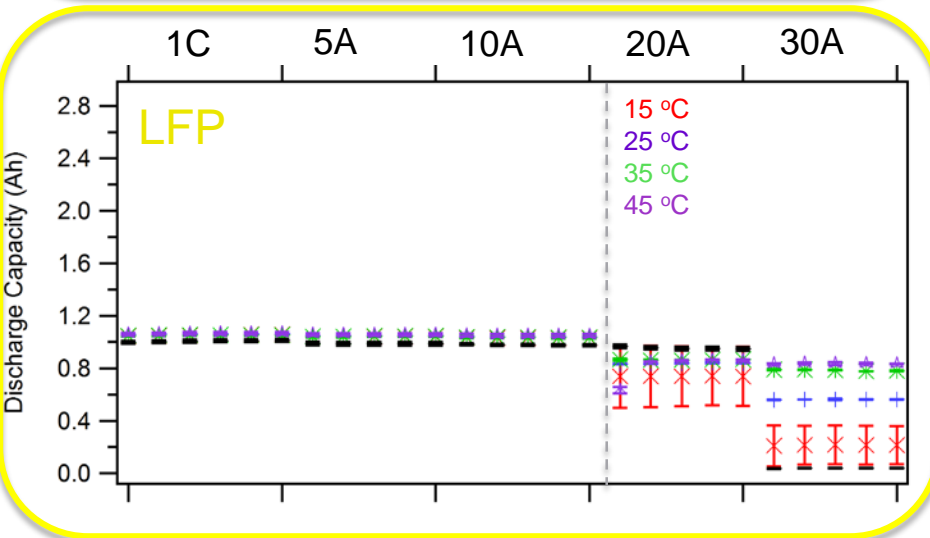
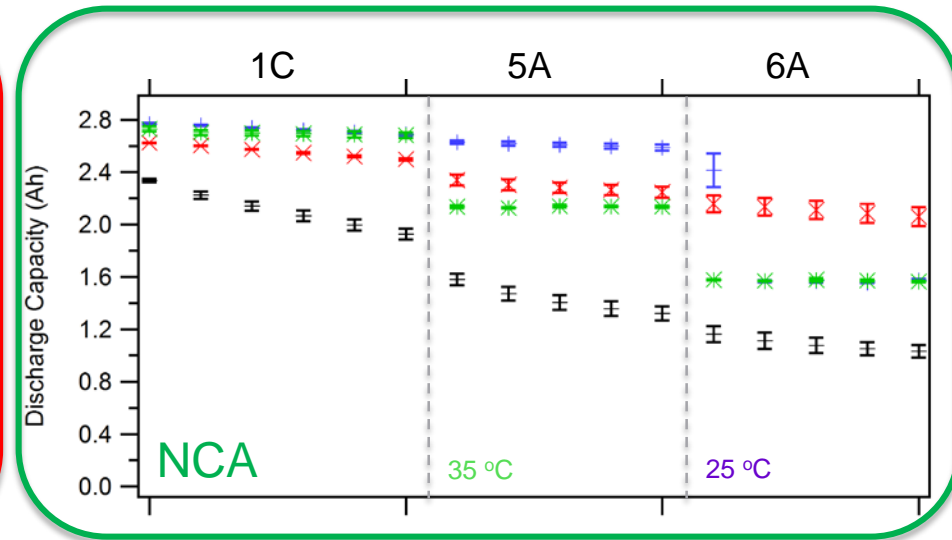
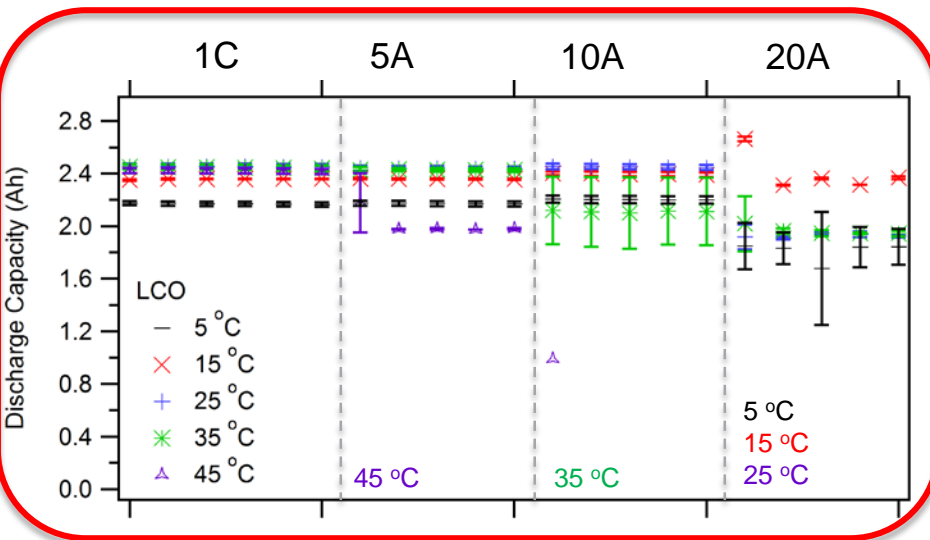
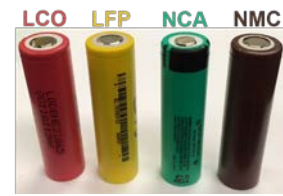
dQ/dV elucidates key reactions/changes



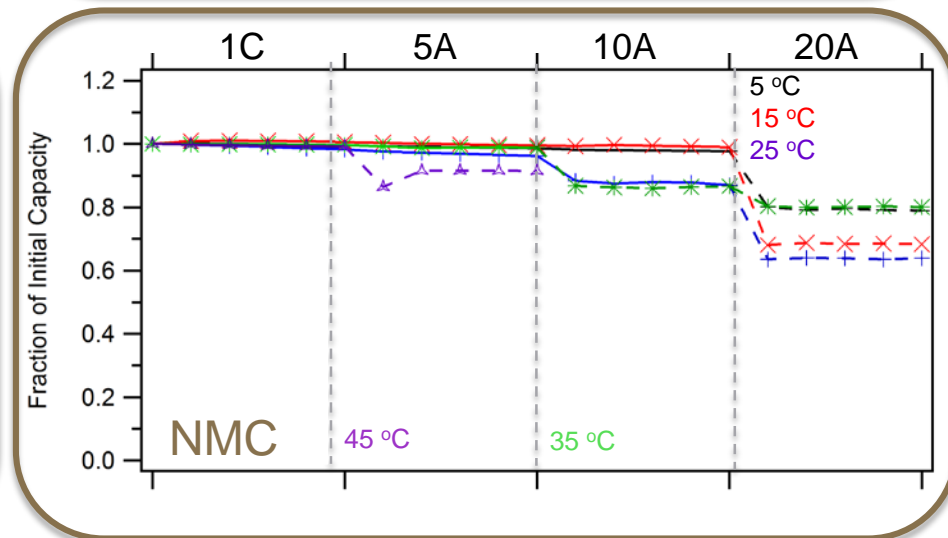
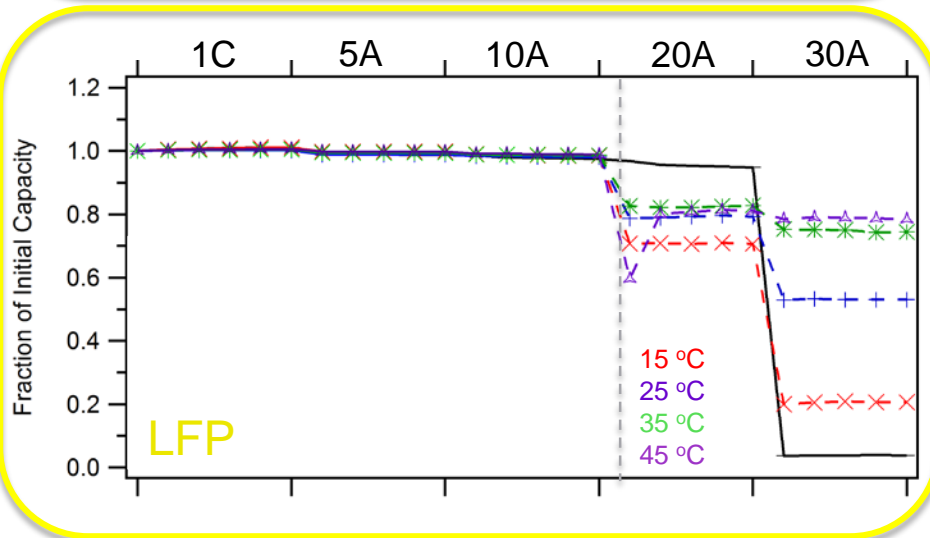
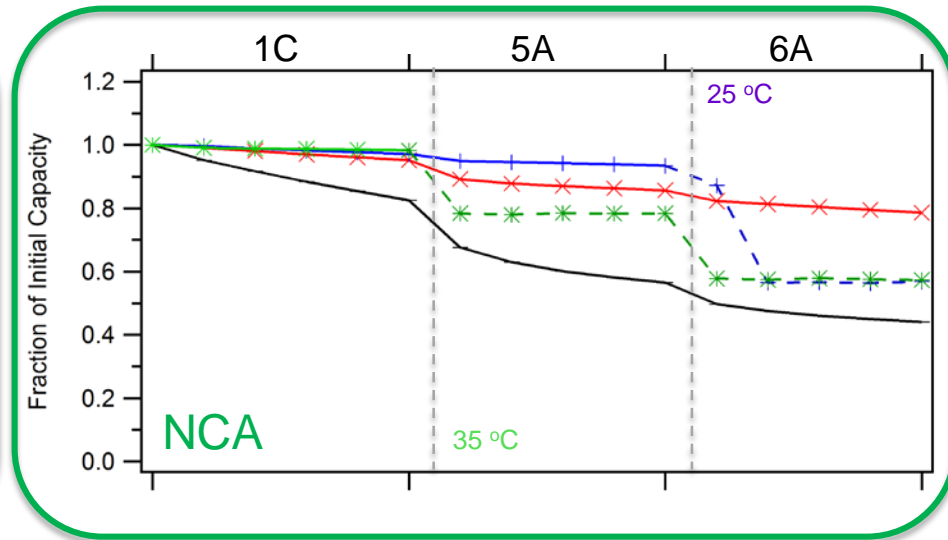
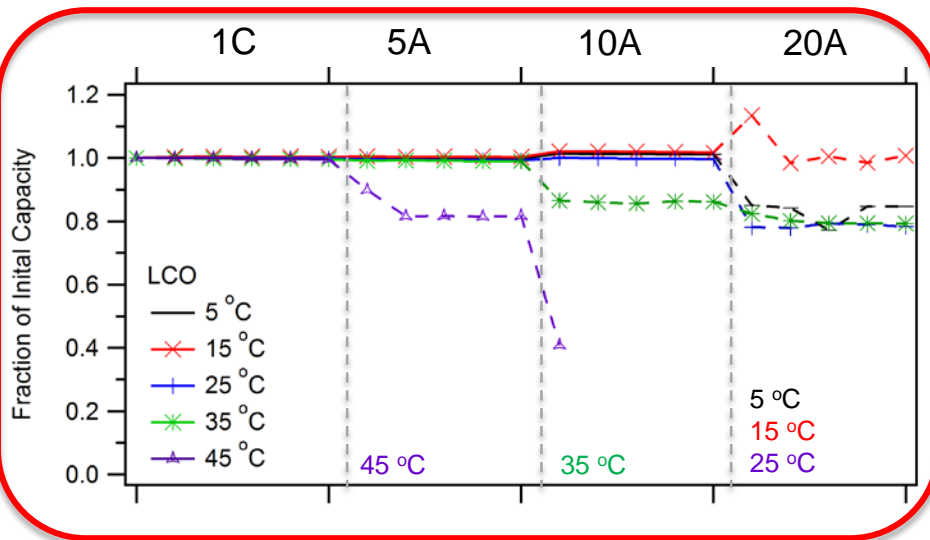
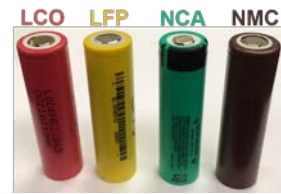
Anode de-lithiation occurs within normal operating T regions



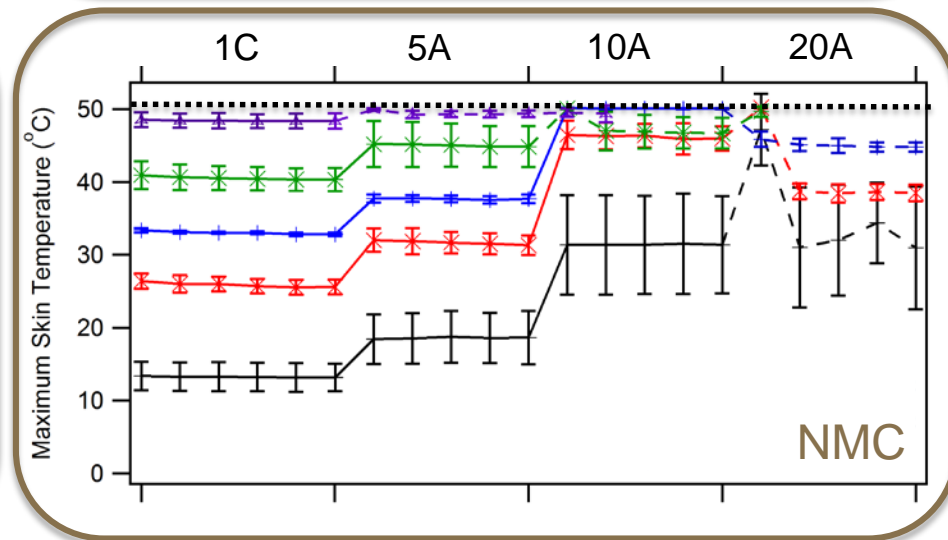
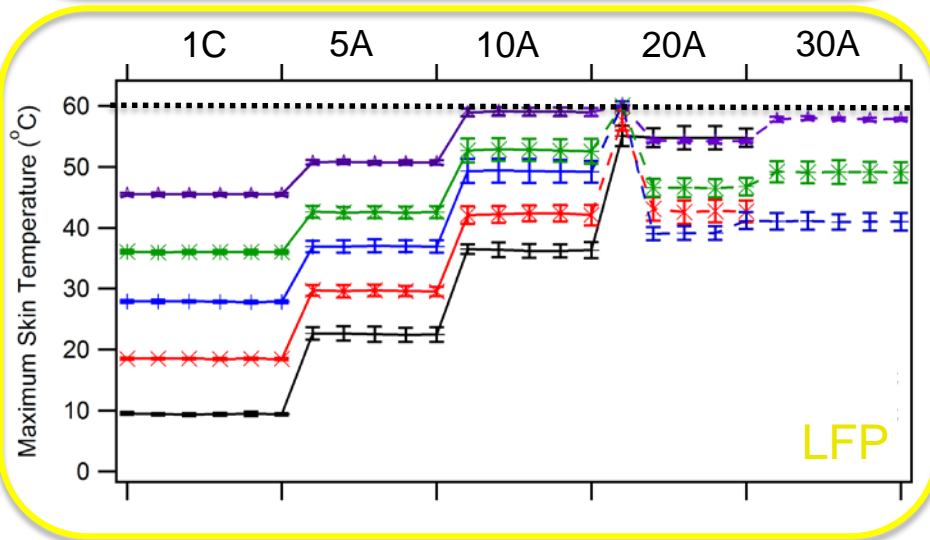
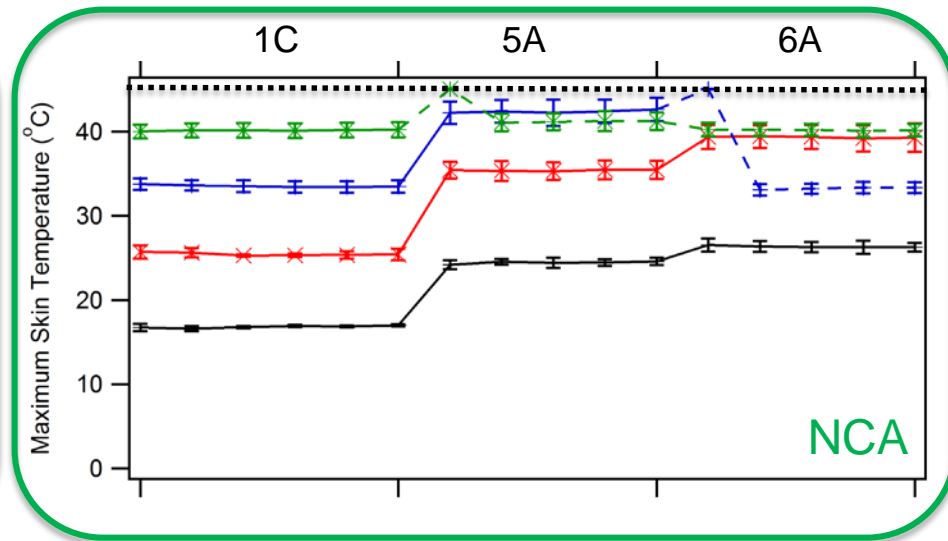
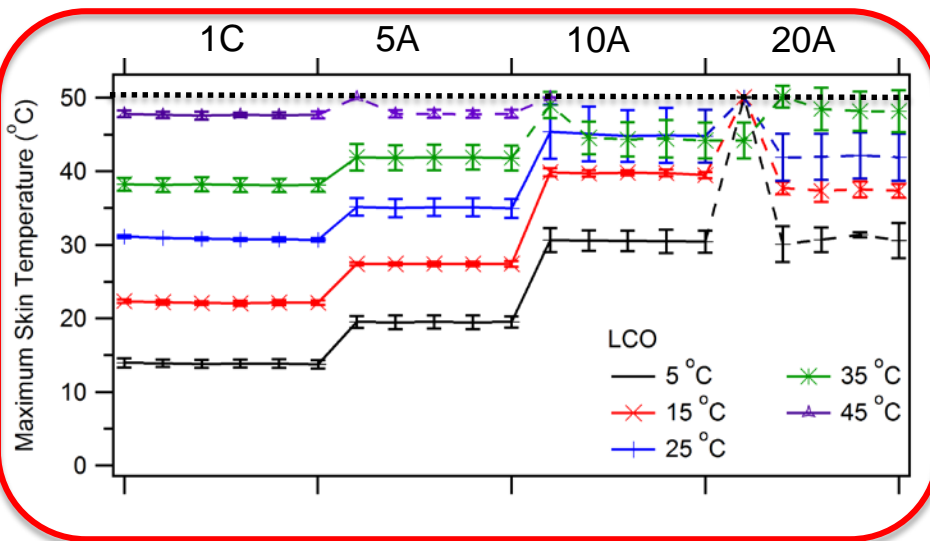
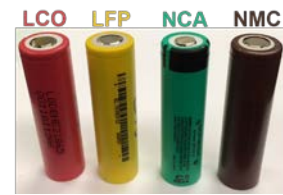
Degree of capacity loss varies with T and current



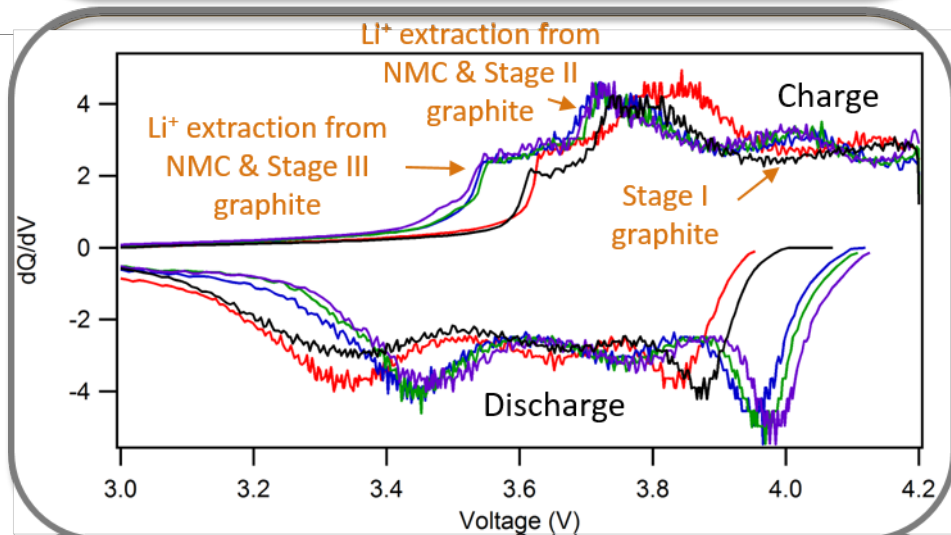
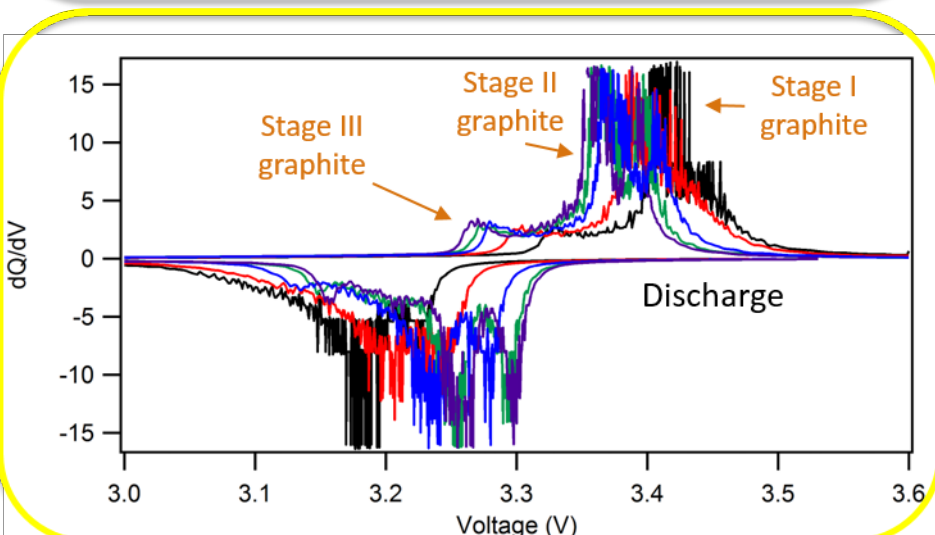
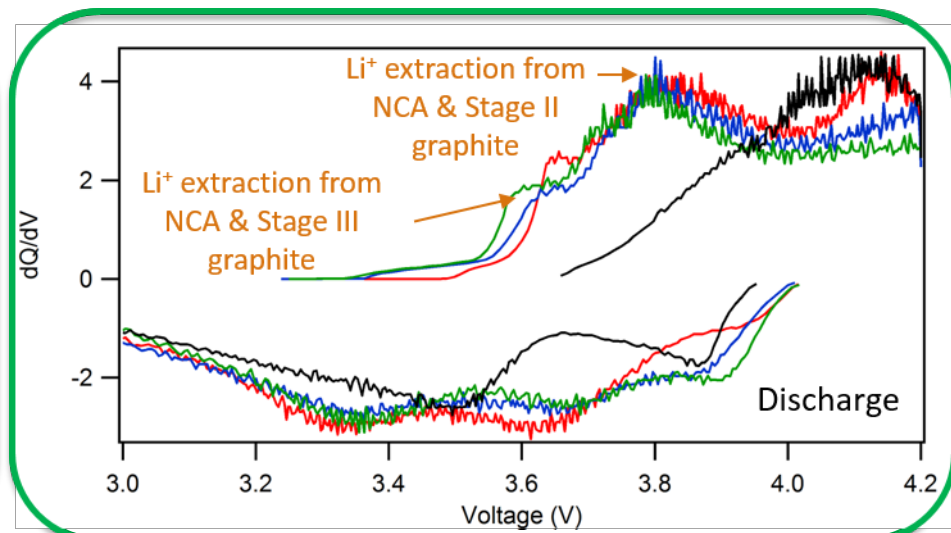
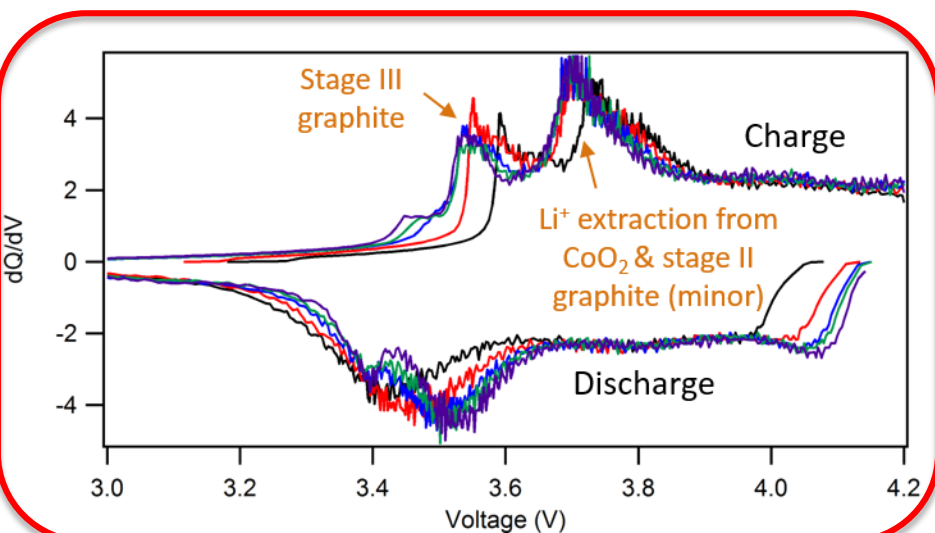
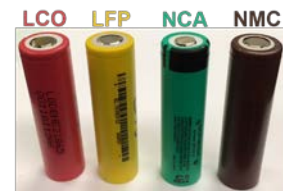
Large contrast in capacity retention



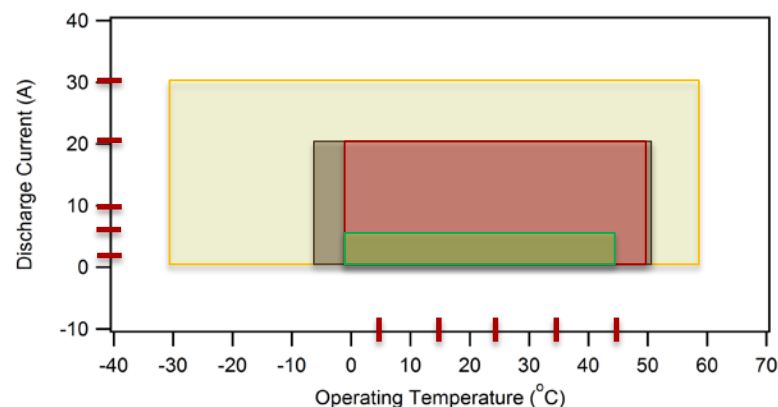
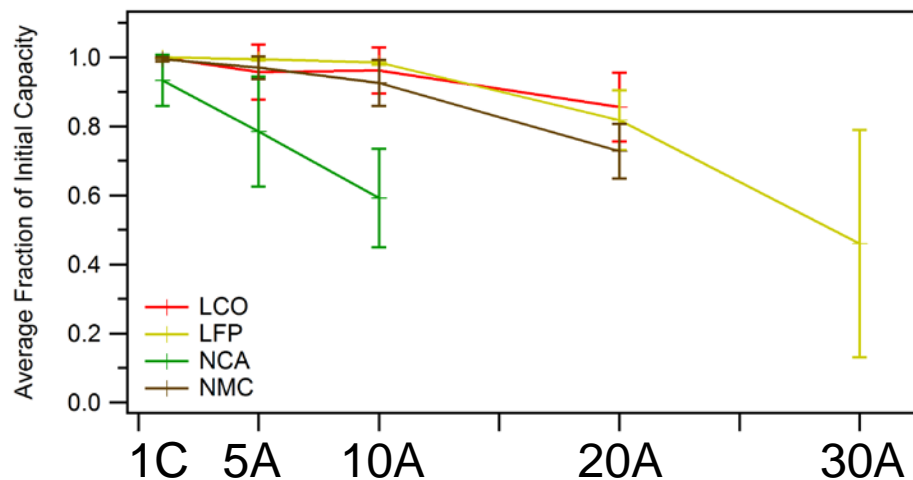
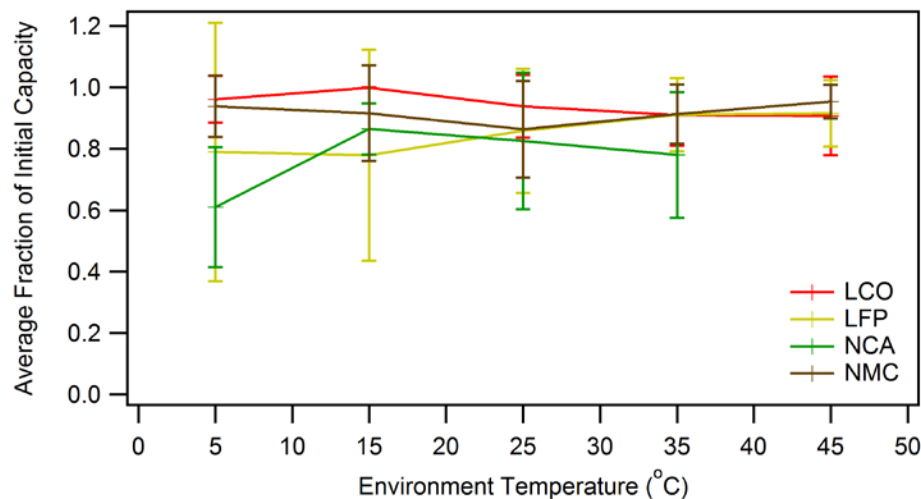
NCA Displays Minimal Self-Heating



Insights into Source of Variation



Determining tradeoffs is clearer with a comprehensive performance evaluation



References

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- Muenzel, V.; Hollenkamp, A. F.; Bhatt, A. I.; Hoog, J.; Brazil, M.; Thomas, D. A.; Mareels, I. *JECS* **2015**, *162*, A1592-A1600.

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