

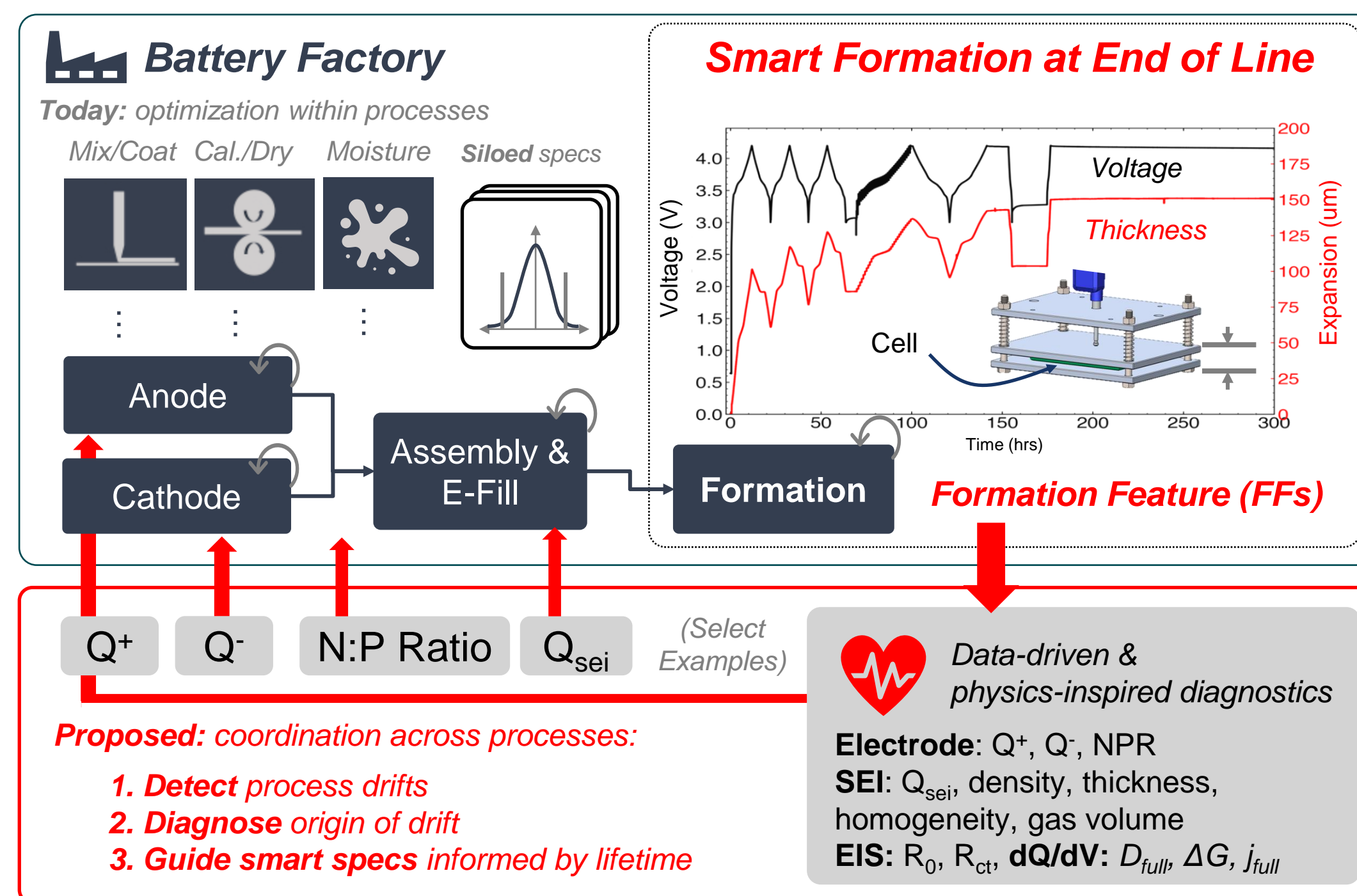
Introduction

Battery formation, the last step in battery manufacturing, is painful...



...but provides an untapped source of electrochemical data that can improve cell performance diagnostics, upstream process control, and formation speed. Yet, data interpretation remains challenging without a model-based understanding of the formation process.

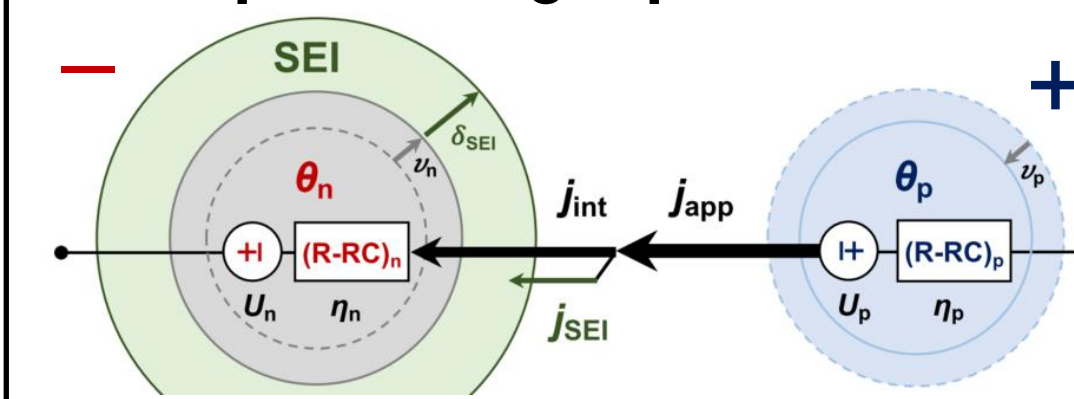
Smart Formation: A Proof-of-Concept



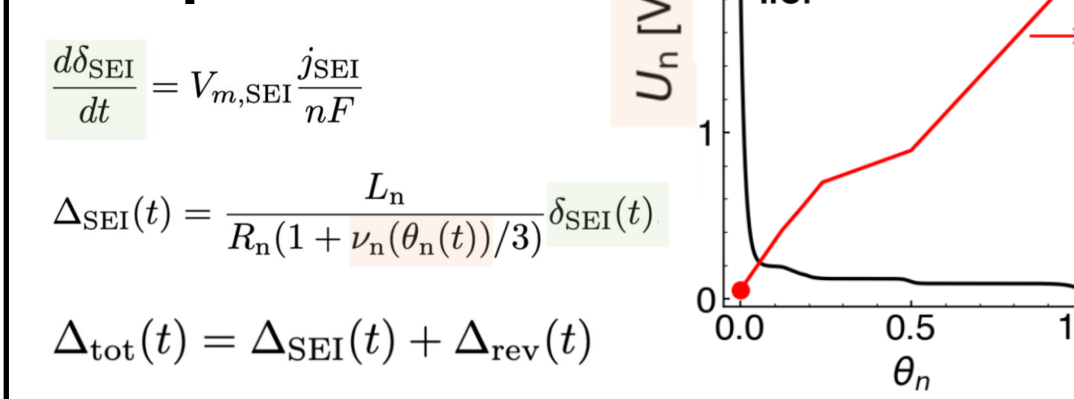
Modeling Formation

A minimum set of elements for building a formation process model:²

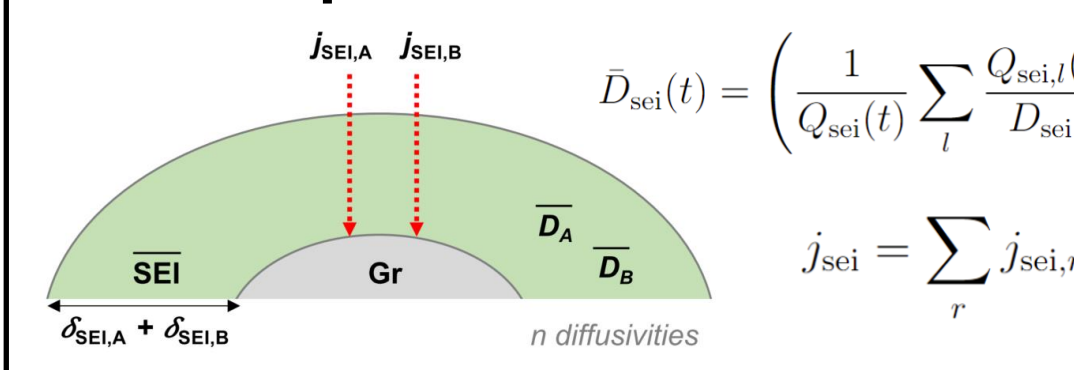
1. Simplified single-particle model



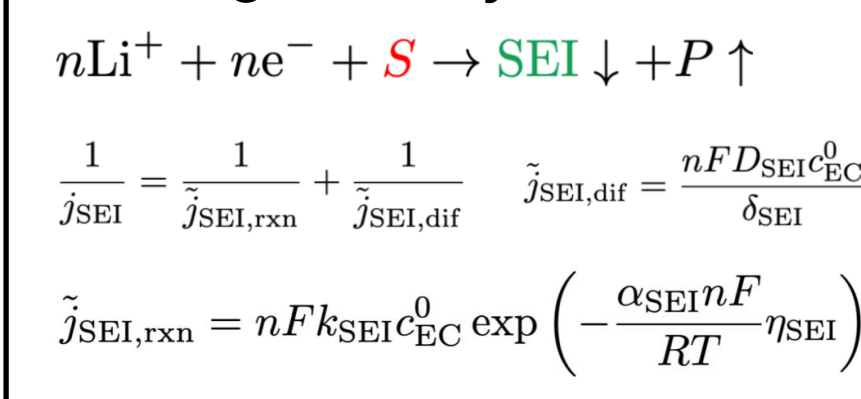
3. Expansion



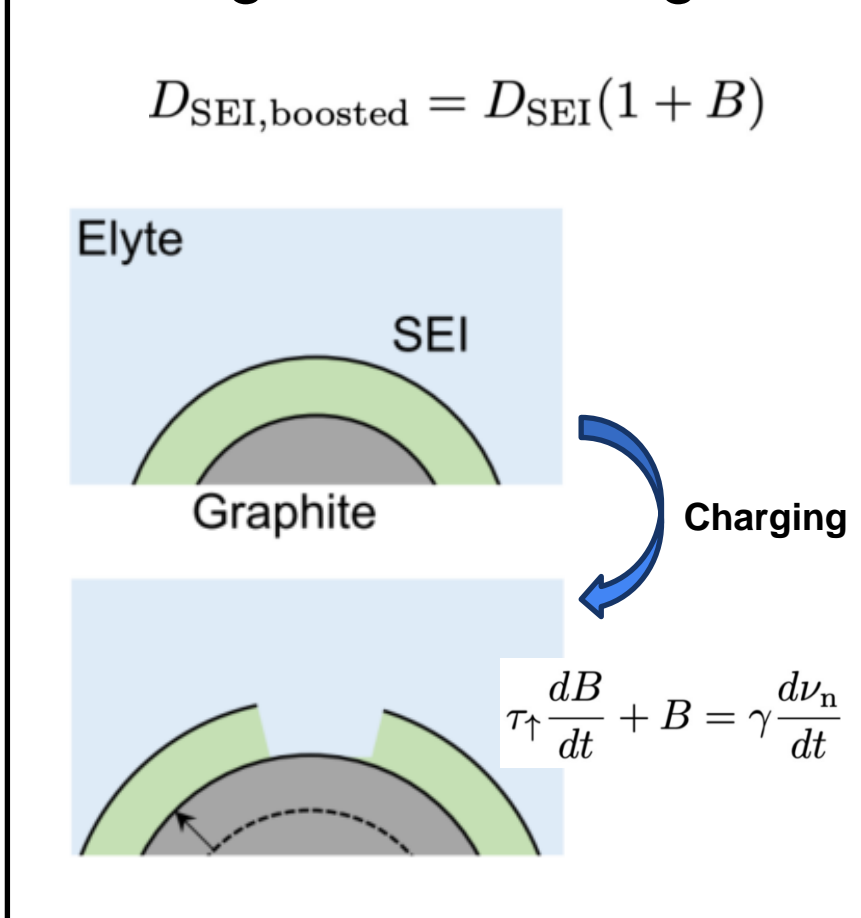
5. Multi-species reactions



2. SEI growth dynamics

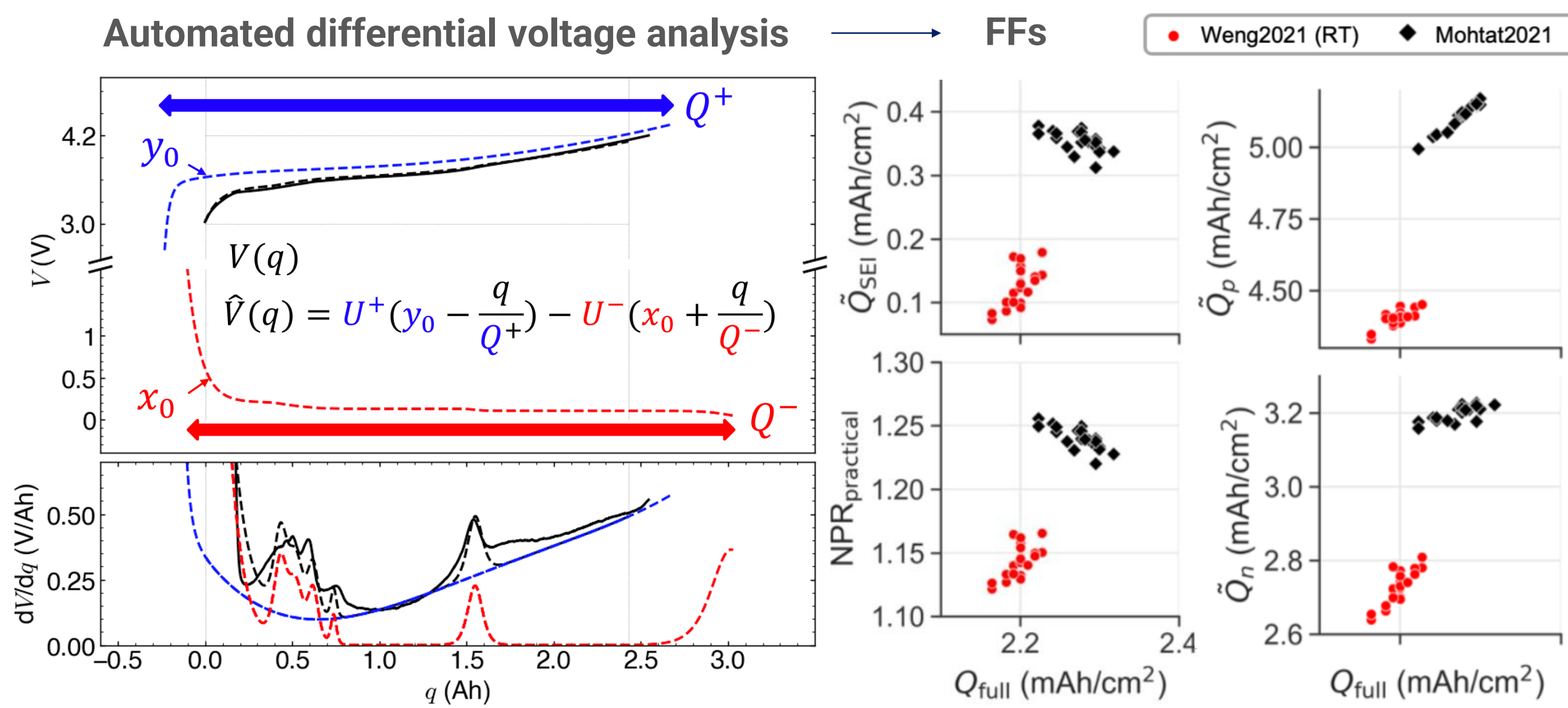


4. SEI growth boosting

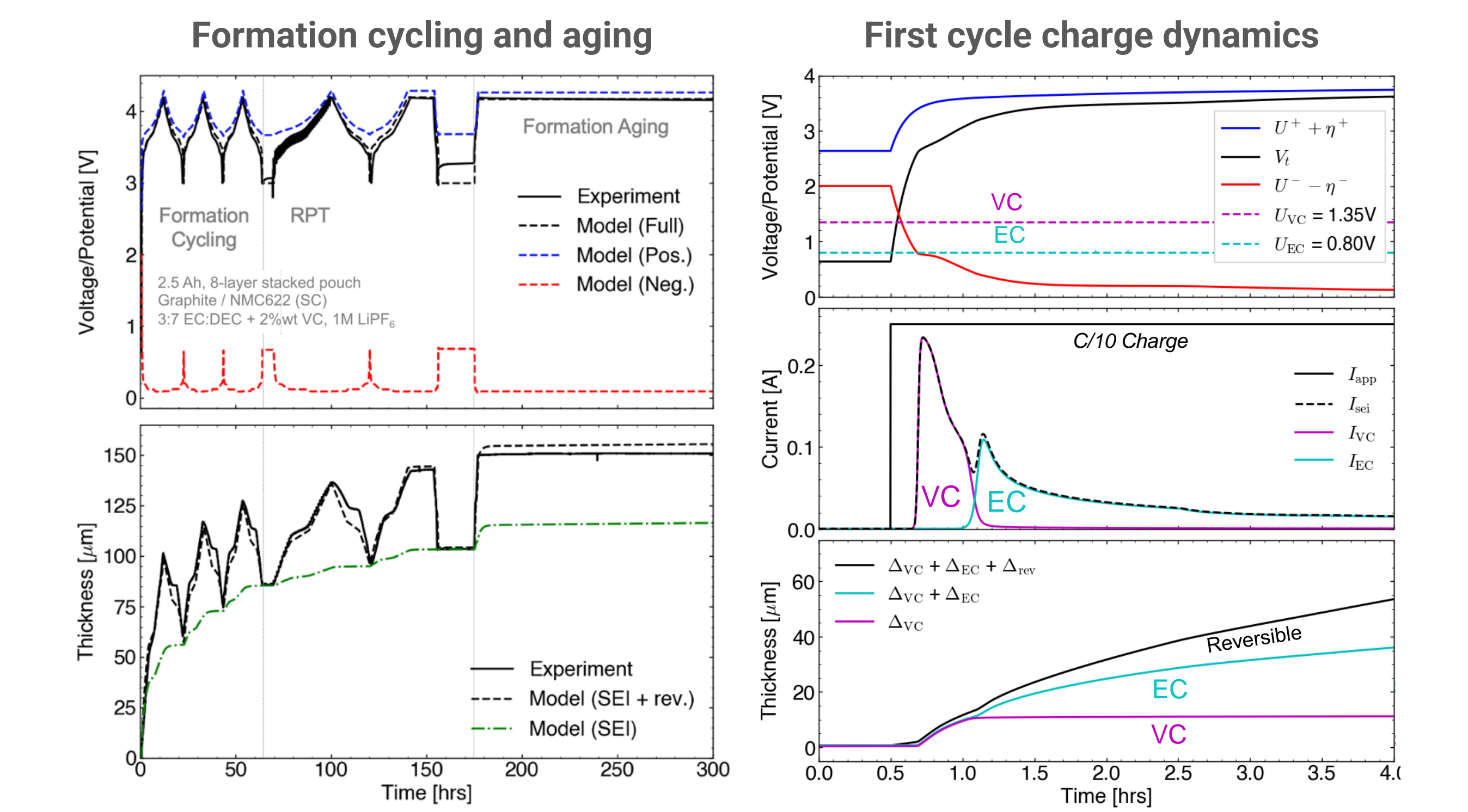


The Three Pillars of Smart Formation

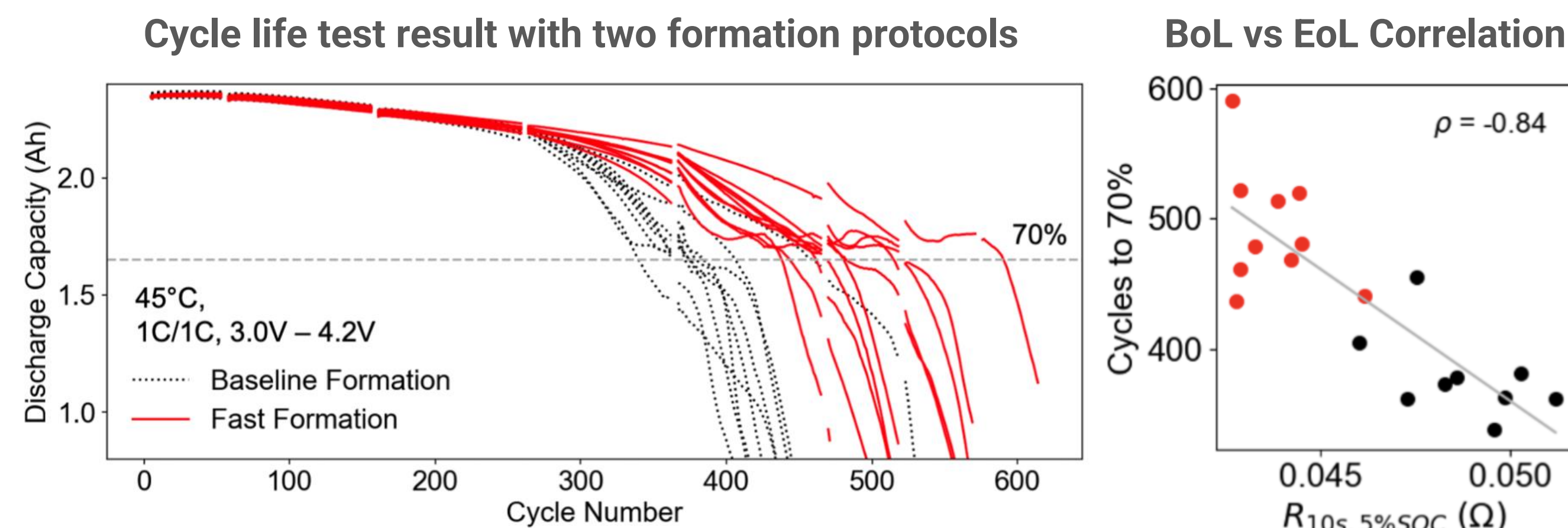
1. Formation features (FFs) enable scalable, non-destructive extraction of electrochemically-meaningful performance metrics at the end-of-line, via formation:¹



2. Physics-based formation models set a foundation for interpreting FFs, developing new FFs, and enabling model-based control of formation protocols:²

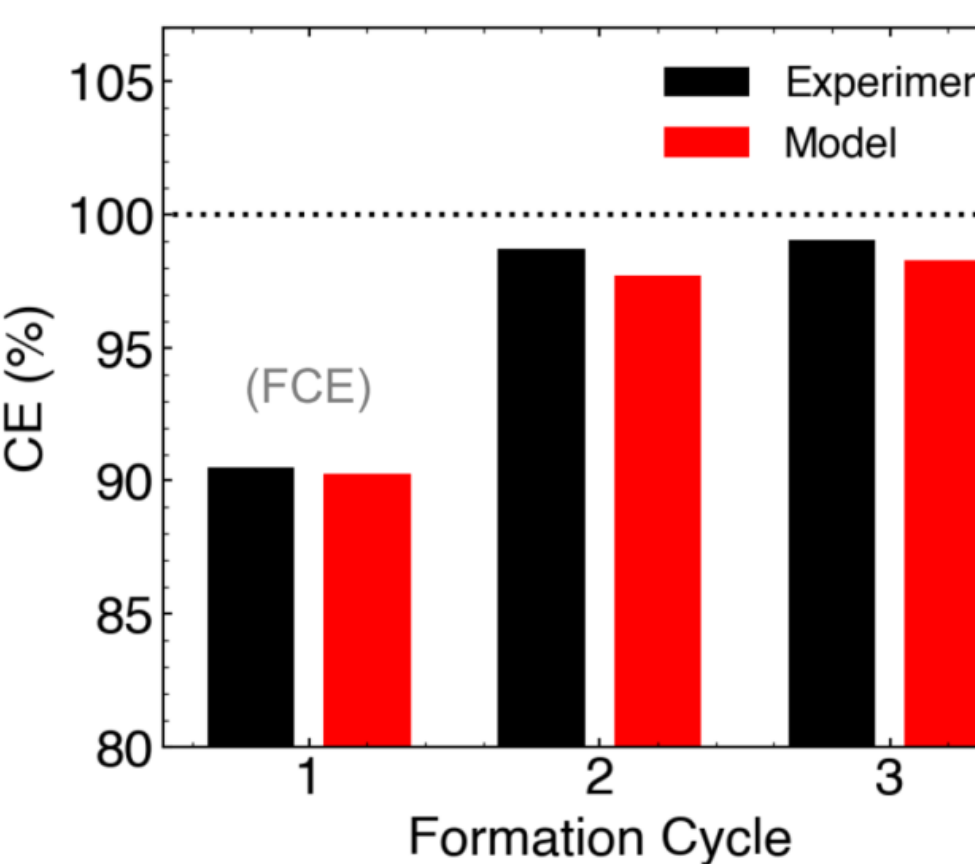


3: Lifetime understanding enables setting of FF specs, e.g., the resistance at low-SOC (R_{10s,5%SOC}), informed by end-of-life performance.³

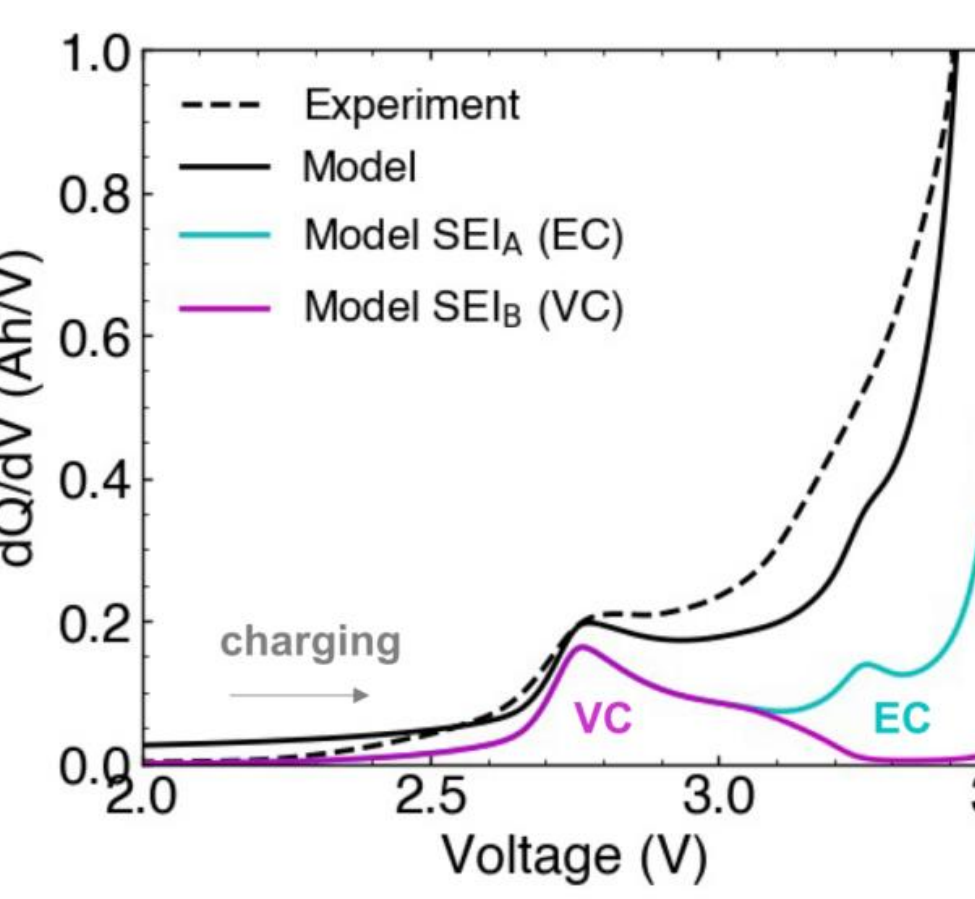


Model Validation

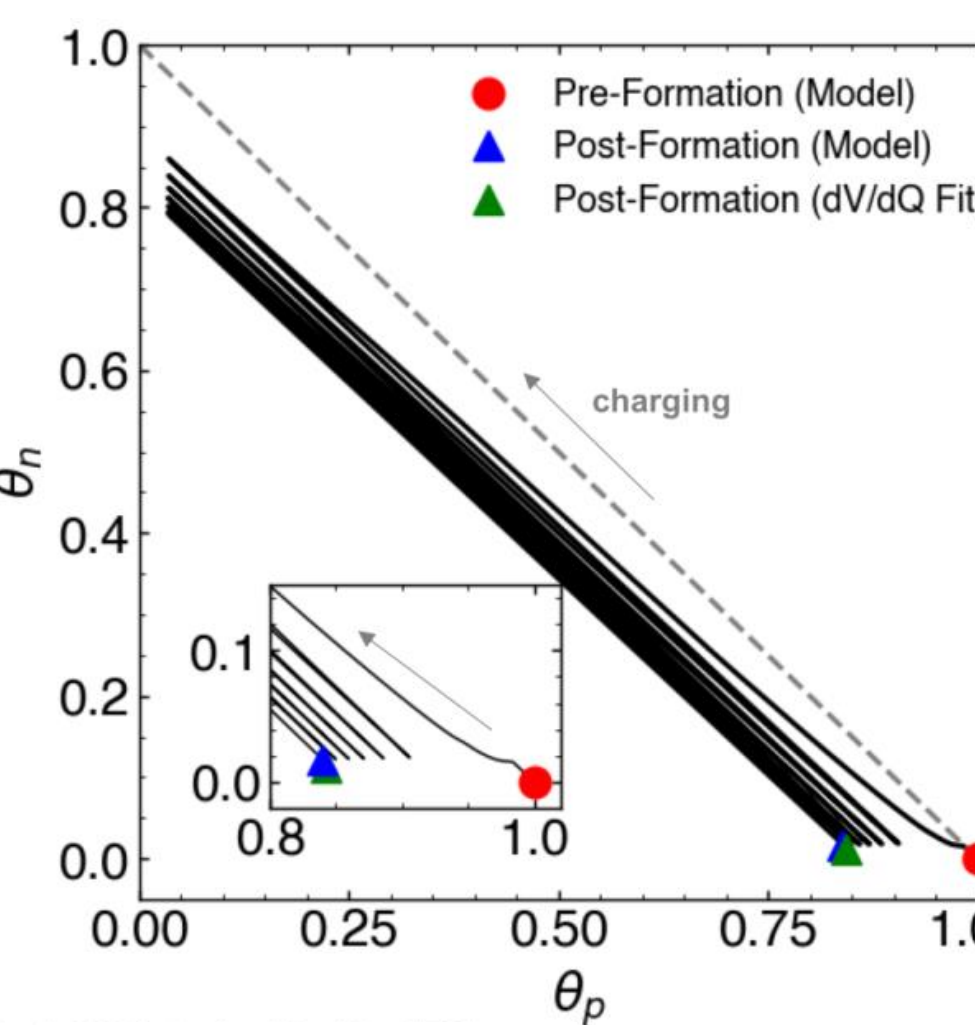
A: First cycle efficiency (FCE)



B: 1st cycle VC reduction peak



C: Li stoic. at end of formation (verified by dV/dQ fitting)

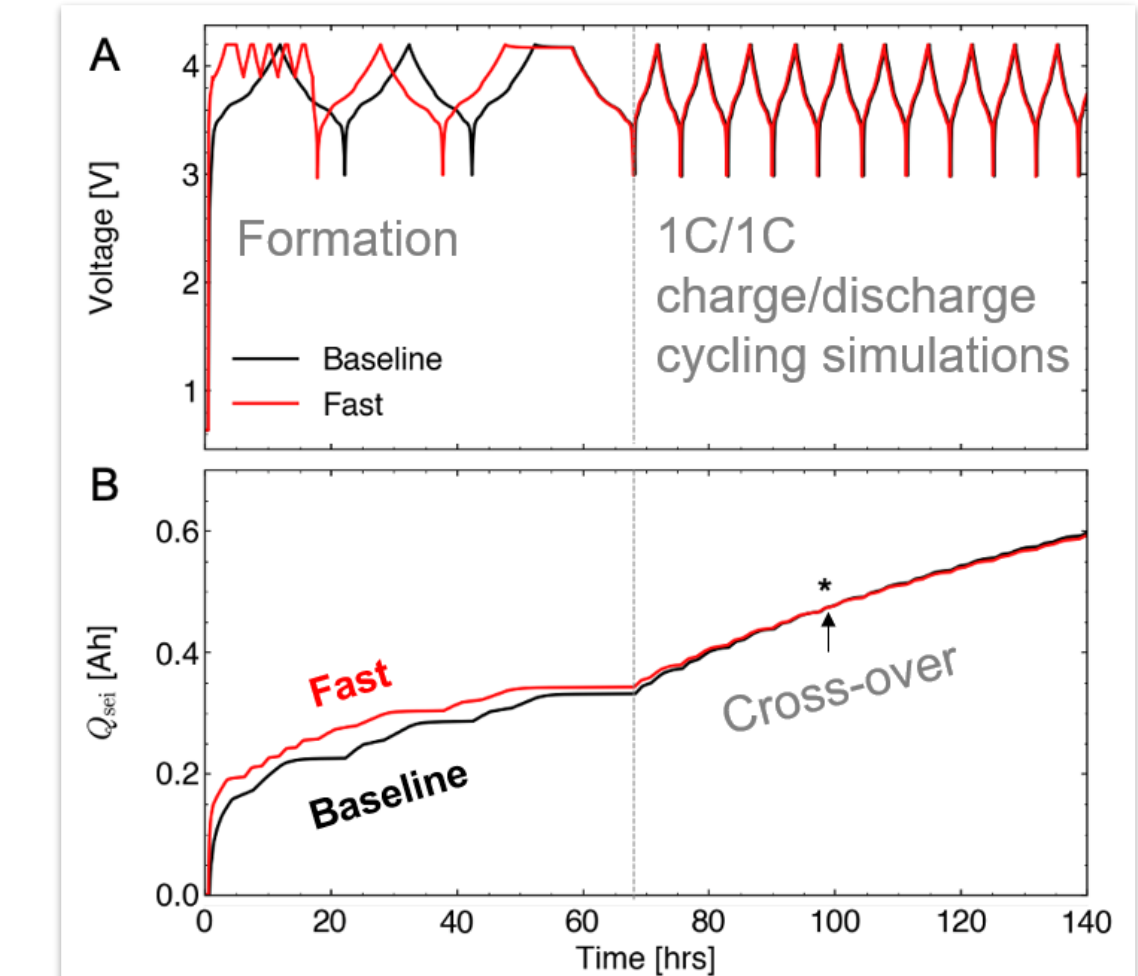


Outlook

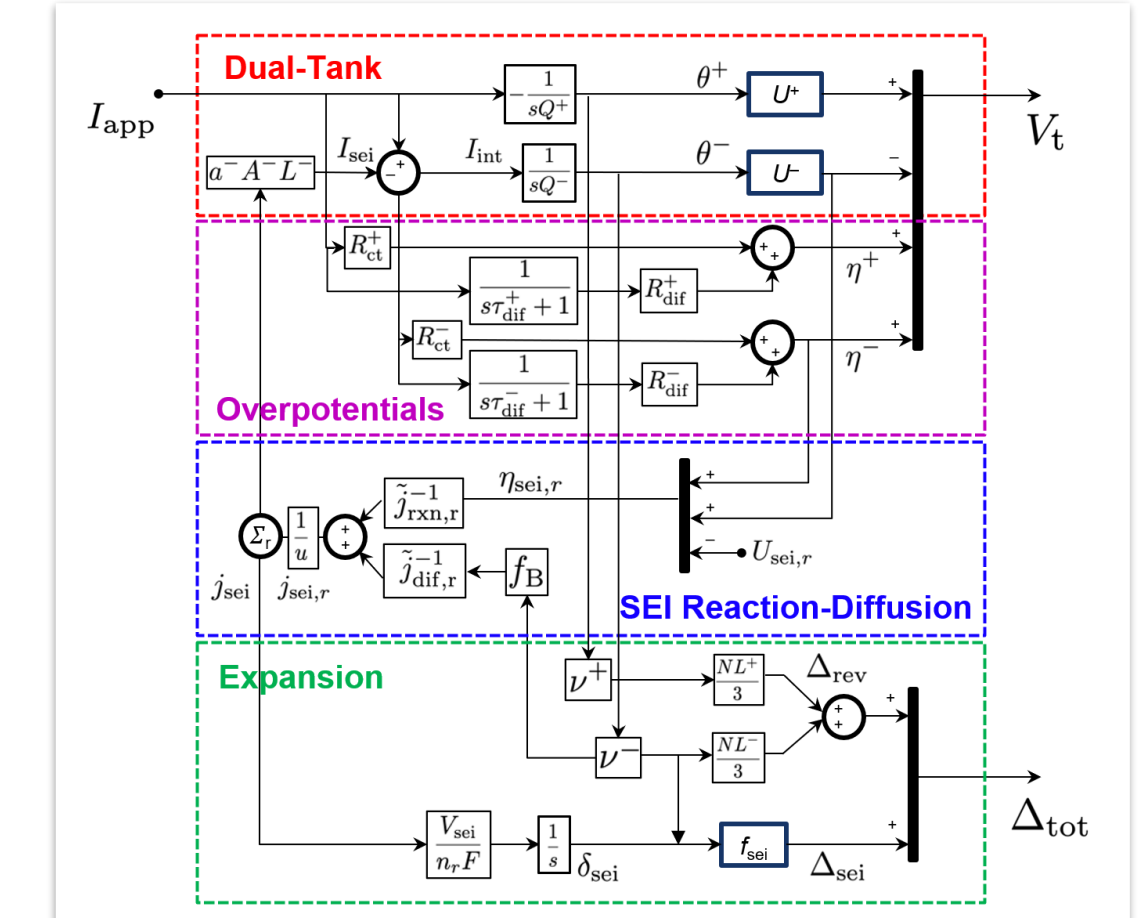
Physics-informed battery formation models can help improve end-of-line diagnostics by improving the interpretability of formation features and identifying design rules for formation protocol optimization. We showed how a simple formation model can enable a rich set of state predictions. The model can potentially be used to develop adaptive formation protocols and, perhaps, enable online, closed-loop manufacturing process control for future factories.

Future Work

Lifetime Simulations



Formation Controller Design



References

- Weng et al., "Differential voltage analysis for battery manufacturing process control," Front. Energy Research, 2023, 11
- Weng et al., "Modeling Battery Formation: Boosted SEI Growth, Multi-Species Reactions, and Irreversible Expansion," J. Electrochem. Soc., 2023, 170(090523)
- Weng et al., "Predicting the impact of formation protocols on battery lifetime immediately after manufacturing," Joule, 2021, 5(11), 2971-2992

