Pacific Northwest
NATIONAL LABORATORY

Reliability Assessment of Li-ion Battery Single Cells under Grid Services

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DOE-OE Peer Review
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U.S. DEPARTMENT OF ENERGY BATTELLE

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OUTLINE

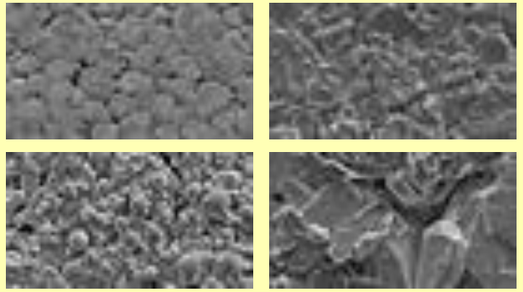
- Project Overview
- Old test update (1st batch)
- New test setup & update (2nd batch)
- Future plan (3rd batch)
- Summary

PROJECT OBJECTIVES

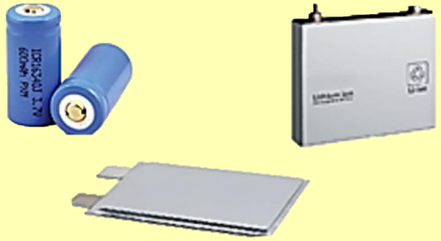
- Develop testing schedules based on standard protocols for industry specific reliability.
- Performance comparison of various commercial Li-ion battery chemistries and formats.
- Battery performance data processing and analyses.
- Correlate single cell performance to module with BMS.
- Support degradation model, state-of-health and prediction.

PROJECT OVERVIEW

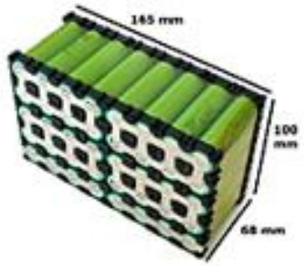
Chemistry Comparison Degradation Study



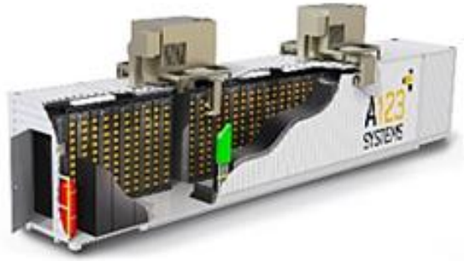
Lifecycle Prediction



BMS Control State-of-health Monitoring



Field Use-Case Data



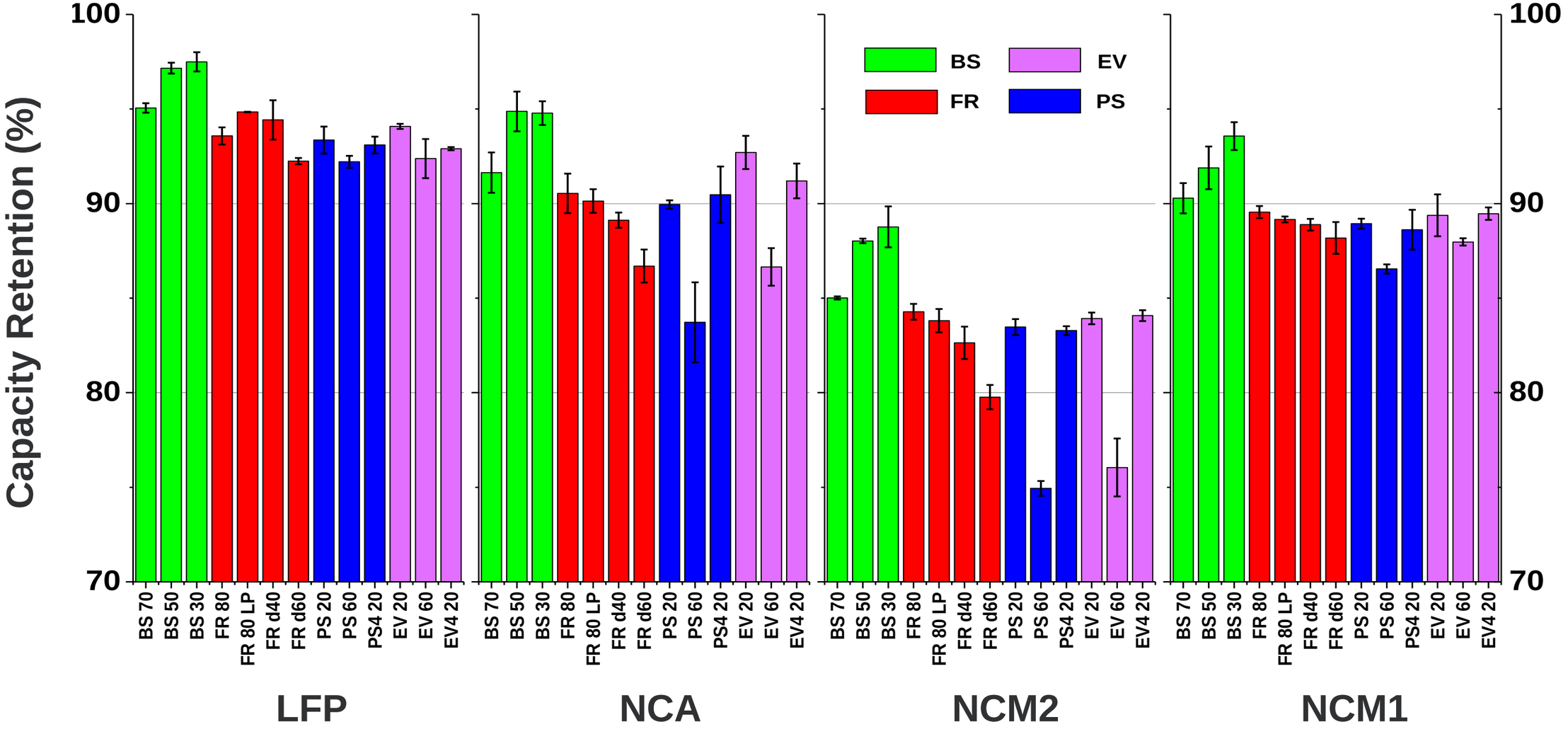
Materials ⟷ **Single Cell** → **Modules < 100kW** → **Deployed ESS**

Scientific Data

Practical Data

OLD TEST UPDATE

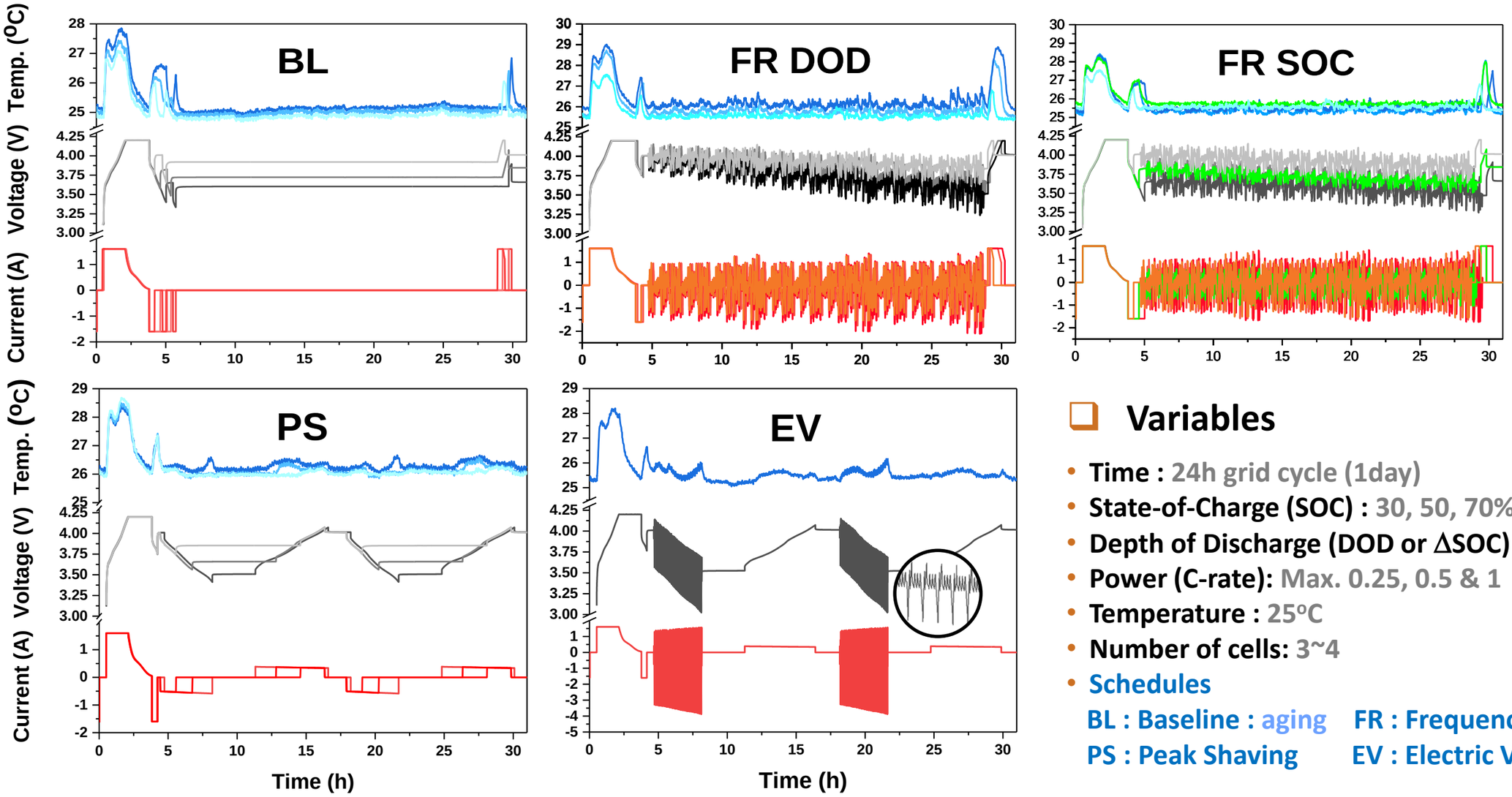
- Test started in 2018, 540 days of cycles within 2.66 years period.



NEW TEST SETUP

- Continue old test for end-of-life study and characterize degraded cells.
- Based on previous experience, new test was designed using more advanced setup and schedule program to ensure highest accuracy.
- ΔSOC or DOD of each service with <1% accuracy.
- Start and end of test occur at same time on all cells (with time limit on each steps).
- Power service signals are used instead of current signals.
- Cell temperature is measured on all cells.

NEW TEST SCHEDULES

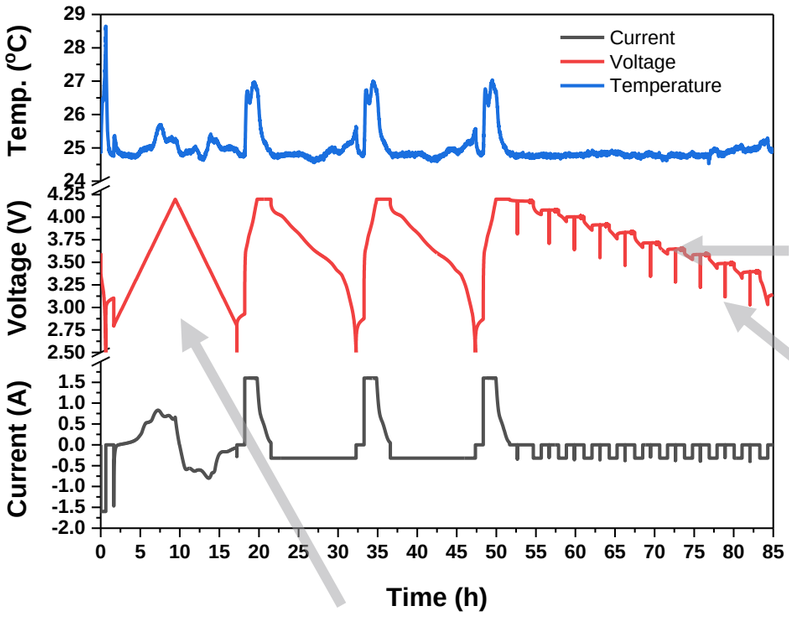


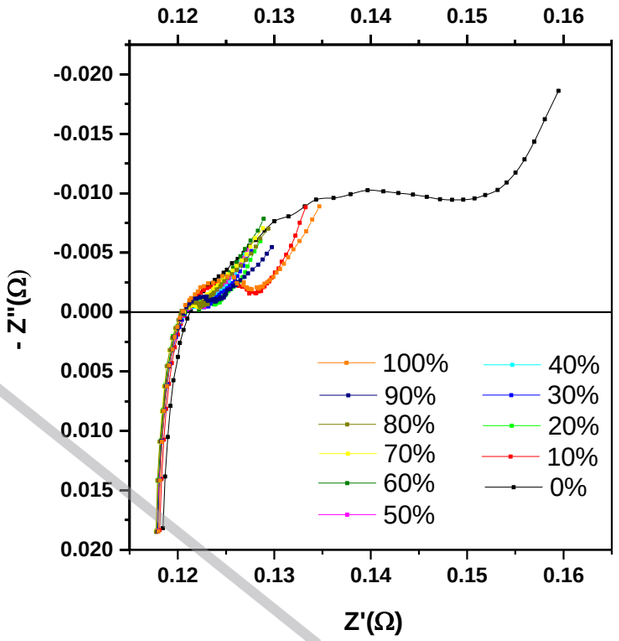
Variables

- **Time :** 24h grid cycle (1day)
- **State-of-Charge (SOC) :** 30, 50, 70%
- **Depth of Discharge (DOD or ΔSOC) :** 20, 40, 60%
- **Power (C-rate):** Max. 0.25, 0.5 & 1
- **Temperature :** 25°C
- **Number of cells:** 3~4
- **Schedules**

BL : Baseline : aging **FR : Frequency Regulation**
PS : Peak Shaving **EV : Electric Vehicle**

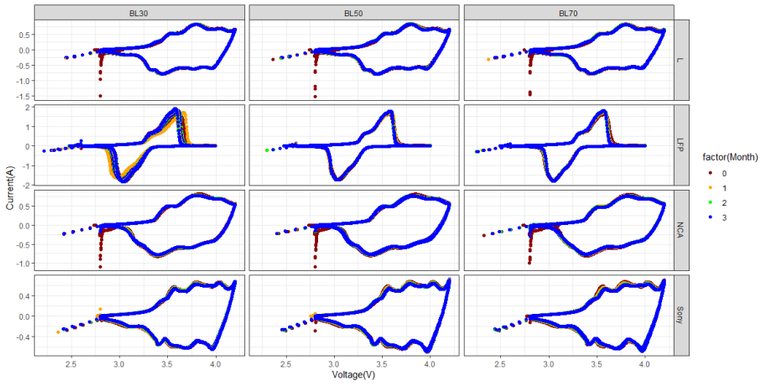
NEW TEST SCHEDULES



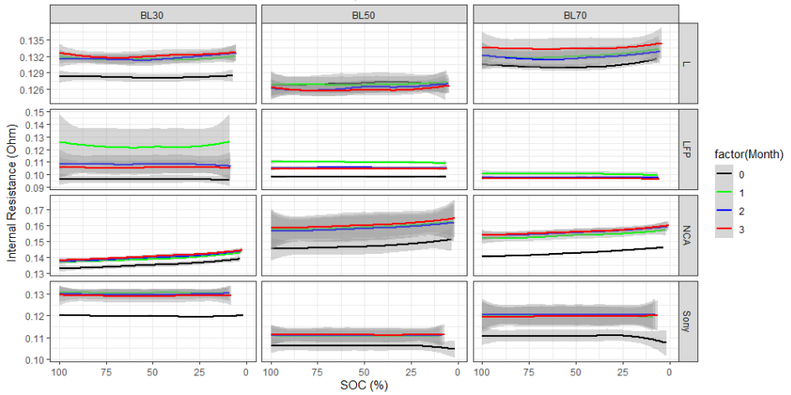


Performance Data Analyses

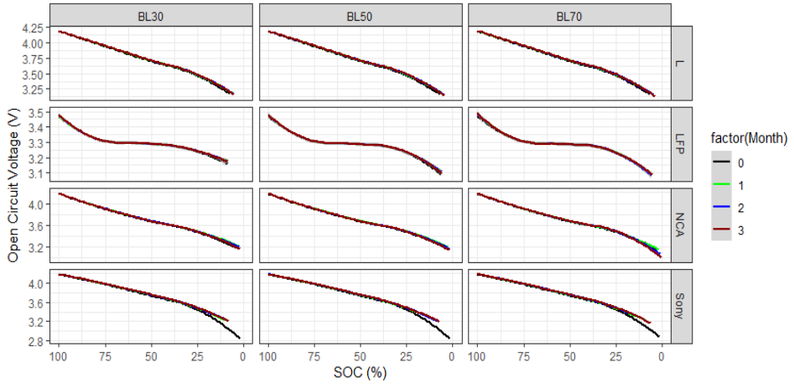
- **CV (dQ/dV) :** voltage profile change and redox activity
- **Capacity:** degradation of cell
- **dV/dQ:** cathode or anode capacity change
- **AC impedance :** every 10% ΔSOC
- **DC resistance :** every 10% ΔSOC
- **OCV :** every 10% ΔSOC
- **Temperature :** Cell temperature will be used to calculate the amount of heat energy released after ARC measurement on each cell



CV

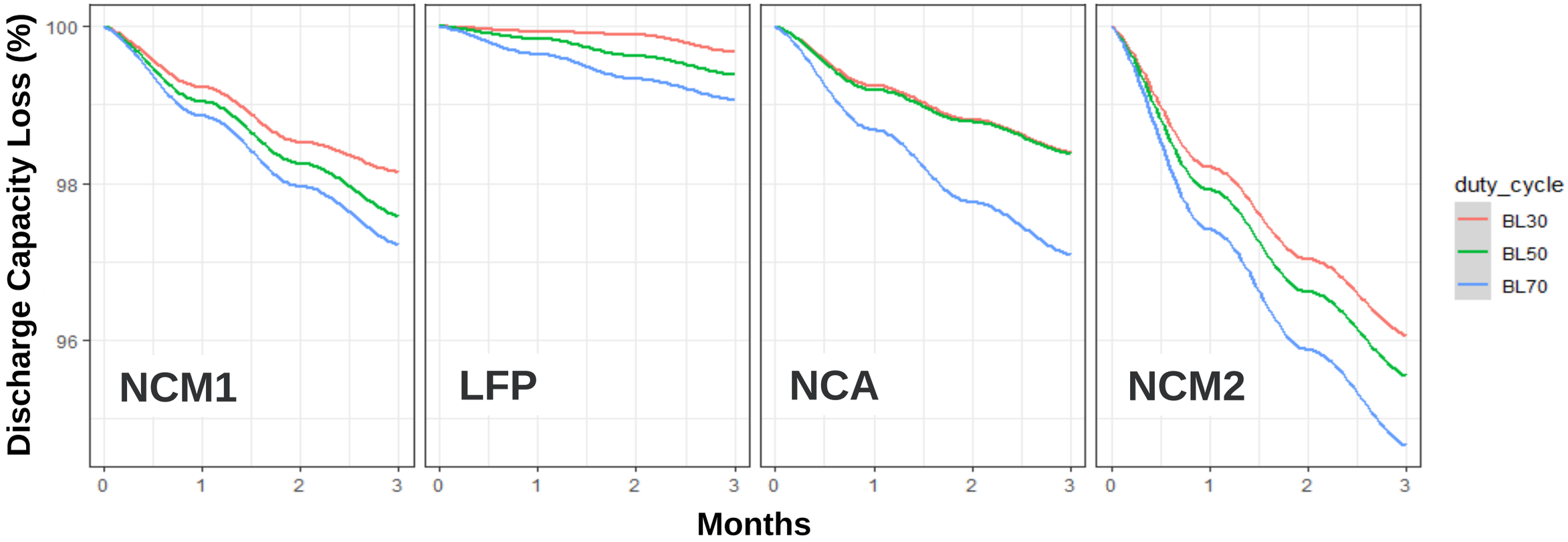


DC resistance



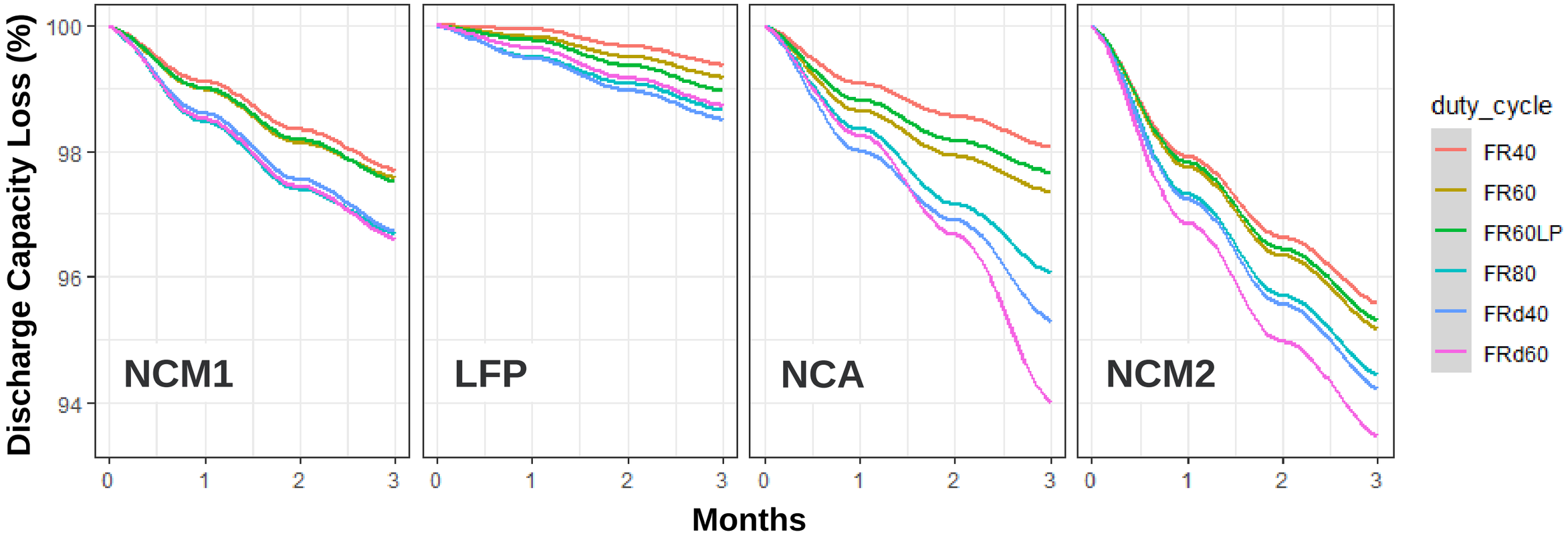
OCV

NEW TEST RESULTS



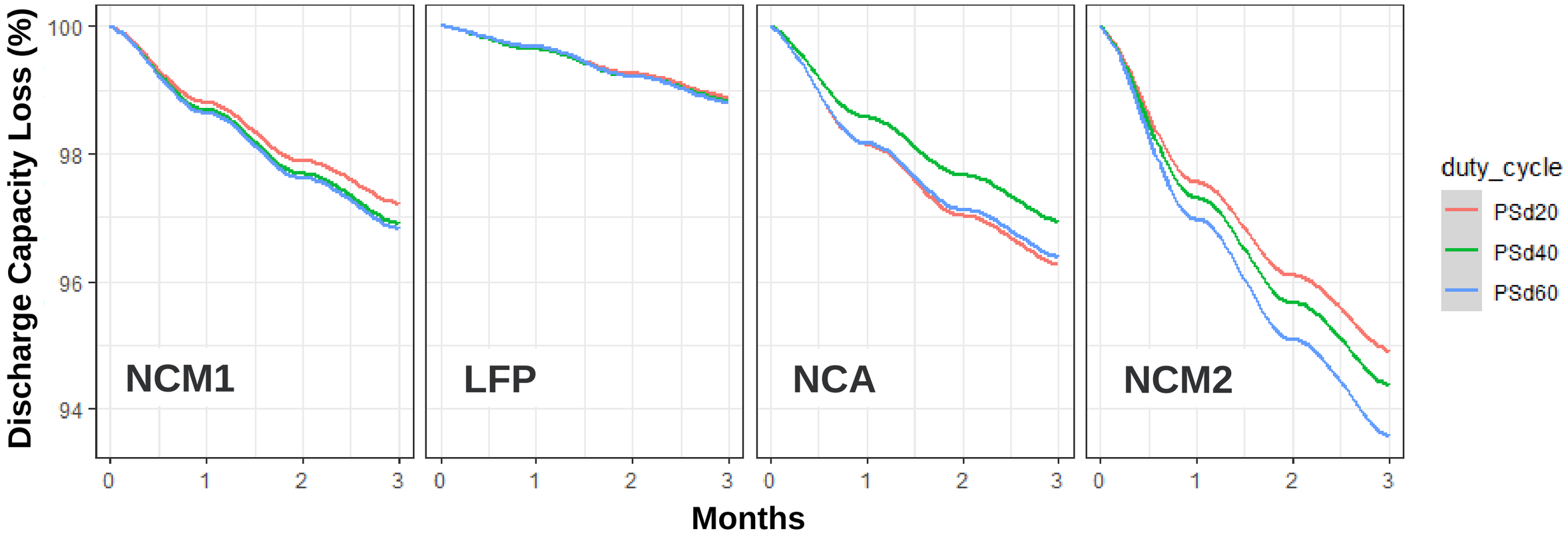
- Higher SOC level degrades the battery faster.

NEW TEST RESULTS



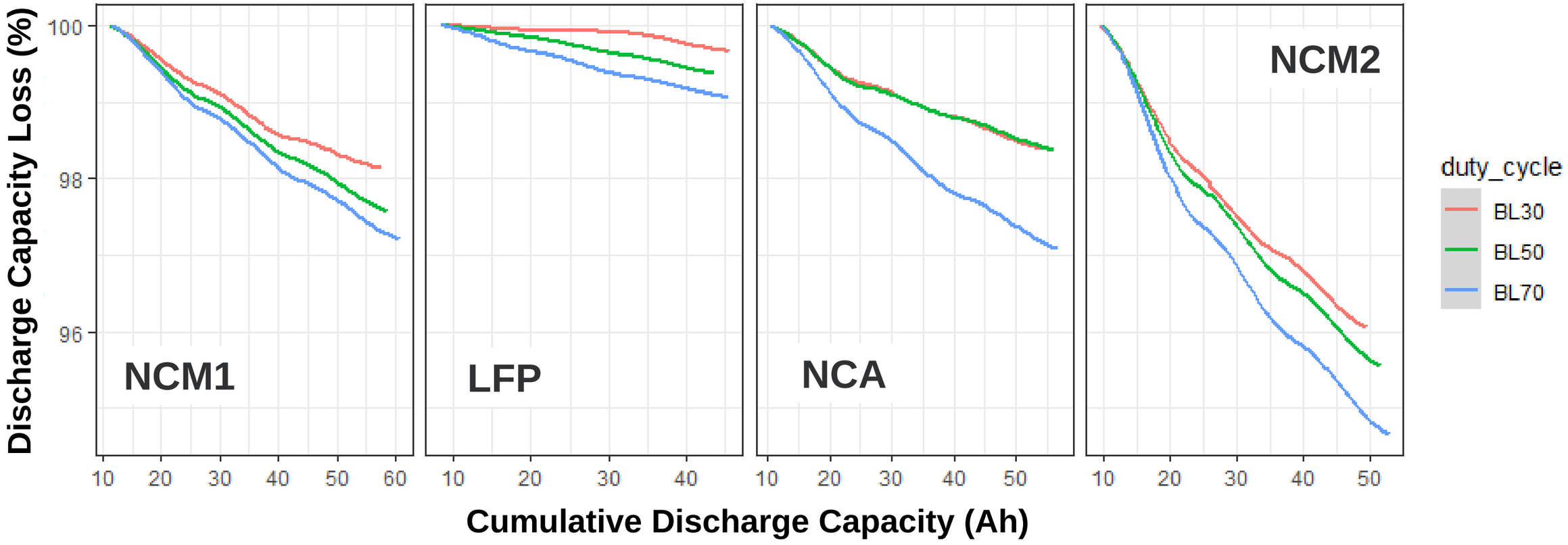
- Larger DOD (ΔSOC) degrades the battery faster than higher SOC.

NEW TEST RESULTS



- Larger DOD (ΔSOC) degrades the battery faster but negligible for LFP cells.

NEW TEST RESULTS



- LFP cells degrades the least in all cases.

FUTURE OBJECTIVES

- Add 4 more cell chemistries
  - Cylindrical Cell – identical cell used in modules to be tested
- Performance data analyses
  - Program development
  - Cell temperature – heat relation using ARC measurements
  - AC impedance
- In-operando/post-mortem study (characterization)
- Degradation modeling & prediction support

SUMMARY

- After 2.5 years of testing, some cell chemistry degraded > 20% of the initial capacity.
- LFP cells have better aging, capacity, and energy retention.
- New test setup provides more information with higher accuracy.
- In general, higher SOC level and DOD degrades the battery more but cell chemistry is more important.

ACKNOWLEDGEMENTS

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Thank You!

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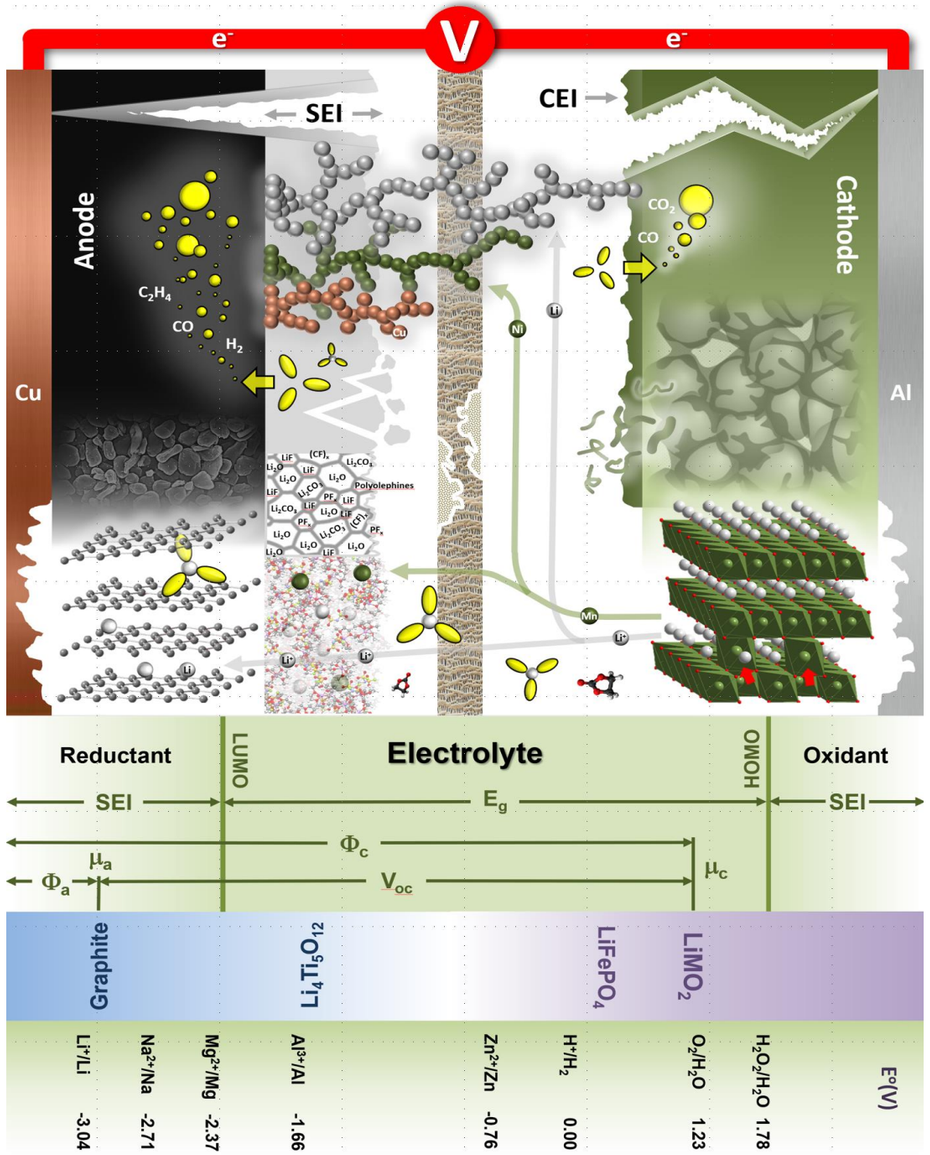
DEGRADATION MECHANISMS


e⁻
V
e⁻
Cu
Anode
SEI
C_2H_4
CO
H_2
Cu
Li
Ni
Li⁺
Li⁺
Li⁺
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Li
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Li