



Lithium Plating Quantification in Commercial Graphite||LiFePO₄ batteries

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Objectives & Motivations

What is Lithium plating?

Li-ions deposit as metallic Lithium on the negative electrode during charge

Effects of Lithium plating?

Lithium plating identification is of critical
importance in lithium ion battery systems

Objectives:

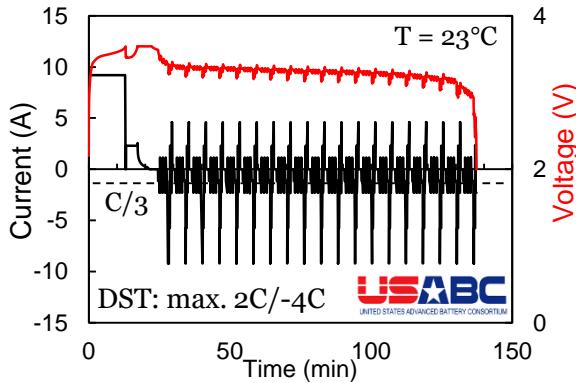
1. *In situ* detection and quantification
2. Decipher origins and effects of Li plating

Our approach: combine testing & emulation

GIC||LFP cells

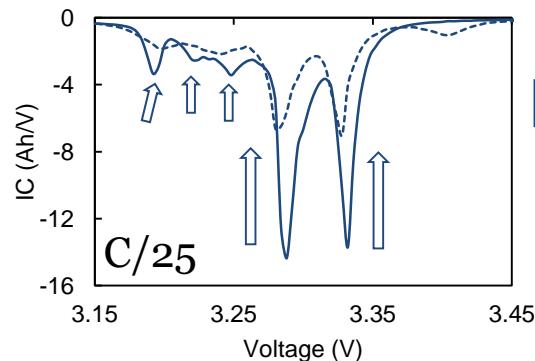
Cell Testing

1. EV cycling: 4C/DST



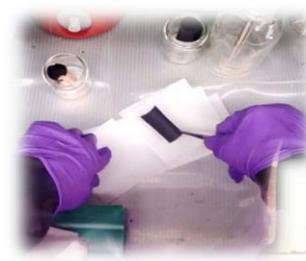
2. Reference testing (RPT)

3. Study aging: ICA



Cell emulation

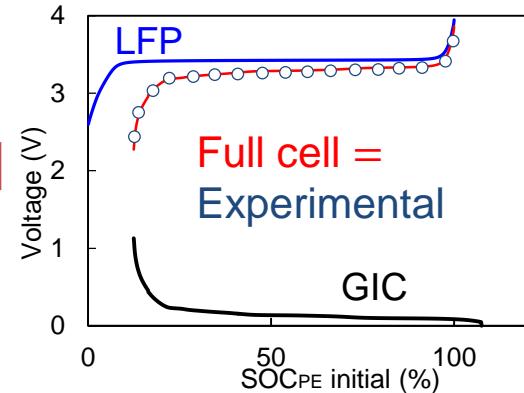
1. Harvesting electrodes



2. Half-cell testing



3. Full cell module



In situ quantification



'alawa

Emulate degradation
study effect on full cell
(capacity and voltage)

LLI

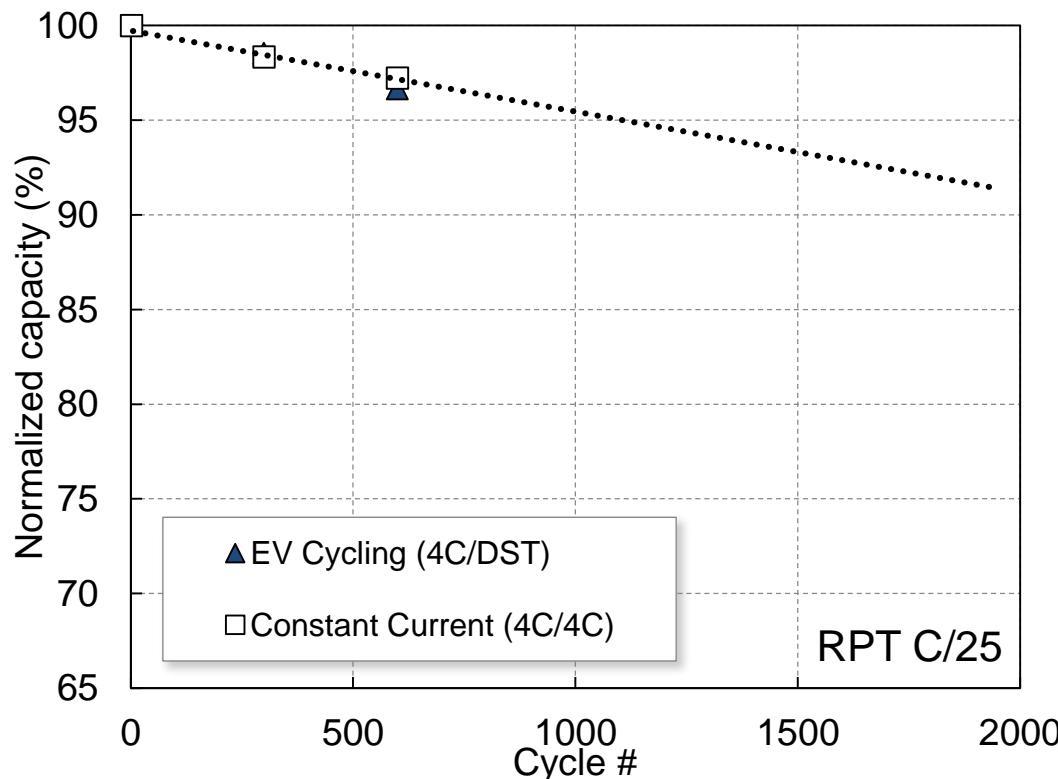
LAM

Kinetics



Cell testing: normalized capacity evolution

EV cycling (4C/DST) vs.
Constant current (4C/4C)^[1,2]



Constant current cycling
No signs of Li plating

Aging modes:

LLI

LAM_{deNE}

Ratio 1.5:1

Cell degradation (%)

EV cycling

- **Complex degradation**
- Two stages identified
- DST is detrimental

Need for advanced analysis: ICA



What happened?
Any warning signs?

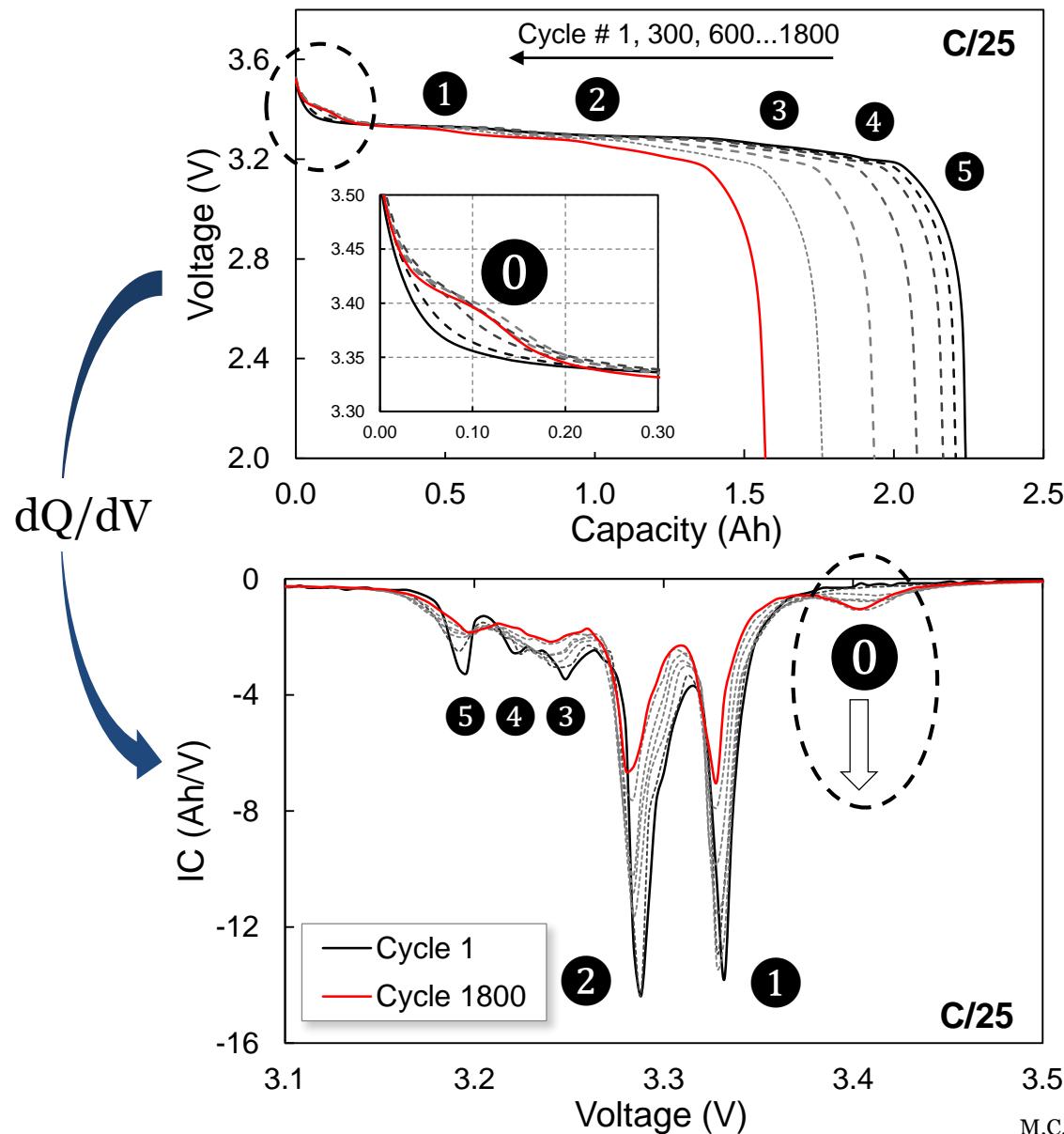
[1] D. Anseán, M. González, J.C. Viera, et al. *J. Power Sources*, **239** (2013) 9-15

[2] D. Anseán, M. Dubarry, A. Devie, et al. *J. Power Sources*, **321** (2016) 201-209

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Incremental Capacity Analysis

5



Complex IC evolution
All peaks (1-5) change:

LLI + LAM

New phase: peak 0

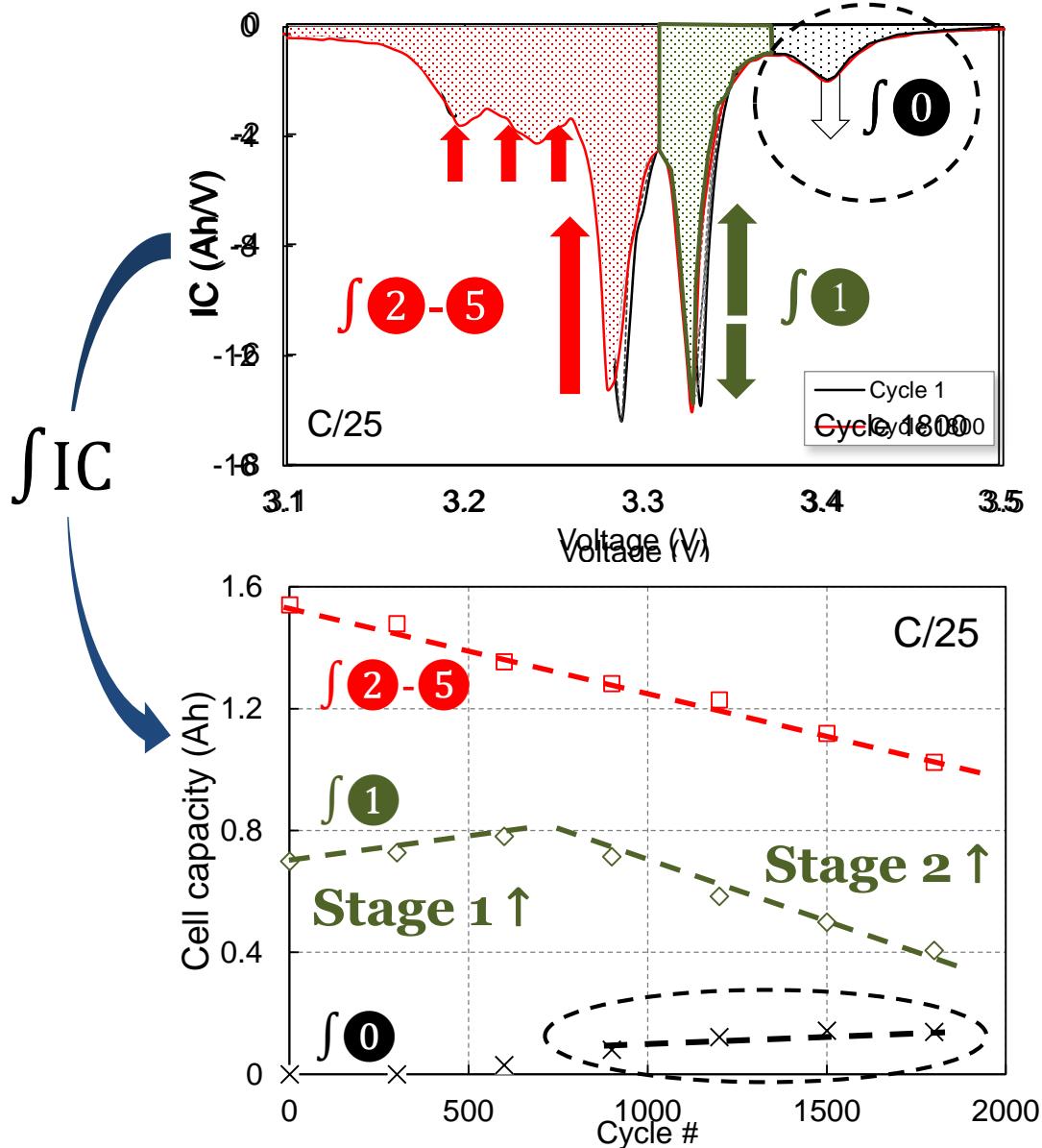
(peak 0 → cycle >900)



Peak 0 :
Detection of Li plating

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Peak Area Analysis



Peculiar PA evolution:

$\int 2-5 \rightarrow$ linear decrease

$\int 1 \rightarrow$ two linear stages ($\uparrow \downarrow$)

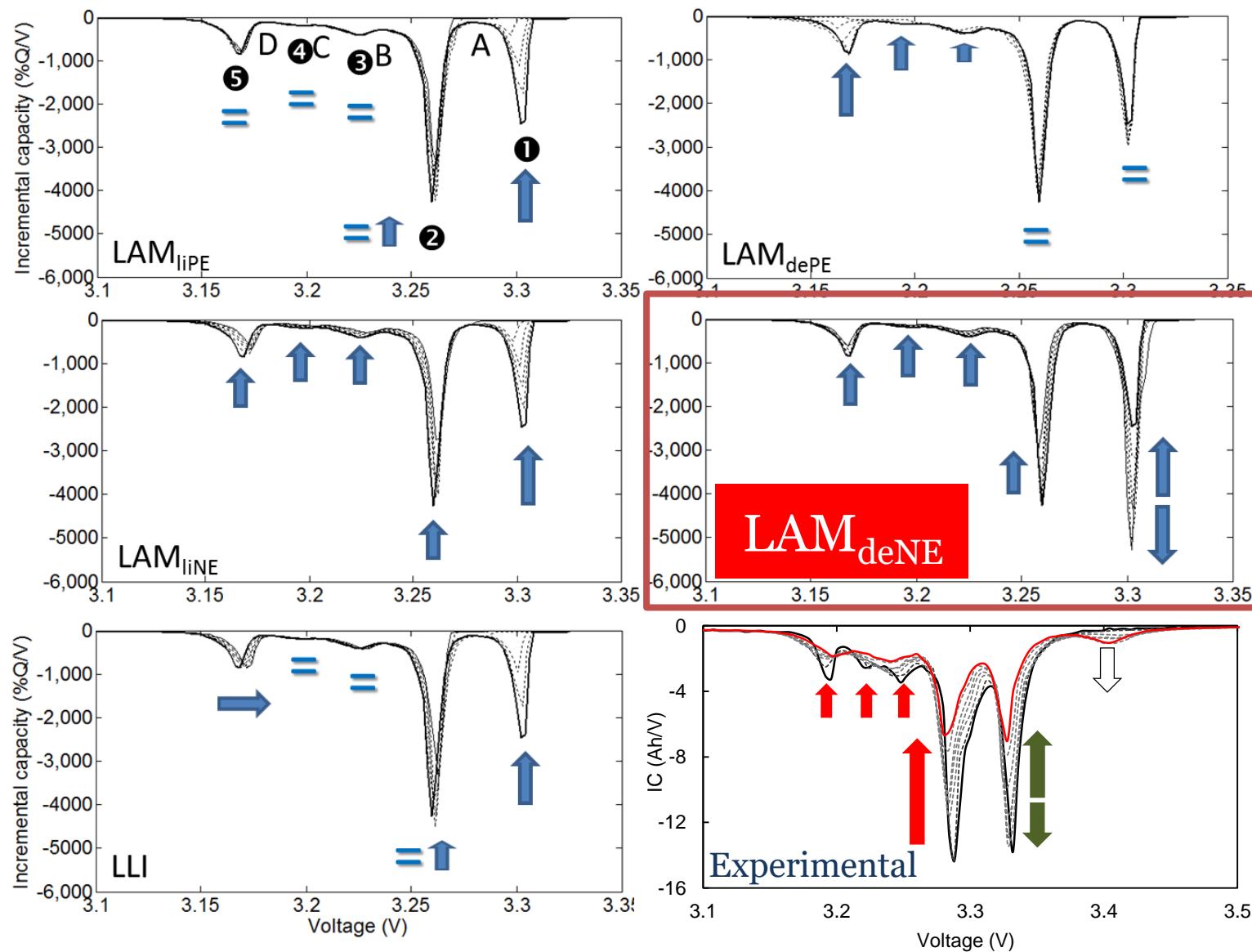
Peak $\int 0$:
Quantification of Li plating

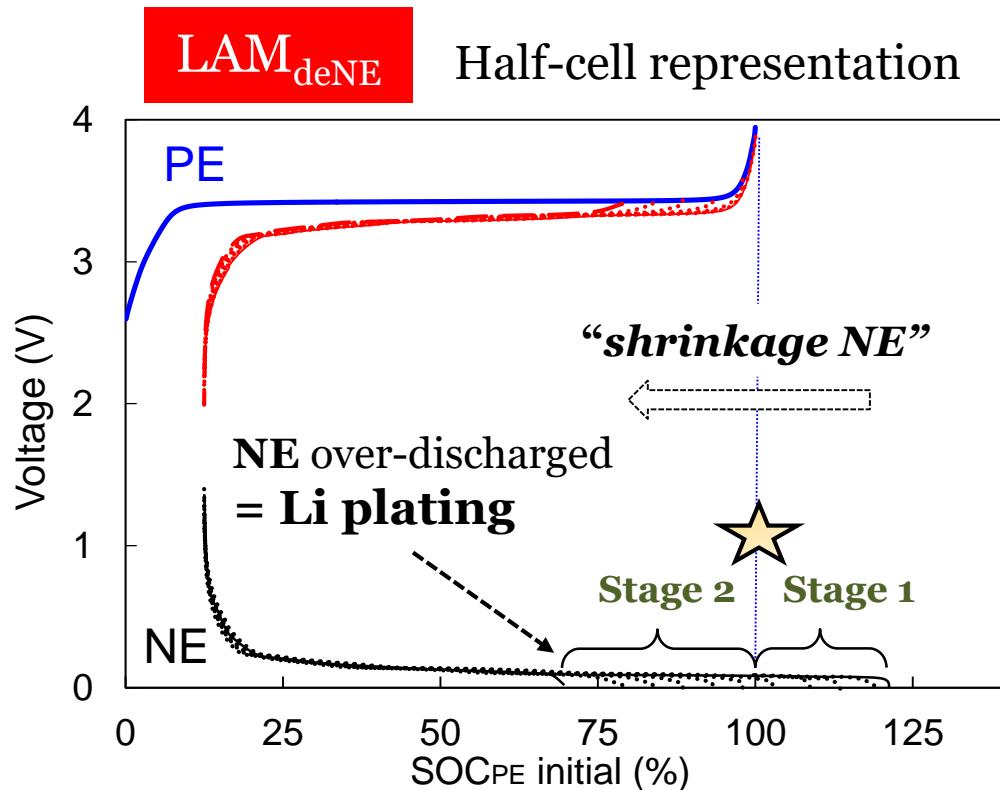
$\int 0 \rightarrow$ stable 900 onwards

Aging modes & origins?
Aging quantification?

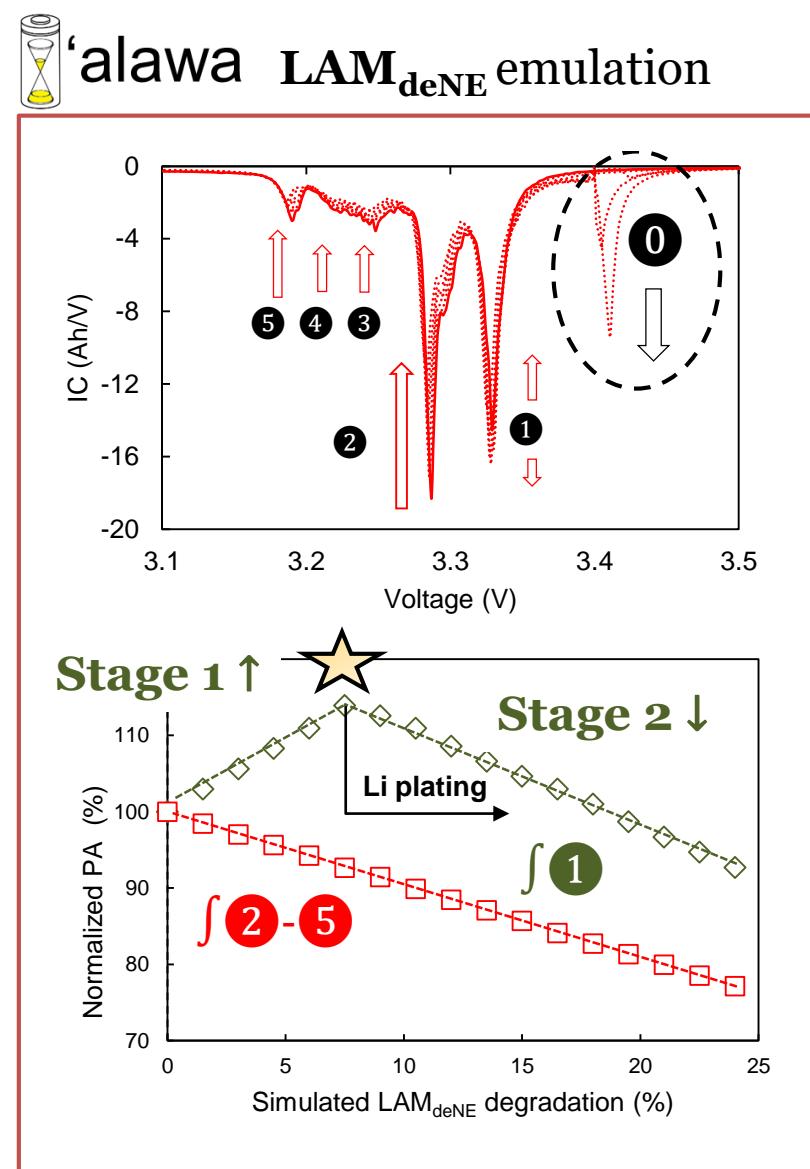


Cell emulation

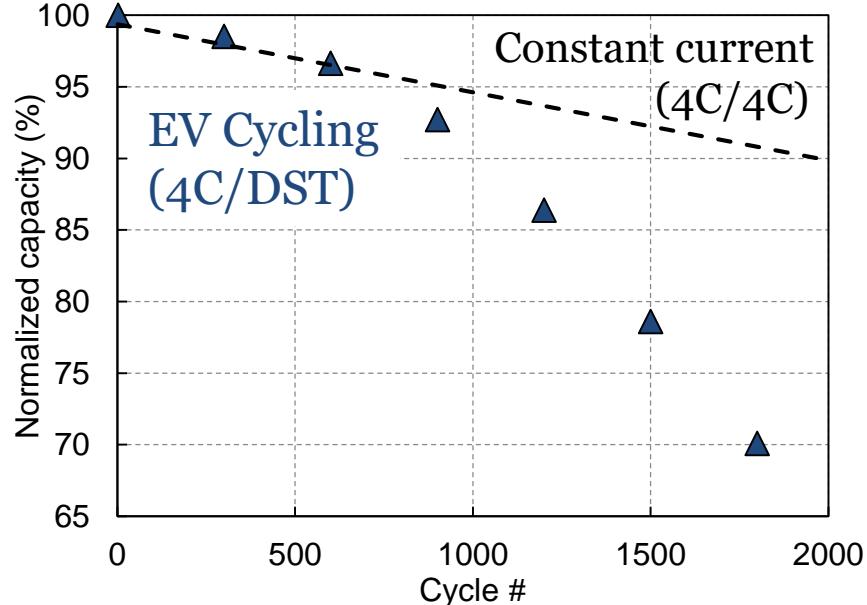
Degradation maps Graphite||LiFePO₄

LAM_{deNE} evolution: degradation effects

Li plating **origins** → LAM_{deNE}
 Li plating **warning** signature
 (Peak $\int 1 \uparrow$)



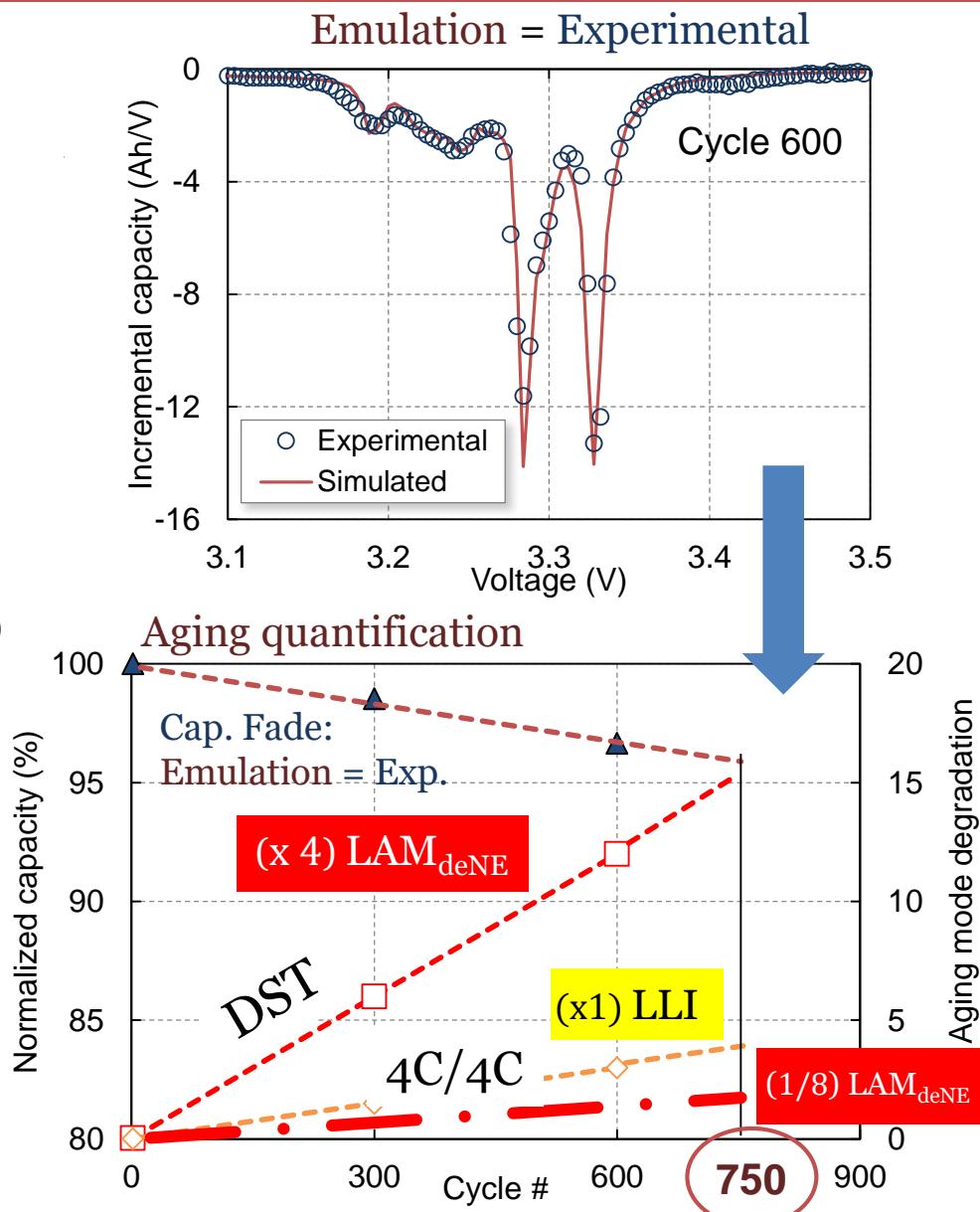
Emulation Stage 1: prior Lithium plating



Aging modes quantification (%):

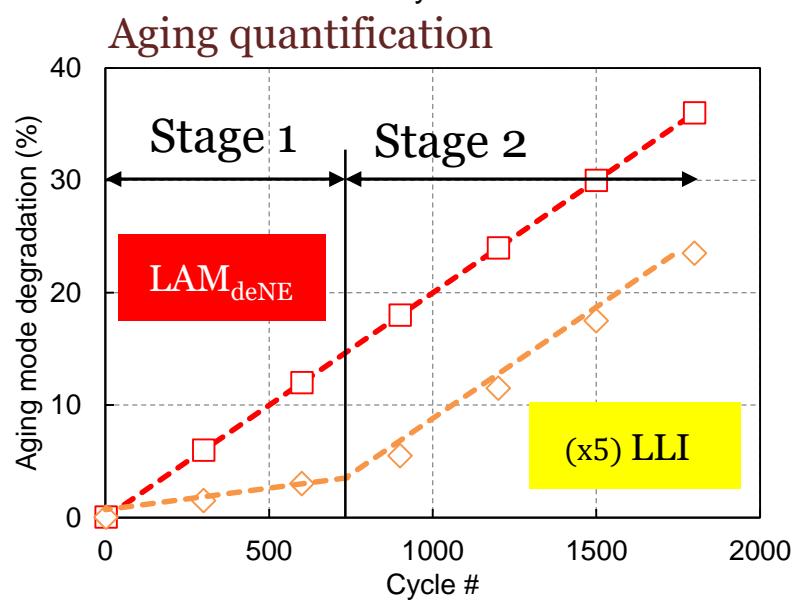
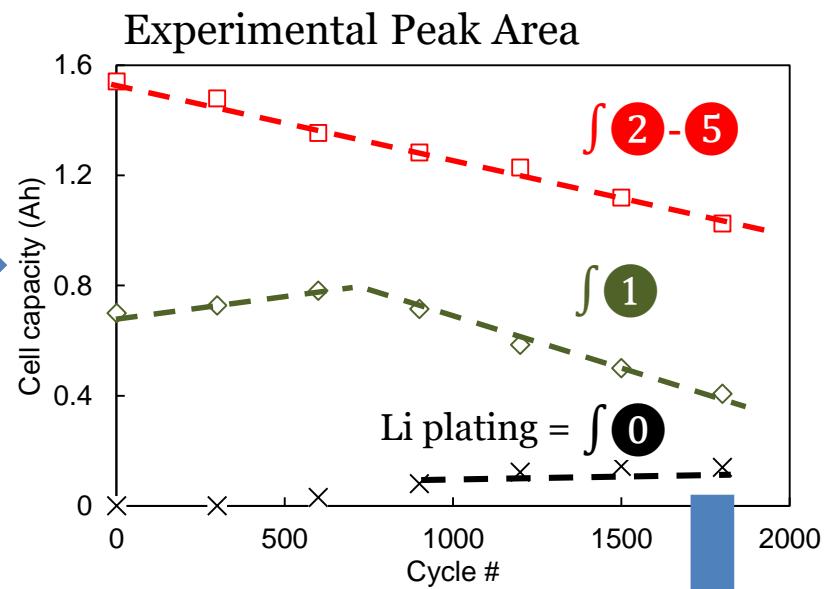
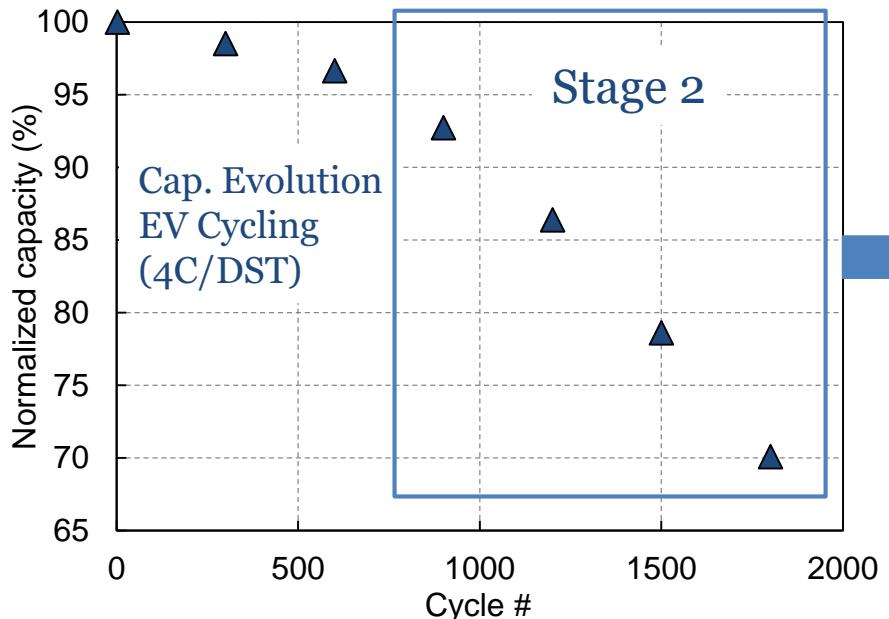
$LAM_{deNE} > LLI$ (ratio 4:1)

Imminent Li plating → cycle 750

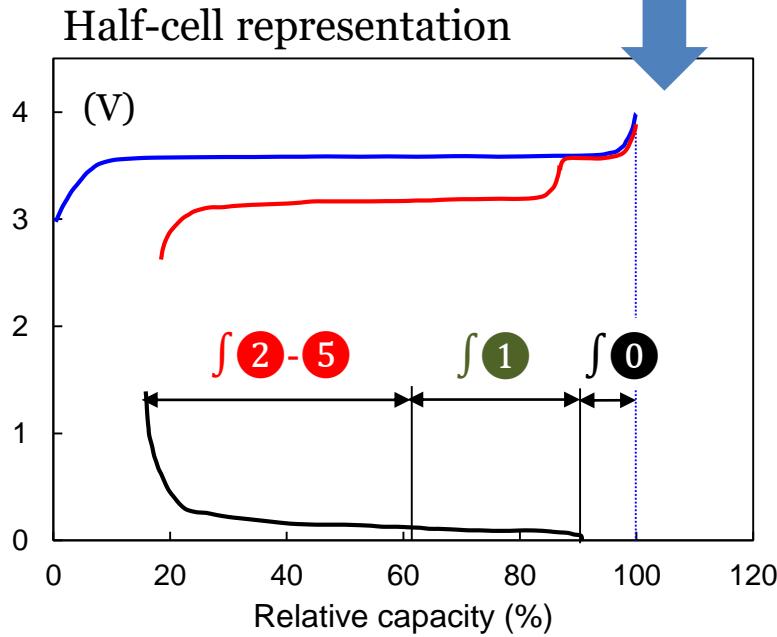


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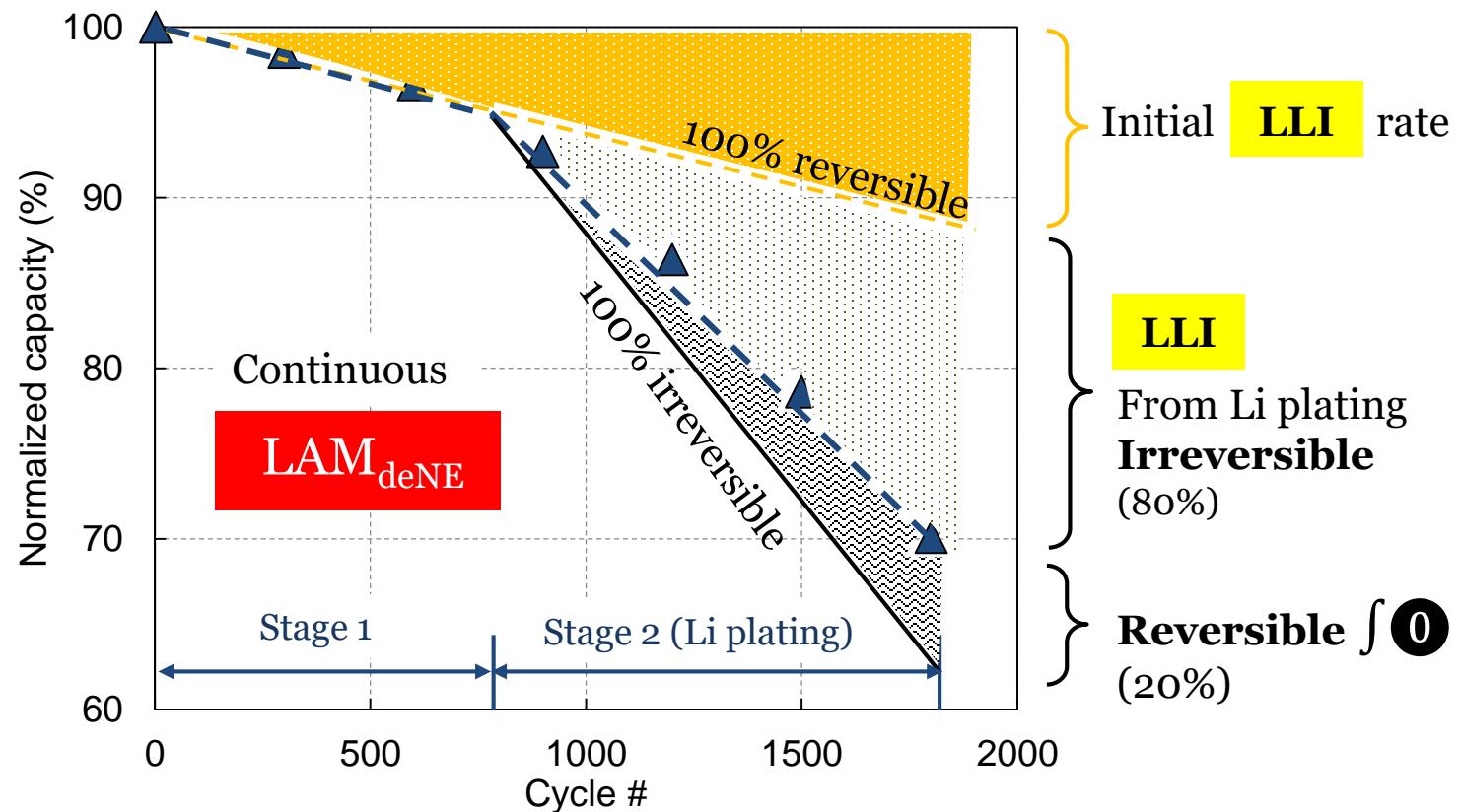
Emulation Stage 2: Lithium plating (cycle 750 → 1800)



alawa
input
parameters



Aging evolution with cycling



Li plating effects:

- Increases LLI (x5)
- Increases cap. fade (x5)

Conclusions

Degradation origins

- DST cycling accelerates capacity loss
- DST cycling induces large LAM_{deNE}
- Large LAM_{deNE} leads NE to over-discharge → Li plating

Lithium plating detection

- Use of ICA to detect new phases (peak 0)
- Use of Peak ∫ 1 (↑) as an early indicator of Li plating

Aging mechanisms quantification

- Use of ICA and ‘alawa toolbox
- LAM_{deNE} > LLI (ratio 4:1)
- Li plating increases rate of LLI (x5)
- Irreversible Li plating (80%) vs. reversible (20%)

Acknowledgments

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Thank you for your attention!

Rescheduled talk by M. Dubarry: today 5:40 p.m. Room 312