Influence of temperature inhomogeneity on cycling characteristics and local aging behavior of lithium-ion battery cells

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Abstract

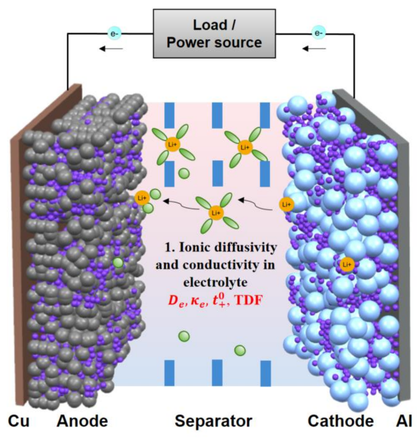
This work presents a three-dimensional electrochemical thermal model to investigate the temperature inhomogeneity effects on lithium-ion batteries. The side reaction models of solid electrolyte film growth and lithium deposition are combined into the current model to simulate the aging process. The cycling performance and aging mechanism of battery cells under different temperature gradients are discussed.

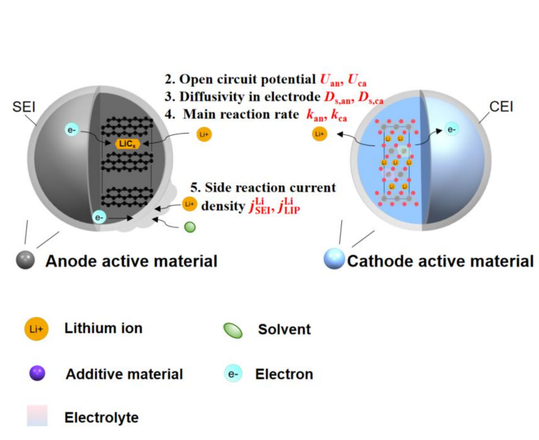
Conclusion

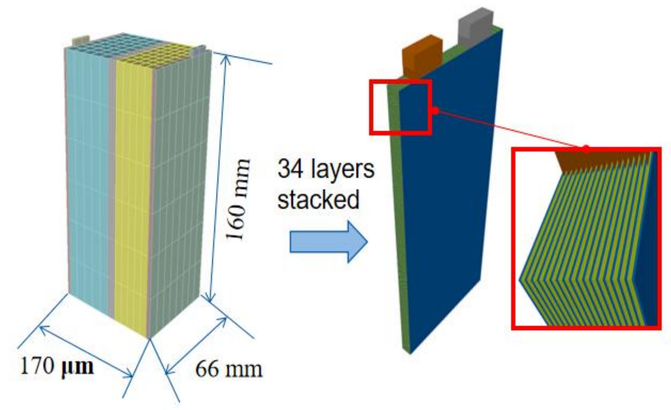
Higher lithium-ion concentration can be found in the low-temperature region of the negative electrode near the separator. The inconsistent distribution of polarization caused by the temperature distribution will further negatively impact the distribution uniformity of current density. The low-temperature region of anode has a higher overpotential and Li+ concentration gradient, resulting in larger local degradation in this region.

3D-Electrochemical-thermal modeling

- Lithium-ion battery cell
  - NMC/graphite, Kokam SLPB065070180
- Electrochemical-thermal model
  - Electrochemical-thermal dynamics with partial differential algebraic equations under three dimensional framework.
  - Aging model with SEI growth and Lithium plating.
- Numerical solutions with the finite volume method
  - Single domain multi sub-region treatment.
  - Piecewise linear accelaration method for aging modelling.



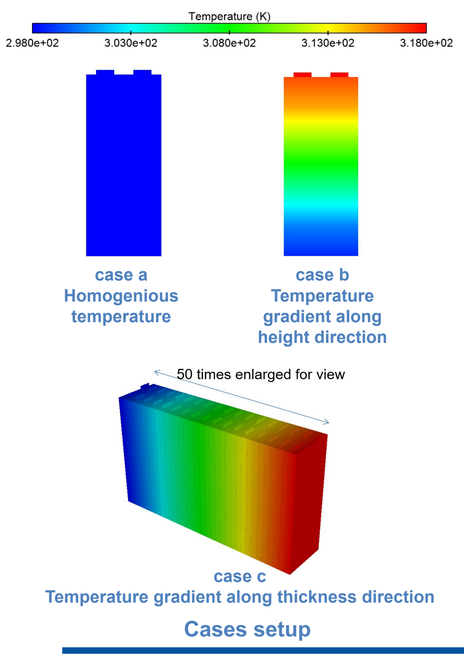




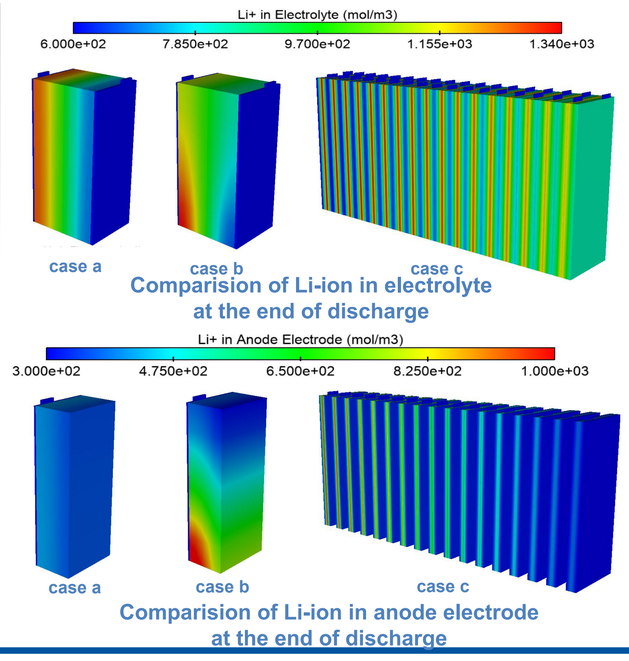
Schematic of major factors affected by temperature inhomogeniety in Li-ion battery

Schematic of mesh model

Temperature inhomogeneity effects on cycling performance

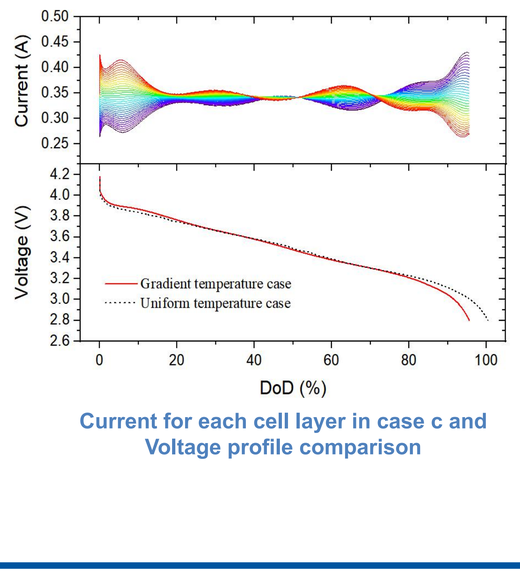


Cases setup



Comparision of Li-ion in electrolyte at the end of discharge

Comparision of Li-ion in anode electrode at the end of discharge

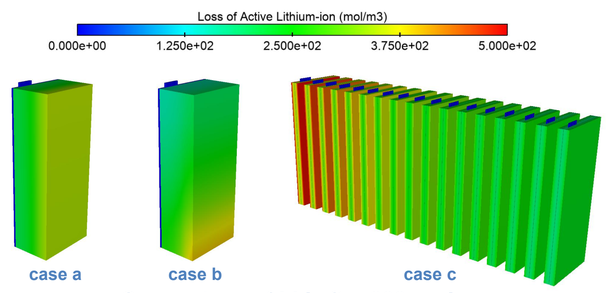


Current for each cell layer in case c and Voltage profile comparison

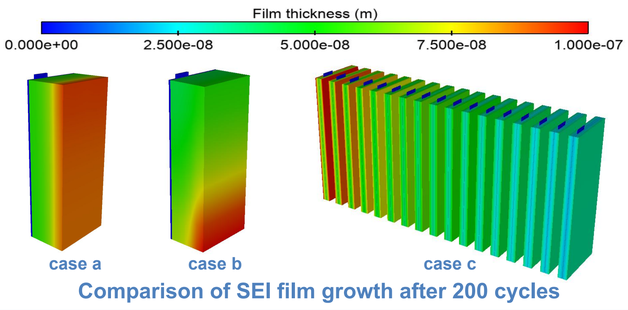
- Cases consider the temperature gradient effects along the cell height and thickness are compared with a homogeneous temperature case.
- Sensitivities of electrolyte properties, electrode diffusivity, main reaction rate and side reaction current density factors to temperature was compared.
- The diffusion and conduction coefficients in the low-temperature region are lower, which increases the difficulty of lithium-ion diffusion in the electrolyte.
- A higher lithium-ion concentration gradient can be found in the low-temperature region.
- Variation of cell current in different layers is related to the temperature distribution and DOD.

Temperature inhomogeneity effects on local aging

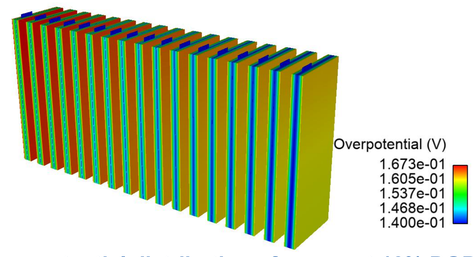
- Side reactions and local degradations are more concentrated in the low-temperature region.
- The potential change in the low temperature region does not match the rate of Li-ion concentration change in the cases with temperature inhomogeneity .
- A higher overpotential is more likely to be found in the low temperature region than in the high temperature region, resulting in greater side reaction intensity.



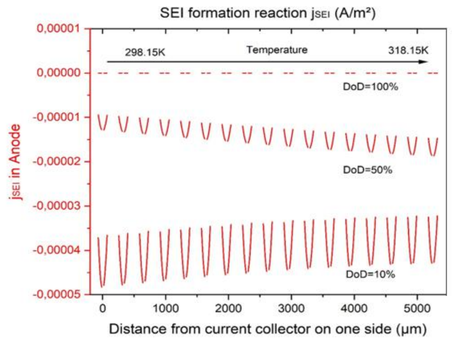
Comparison of LLI after 200 cycles



Comparison of SEI film growth after 200 cycles



Over potential distribution of case c at 10% DOD



Current density of SEI formation of case c

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