Hierarchical multiscale modeling framework and 3D thermo-electrochemical coupled model for Li-ion battery thermal management systems

Mechanical & Industrial Engineering
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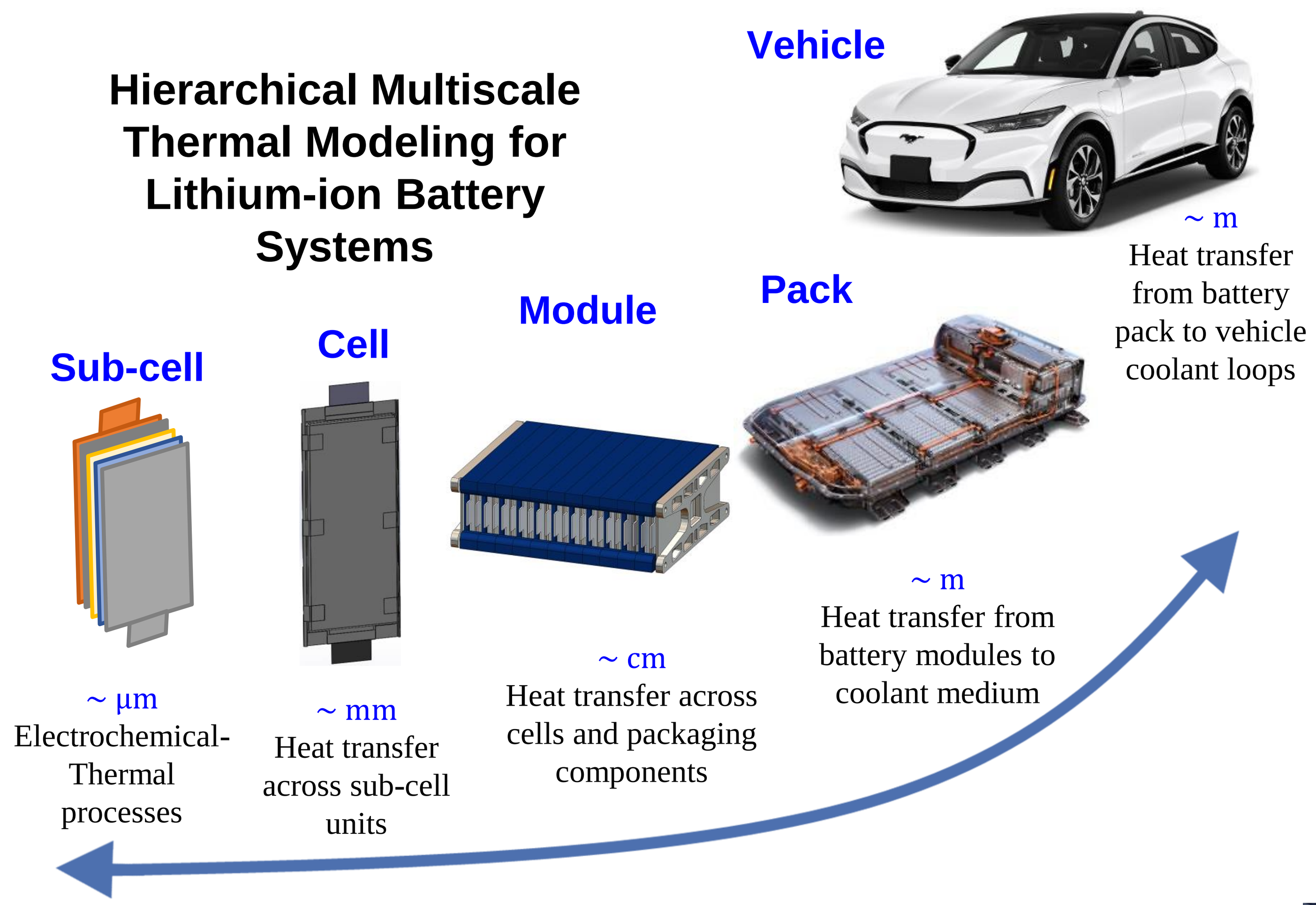
atoms laboratory

Motivation

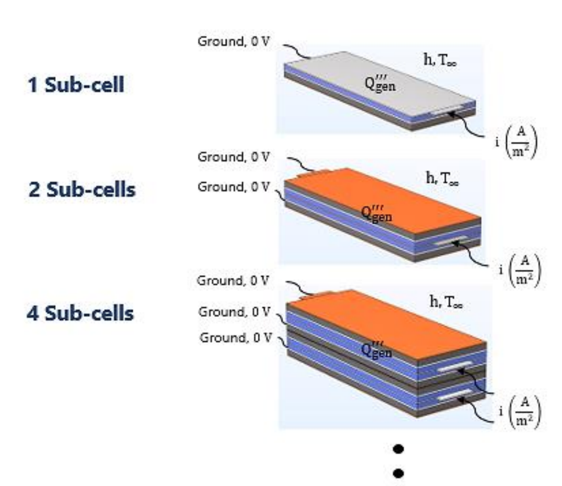


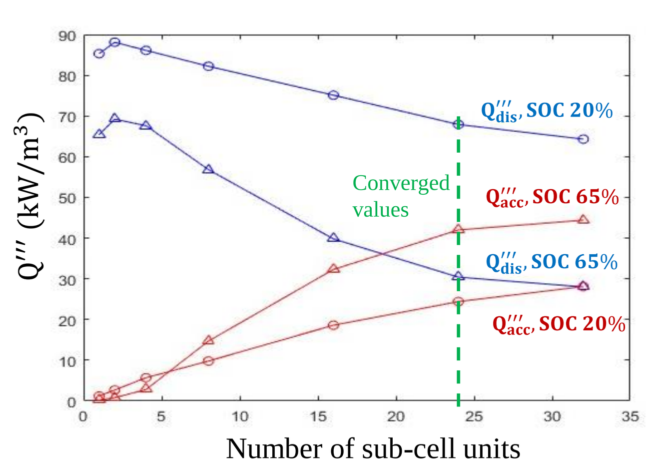
Objectives

- Predict Cell's and Modules' effective thermophysical properties
- Develop a 3D thermo-electrochemical coupled model for cell's thermal performance
- Perform parametric sweep analyses for optimal design at cell level

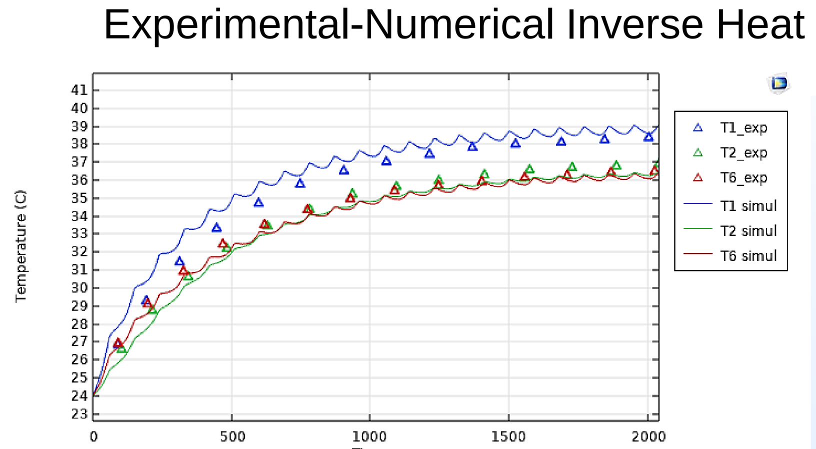
Cell thermal characterization

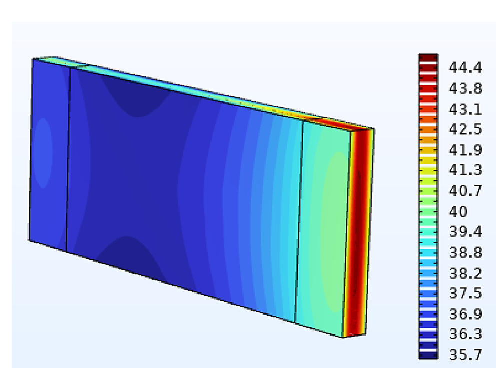
- Effective thermophysical properties predicted from a representative number of sub-cell units





- Effective thermophysical properties predicted through an Experimental-Numerical Inverse Heat Transfer model





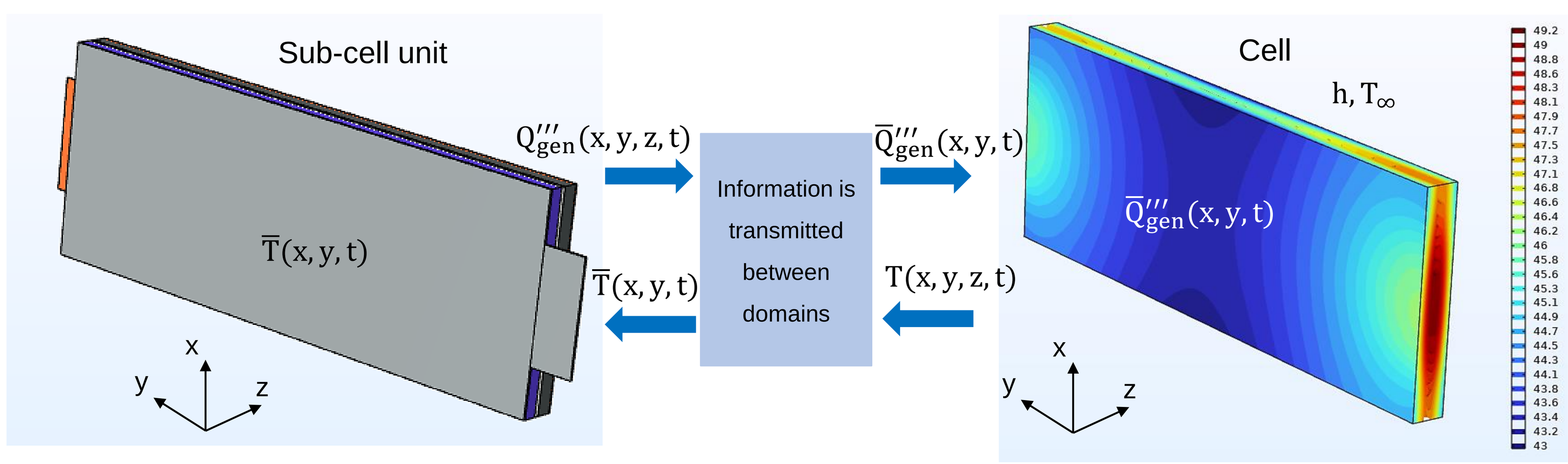
$$k_{eff\,in-plane} = 31.8\,\frac{W}{mK},\; k_{eff\,cross-plane} = 0.31\,\frac{W}{mK},\; c_{p\,eff} = 1{,}038\,\frac{J}{kgK}$$

Three-dimensional (3D) thermo-electrochemical coupled model

Volumetric heat generation rates and temperature field hierarchically transferred between domains

Electrochemical kinetics: P2D model applied to a sub-cell 3D domain

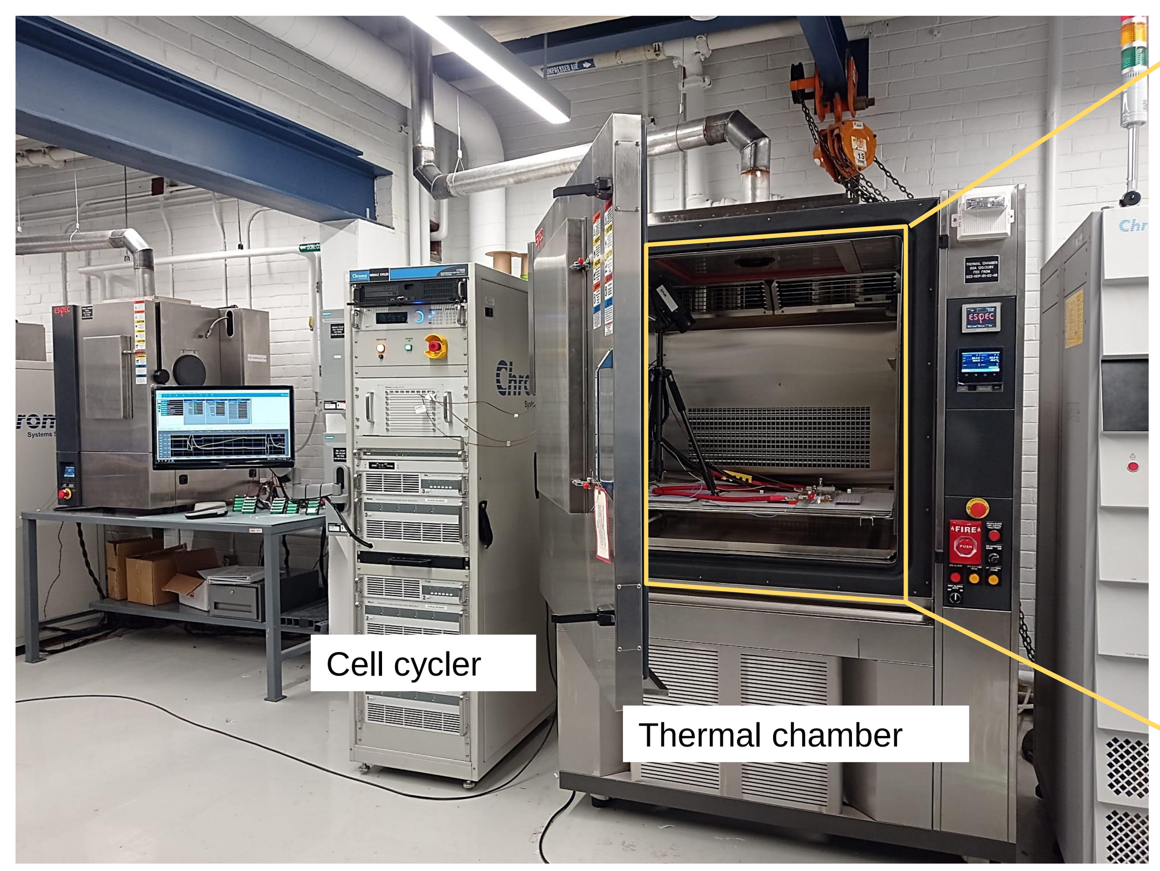
- Conservation of charge
- Conservation of mass

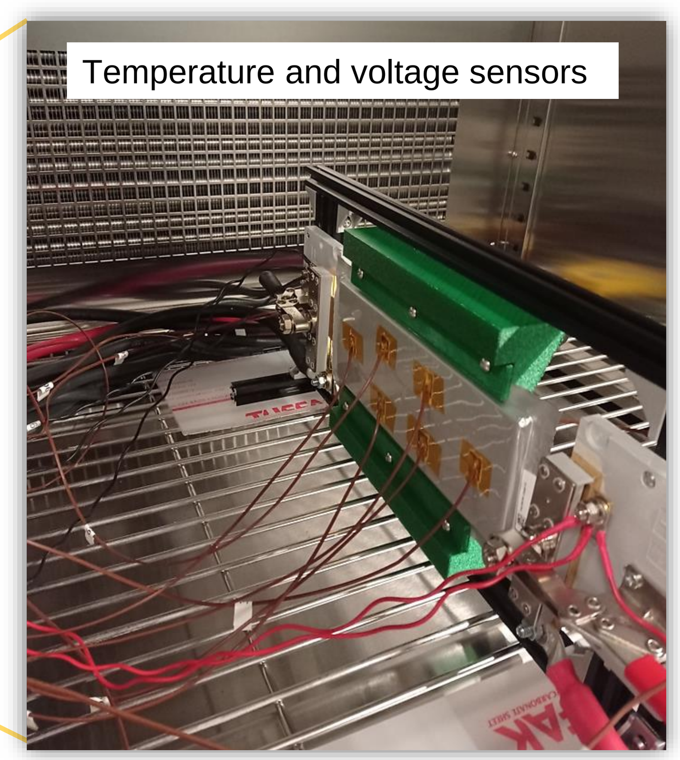


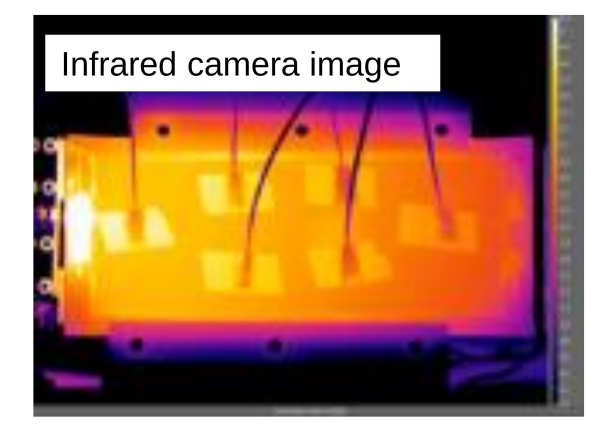
Conservation of Energy applied to a battery cell domain:

Cell is fully exposed to a convective environment

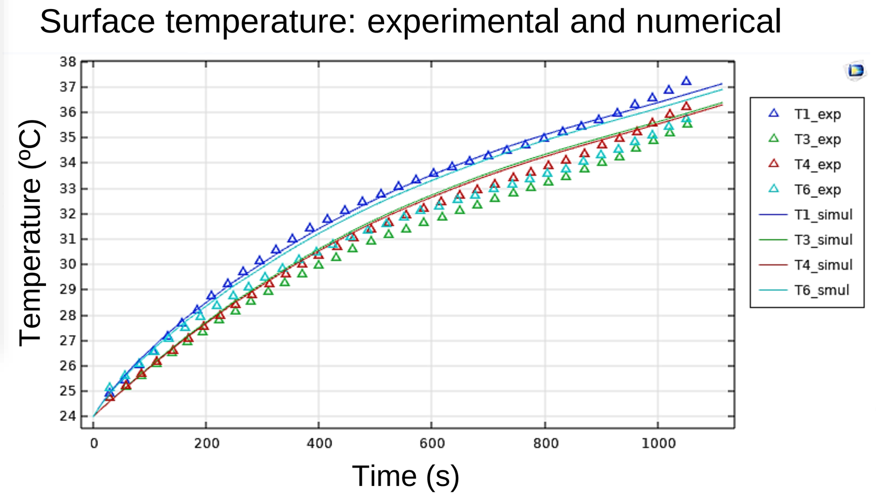
Experimental tests at the Thermal Management Systems (TMS) Lab





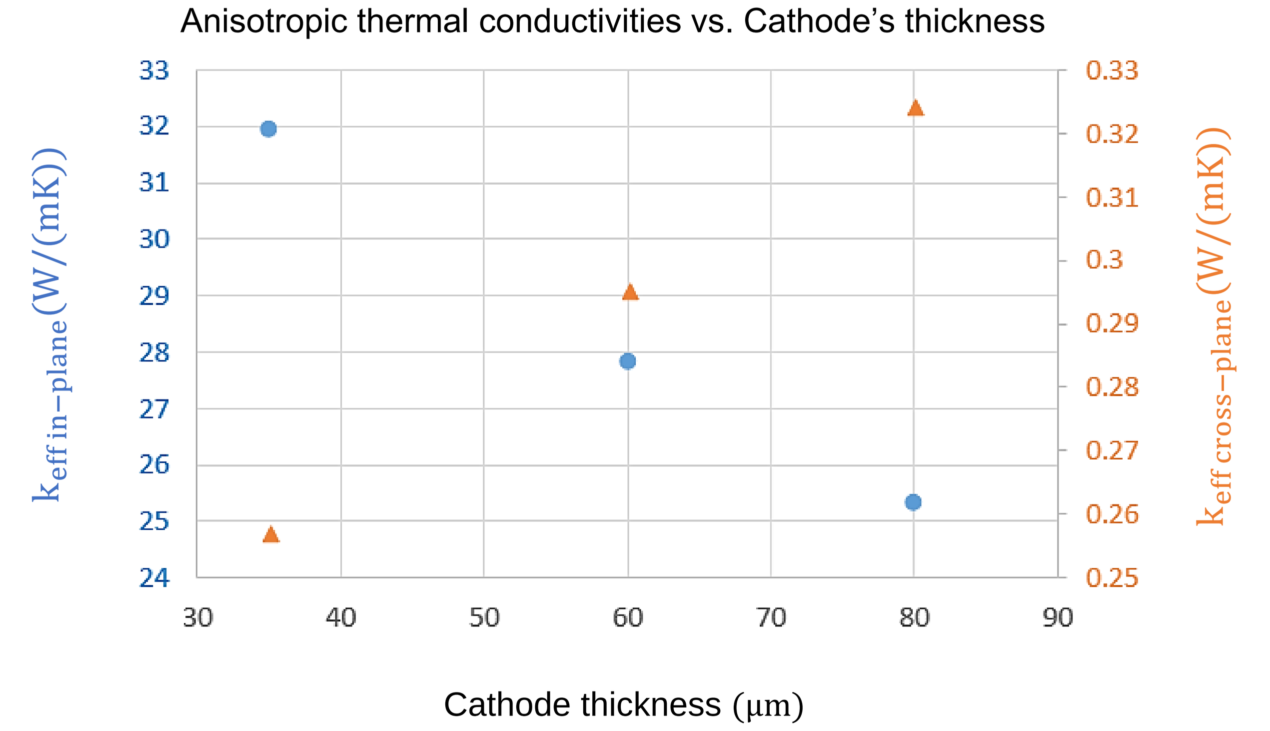


Surface temperature: experimental and numerical

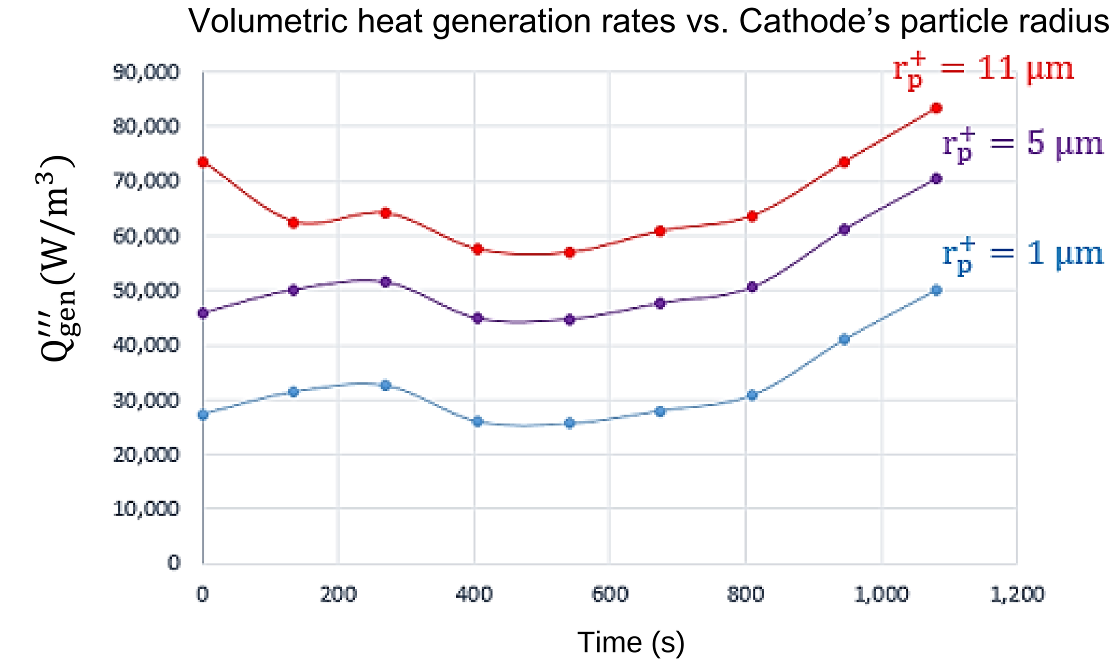


Parametric sweep analysis for cell's thermal performance

Anisotropic thermal conductivities vs. Cathode's thickness

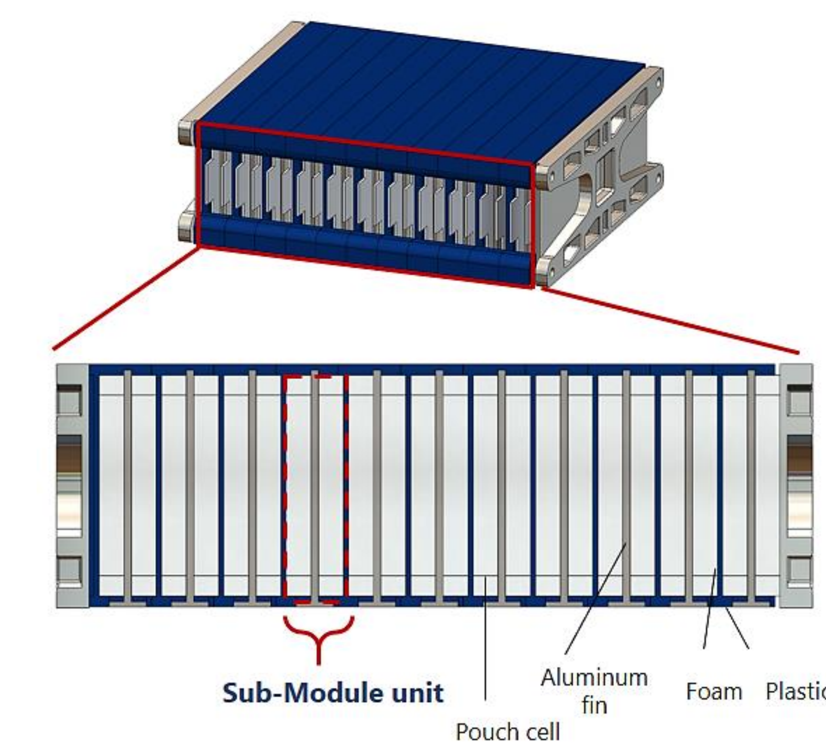


Volumetric heat generation rates vs. Cathode's particle radius

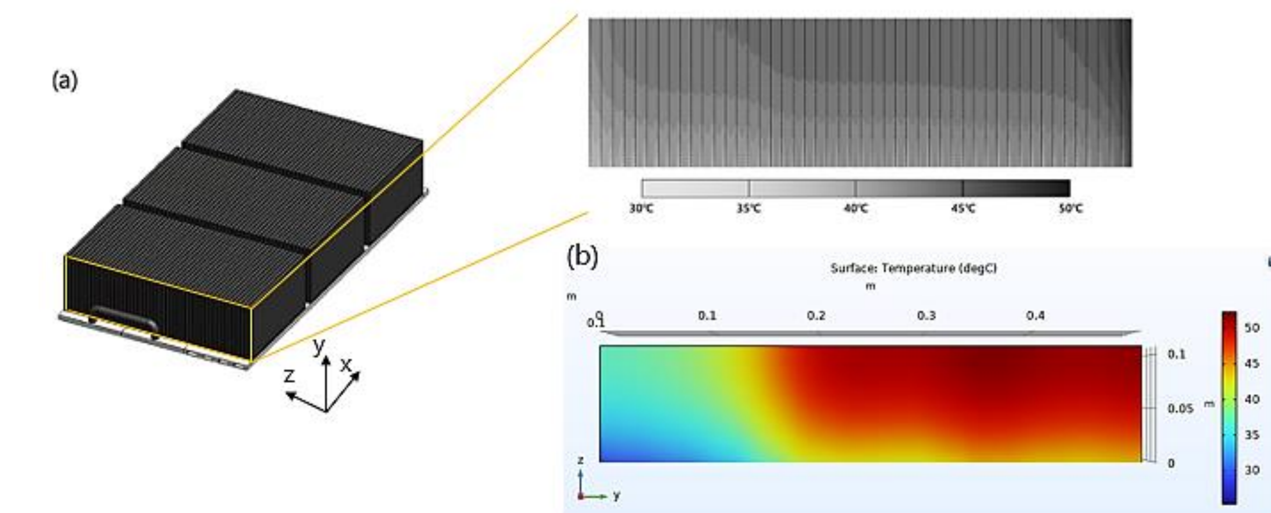


Module thermal characterization

- Effective thermophysical properties predicted from a representative number of sub-module units



Case study: module of pouch cells, fins, foam, and plastic case



(a) Isometric view of case study; (b) cross-section view of temperature gradients: top, original work; bottom, current methodology

Conclusions and next steps

- Effective thermophysical properties can represent cells and modules as homogeneous domains with anisotropic heat transport
- Heat generation rates are highly time and spatially dependent in large format pouch batteries
- Next steps involve proposition of battery thermal management systems and thermal performance metrics

Acknowledgements

This work was supported by the University of Toronto Electrification Hub, the Natural Sciences and Engineering Research Council of Canada (NSERC) through the CREATE TherMET Training Program, Flex-N-Gate, Mitacs Accelerate Program, and CMC Microsystems.