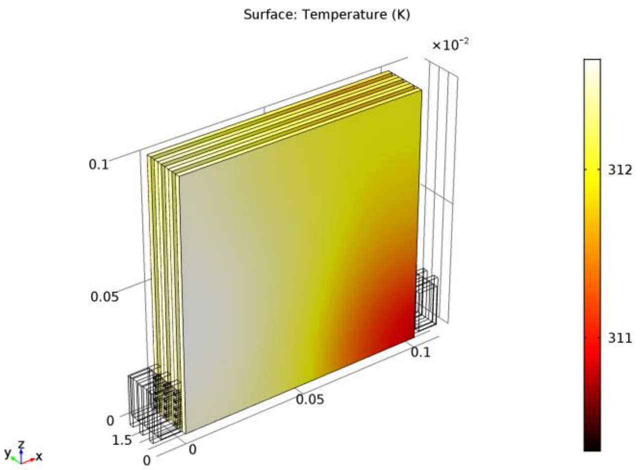
Thermal Modeling of Batteries in COMSOL

Why Thermal Modeling?

- Assess cooling needs
  - High temperatures may increase SEI formation or gassing (aging)
- Identify hot spots and thermal gradients
  - Non-uniform temperature = non-uniform aging
- Start-up dynamics from cold
  - Low temperatures may result in lithium plating on graphite (aging)
  - Low temperature means low electrolyte conductivity (low performance)
- Worst-case scenario assessment
  - Find maximum temperature during abuse (electrolyte ignition)



Temperature distribution in a liquid-cooled battery pack.

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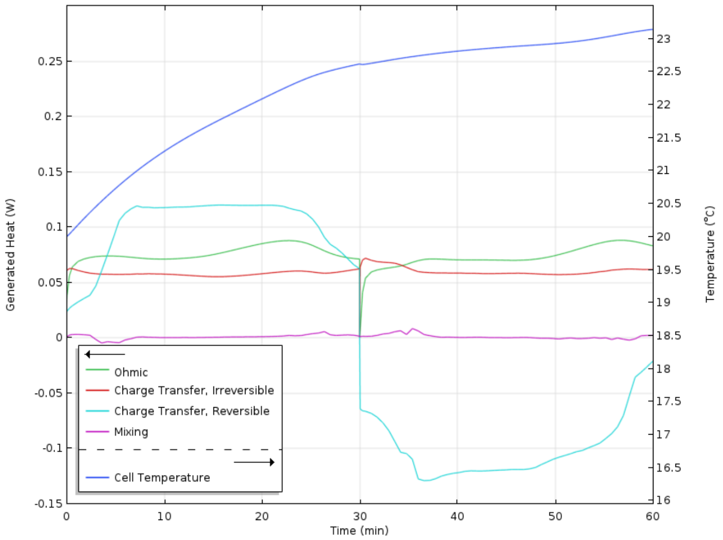
Electrochemical Heat Sources

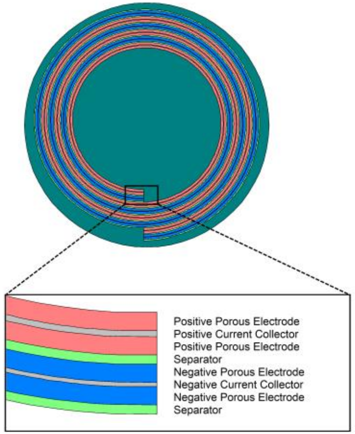
- Ohmic Heating
  - Potential losses due to ion and electron conduction
- Charge Transfer Reactions
  - Irreversible - potential losses
  - Reversible - entropy changes
- Heat of Mixing
  - Potential losses due to concentration gradients



The different heat sources during a symmetrical 1C charge-discharge cycle (25 to 75% state-of-charge).

Cell Thermal Analysis Modeling

- Thermal effects typically needs to be modeled in higher dimensions
  - 2D, 2D with axial symmetry or 3D
- Battery wound geometry consists of multiple (>50) separate layers
  - many details, hard to create computational mesh
- The extra particle dimension may actually imply modeling in 4D
  - many degrees of freedom consumes computer memory and time



Layered spiral geometry of a cylindrical battery. A real battery may contain more than 20 laps. Resolving all these layers is computationally challenging, especially in 3D.

Cell Analysis Simplifications in *li_battery_2d_axi* Tutorial

- Thermal Transport
  - Anisotropic heat conductivities instead of resolving all battery layers (use cylindrical coordinate systems in 3D to cope with spirally wound domains)

- Battery Cell
  - Internal temperature differences are usually low (<5°C)
  - Internal potential drops in current collector foils are usually low (<5mV)
  - Assume a uniform (average) cell temperature in the lumped battery cell model and use an average heat source in thermal model

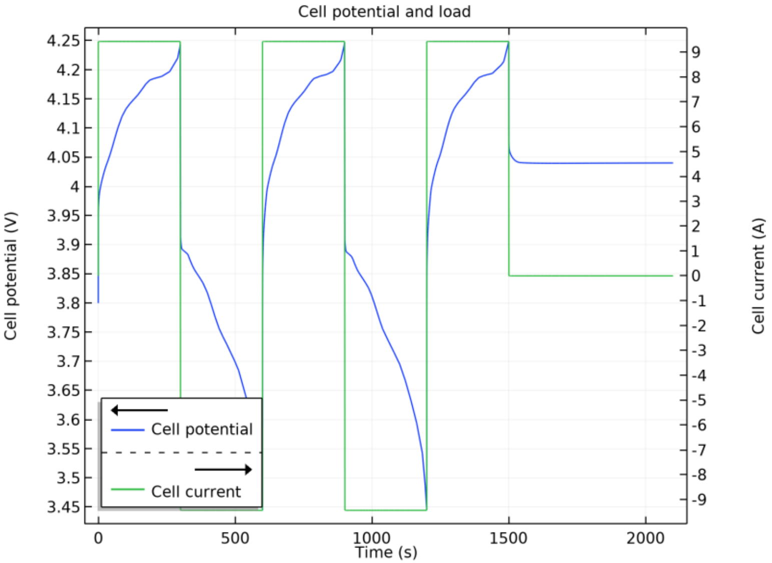
Implementation in *li_battery_2d_axi* Tutorial

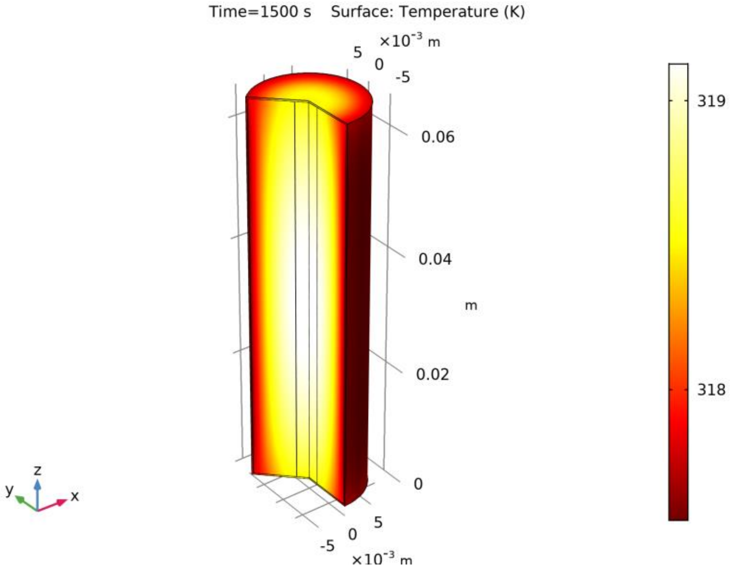
- Thermal model in 2D with axial symmetry using the Heat Transfer in Solids interface.

- Battery model using the Lumped Battery interface, with the *Global* model of coupling to the Heat Transfer interface .
  - The *Global* model requires an average (global) value of temperature from the Heat Transfer interface and similarly provides an average value of generated heat source in the active material domain, to the Heat Transfer interface.

- Electrochemical Heating Multiphysics coupling node is used to couple the temperature and the generated heat source between the interfaces.

Results





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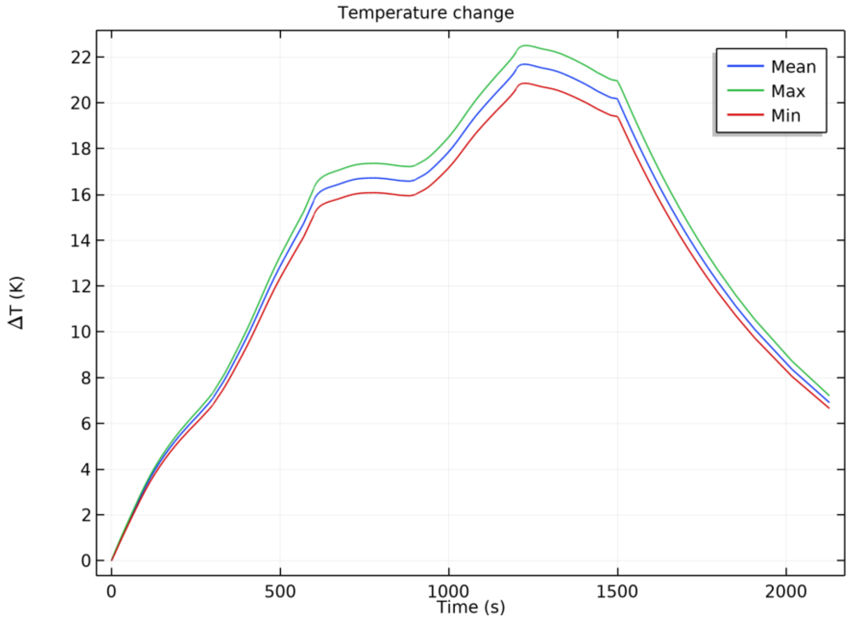
Results

- The difference between maximum and minimum temperature is small

- Heat source during charge and discharge is different
  - This is due to entropy effects (reversible heating)



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