NC STATE UNIVERSITY

Nonequilibrium thermodynamics of rate-capacity lost phenomena for Li-ion battery

Hongjiang Chen and Hsiao-Ying Shadow Huang
Mechanical and Aerospace Engineering, North Carolina State University, Raleigh, NC

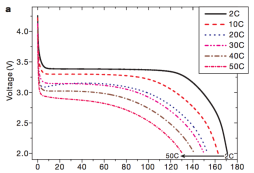
Introduction and Background

Introduction:

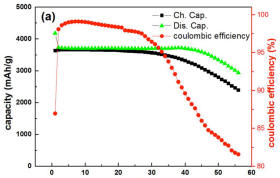
- Lithium-ion batteries are critical to modern and emerging technologies ranging from electric vehicles, high-power tools and wearable electronics to prosthetic limbs and exoskeletons for the physically disabled.

Current Problems of Li-ion battery

- Poor power performance under high C-rate
- Irreversible capacity loss after cycling and limited life time under high C-rate

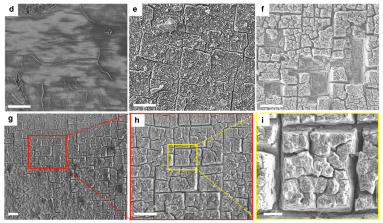


Kang & Ceder, *Nature* 458, 190-193 (03/12/2009)



J. Xie et al, doi: 10.1149/2.0091503jes

Electrodes' cracks and failure



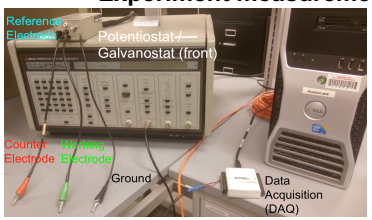
Si anode SEM images after (d)3, (e) 8, (f) 50 and (g–i) 30 cycles. Scale bar, 20μm (d–h), 3 μm (i).
[F. Shi et al, doi: 10.1038/ncomms11886.]

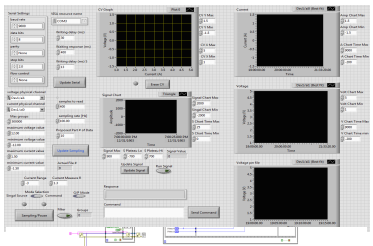
Objective:

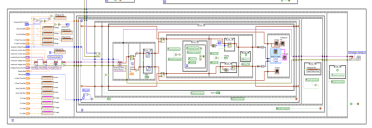
- Describe and predict electrical potential and capacity characteristic under high C-rate (dis)charging.
- Predict Li-ion battery's lifetime under different C-rates.
- Develop approaches to improve Li-ion battery's cycling time and high C-rate performance.

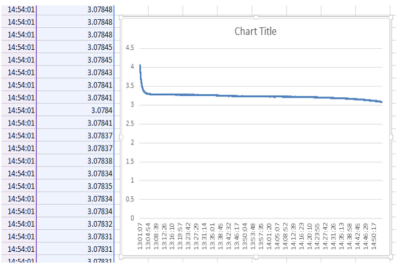
Methods and Current Results

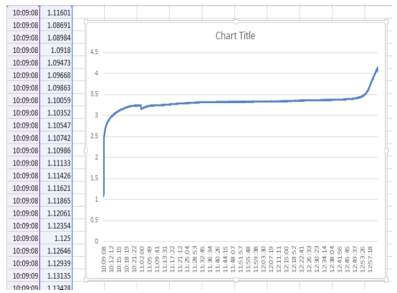
Experiment measurement and LabVIEW Program



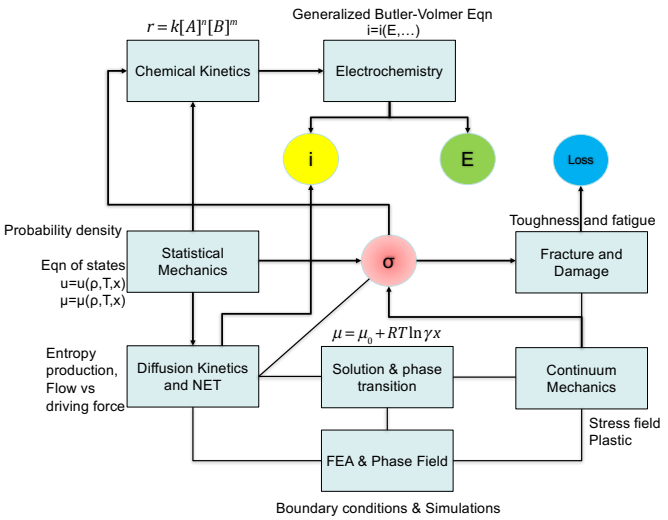


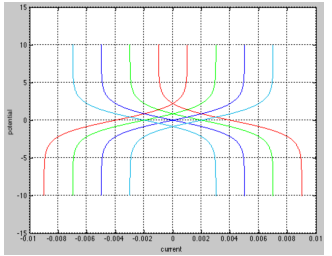




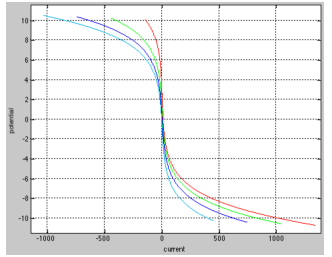


Theory Architecture based on Non-Equilibrium Theory





With diffusion effect



Without diffusion effect

Conclusion and Future Work

- Understanding the loss of power density and capacity involves interdisciplinary theories and models.
- Develop more comprehensive model with less assumption to achieve accurate prediction.
- Model the equations of states: Chemical potentials and specific internal energy incorporating density, fractions and temperature as independent variables.
- Solve equation groups from the above theory architecture and conduct finite element analyses and phase field simulations.
- Damage and capacity loss modeling.

nc state ENGINEERING