Thermal Modeling of Lithium-ion Pouch Type Cell for Batter Cycle Life and Safety Application

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Introduction: Lithium-ion batteries are system of choice because of its several advantages like it is having higher energy densities, lesser weight, good form factor, less self discharge rate etc.[1] For the application of electric vehicle and smart-grid the higher charge/ discharge current (C-rate) needed from battery pack. In this present study the Li-Ion cell is charged and discharged at higher rates (5C). After a critical review of the present literature several research issues has been identified in the thermal modeling of lithium ion cell. One of the important research issues is the non-consideration of contact thermal resistance within the cell. So in this present study thermal contact resistances are considered in between cell layers and simulation results compared with standard literature data [2].

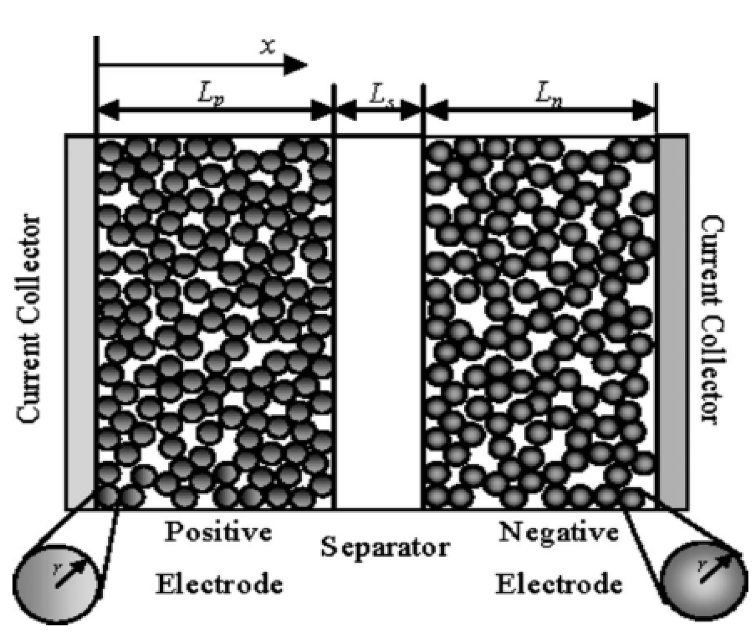

Figure 1. Schematic of a Li-ion cell

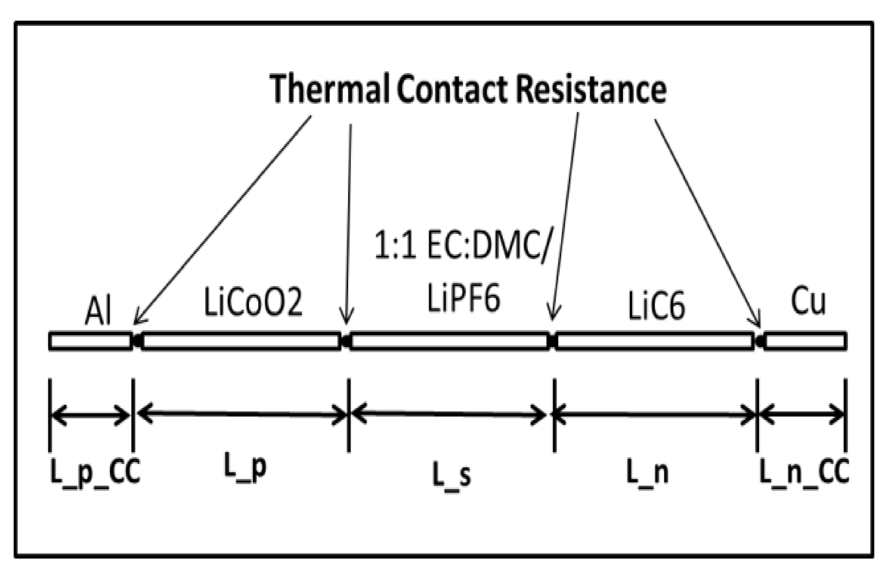

Figure 2. 1-Dimensional Li-ion cell Model

Computational Methods: A one-dimensional cell model used to model the battery cell chemistry and a two-dimensional model is used to model the temperature in the cell.

- Thermal contact resistance is directly related to the heat transfer between two connected bodies. In this work the values of the contact resistances between electrode materials are calculated from experimentally measured temperature data. The mathematical formulation will be following:

$$\frac{q}{A} = \frac{T_1 - T_2}{\frac{L_{p,cc}}{K_{p,cc}} + \frac{L_p}{K_p} + r}$$

Where, q is the heat transfer between positive current collector and cathode material

A is electrode area

T_1 is temperature at positive current collector of cell

T_2 is temperature at negative current collector of cell

$L_{p,cc}$ is length of the positive current collector of cell

$K_{p,cc}$ is thermal conductivity of the positive current collector of cell

L_p is length of the active cathode material of cell

K_p is thermal conductivity of the active cathode material of cell

r is the thermal contact resistance between positive current collector and cathode material

Table 1. Materials used for cell

Name of the cell section	Length of the cell section	Used material
Positive CC	10 µm	Aluminum
Negative CC	7 µm	Copper
Cathode material	55 µm	$LiCoO_2$
Anode material	55 µm	LiC_6/MCMB
Electrolyte soaked separator	20 µm	1:1 EC:DMC/$LiPF_6$

Table 2. parameters of the cell material

Material	Thermal Conductivity ($Wm^{-1}K^{-1}$)	Density ($kg\ m^{-3}$)	Heat Capacity ($Jkg^{-1}K^{-1}$)
Al	170	2770	875
Cu	398	8933	385
$LiCoO_2$	1.58	2328.5	1269.21
LiC_6	1.04	1347.33	1437.4
Separator	0.3344	1008.98	1978.16
Electrolyte (1:1 EC:DMC/ $LiPF_6$)	0.6	1129.95	2055.1

Results: Thermal modeling enables us to understand the thermal behavior of cells, quantification of heat generation inside the cell and changes in cell chemistry at the time of battery operation.

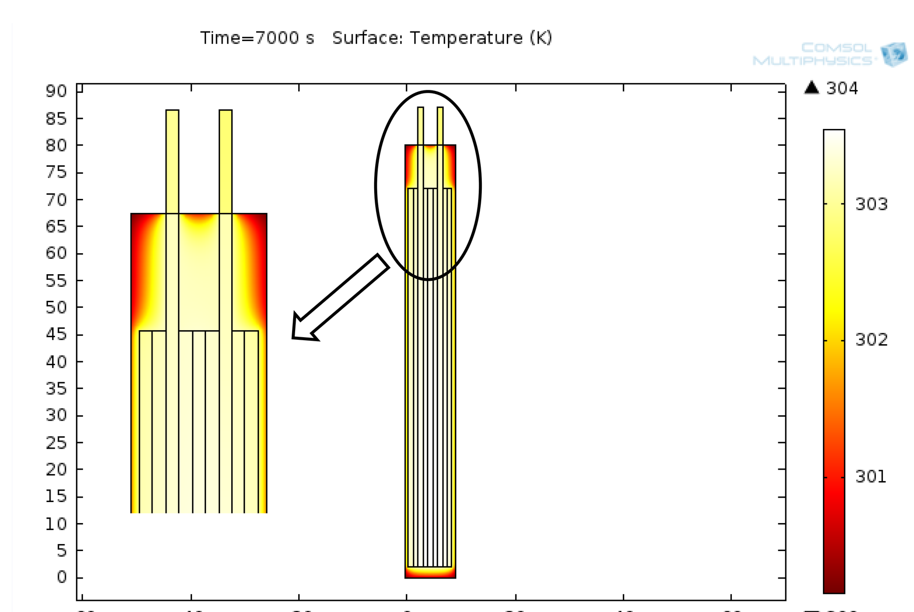

Figure 3. surface temperature of Li-ion pouch cell

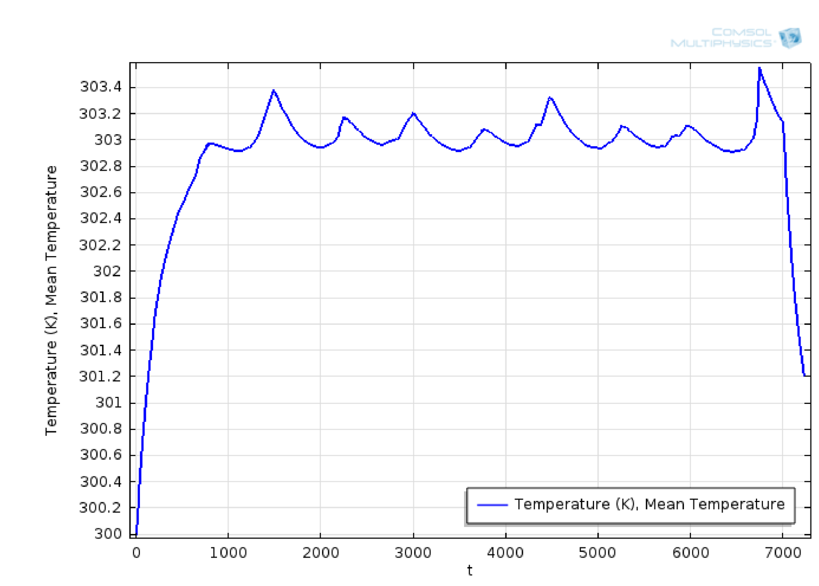

Figure 4. Temperature vs. cell length

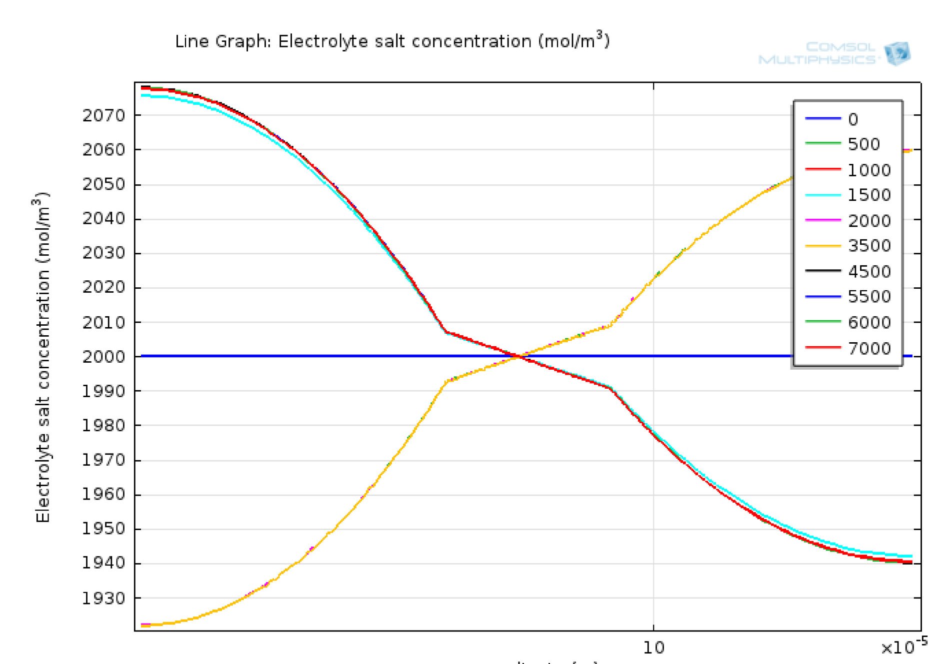

Figure 5. Electrolyte salt concentration vs. cell length

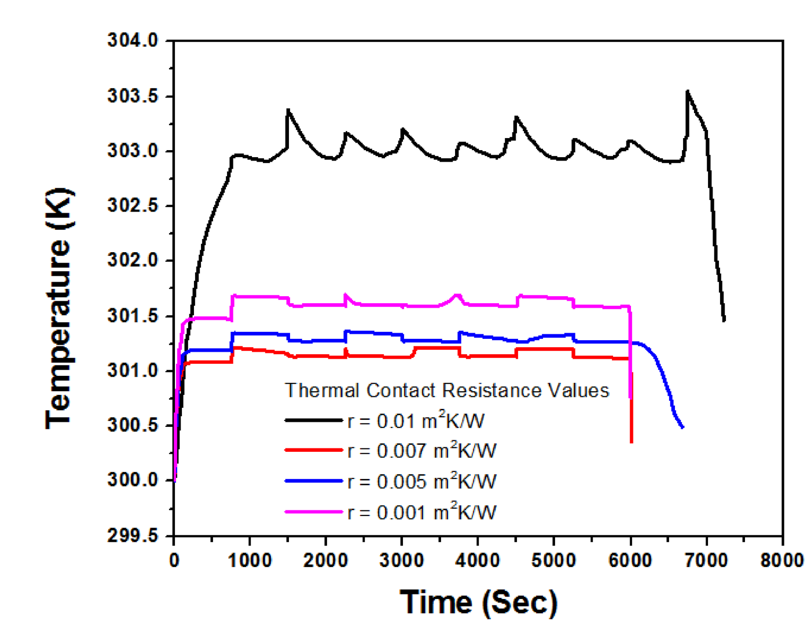

Figure 6. Temperature vs. time with variation of thermal resistance

Conclusions:

- It is found that one of the reason of heat generation inside the cell at the time of battery operation is increased due to the contact thermal resistance present in between different sections of Lithium-ion cells like active battery material layers, Current collectors, separators.
- For higher charge/discharge rate (C-rate) the heat generation inside the cell has been increased.
- The simulation result with consideration of thermal contact resistance is compared with the work done by J. Hoon Song et al.[2] and the similar temperature change has been observed after 3000 seconds cell operation.
- it is observed that that the thermal contact resistance values are very less in between electrolyte soaked separator and electrodes compared to the positive or negative Current Collector with cathode or anode materials.

References:

1. B. Wu et al., Thermal Design for the Pouch-Type Large-Format Lithium-Ion Batteries, *J. of Electrochemical Society,* **162(1)**, A181-A191, (2015).
2. J. H. Song et al., Numerical modeling and experimental validation of pouch-type lithium-ion battery, *J. of Applied Electrochemistry*, **44**,1013–1023, (2014).
3. L. Cai et al., An Efficient Electrochemical–Thermal Model for a Lithium-Ion Cell by Using the Proper Orthogonal Decomposition Method, *J. of The Electrochemical Society*, **157(11)**, A1188-A1195, (2010).