Thermal Battery Cell Modeling in a Spirally-Wound Geometry

NEXT ENERGY
EWE-Forschungszentrum für Energietechnologie e.V.

G. Liebig, H. Seeba, P. Bohn, P. Bise, L. Komsiyska, S. Vasić

NEXT ENERGY·EWE- Research Centre for Energy Technology Oldenburg, Germany, www.next-energy.de
Gerd.Liebig@next-energy.de

Introduction

At NEXT ENERGY a two dimensional cell-level thermal model was created based on the discharge characteristics of a cylindrical 18650 secondary Li-ion battery cell. With focus on the spiral geometry the heat transfer in solids interface of COMSOL Multiphysics® was used to describe the temperature gradient in radial direction during discharge at 1C. Experimental input parameters such as heat capacity and thermal diffusivity were defined using Differential Scanning Calorimetry (DSC) and Laser Flash Analysis (LFA).

Modeling Approach with COMSOL Multiphysics®

Definition of the Model Geometry

- For the current study the single cell components (anode, separator, cathode, current collectors and electrolyte) are grouped in one spirally-wounded sheet and are not modeled separately.

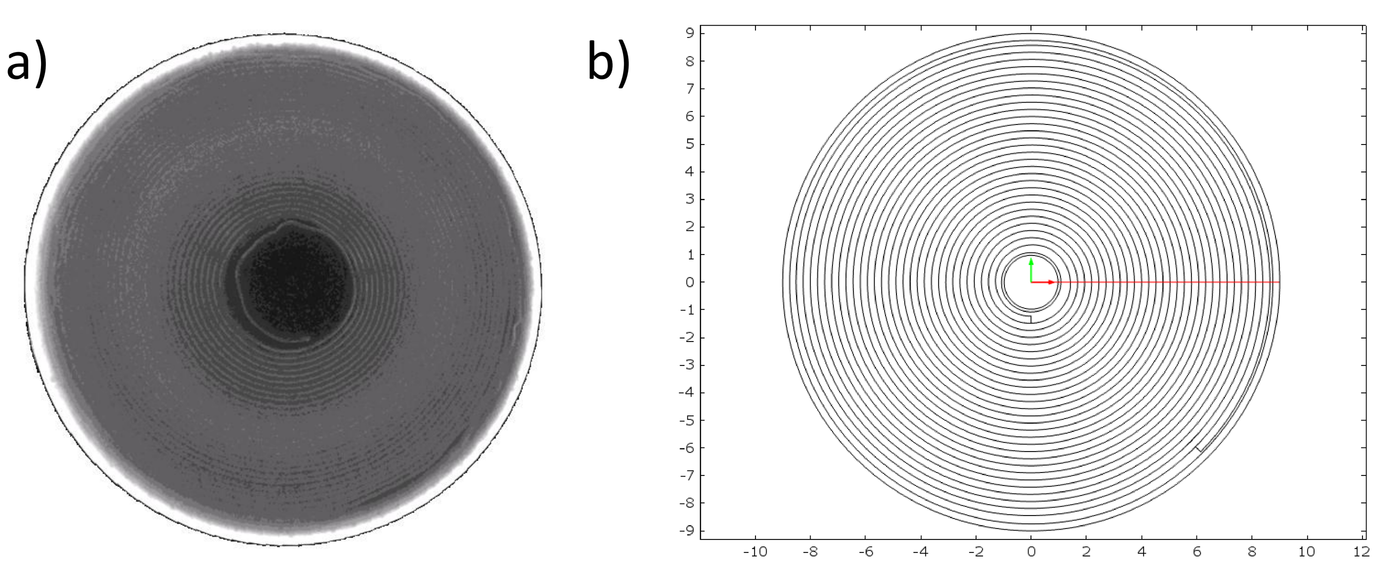

Figure 1: a) Micro-CT cross-section of a cylindrical 18650 battery b) Modelled geometry: spirally-wounded sheet consisting of anode, separator, cathode and electrolyte

Mathematical Characterisation

Table 1: Calculated Variables, input and output parameter

Input parameter		Unit
E_{OCV}	Open Circuit voltage	$[V]$
E	Cell voltage	$[V]$
I	Applied Current	$[A]$
C_n	Nominal Capacity	$[A\,h]$
Vol	Volume of Cell material	$[m^3]$
ρ	Density	$[kg\ m^{-3}]$
C_p	Specific heat capacity	$[J\ K^{-1}\ kg^{-1}]$
α	Thermal diffusivity	$[m^2\ s^{-1}]$
Calculated Variables		
k	Thermal conductivity	$[W\ m^{-1}\ K^{-1}]$
Q	Heat source	$[W\ m^{-3}]$
SoC	State of Charge	$[n/a]$
Output parameter		
T	Temperature	$[K]$

- Numerical simulation is done by solving the heat transfer equation and setting initial boundary conditions.
- The temperature gradient propagation as a function of the time during cell discharge is simulated.

Thermal Input Parameters

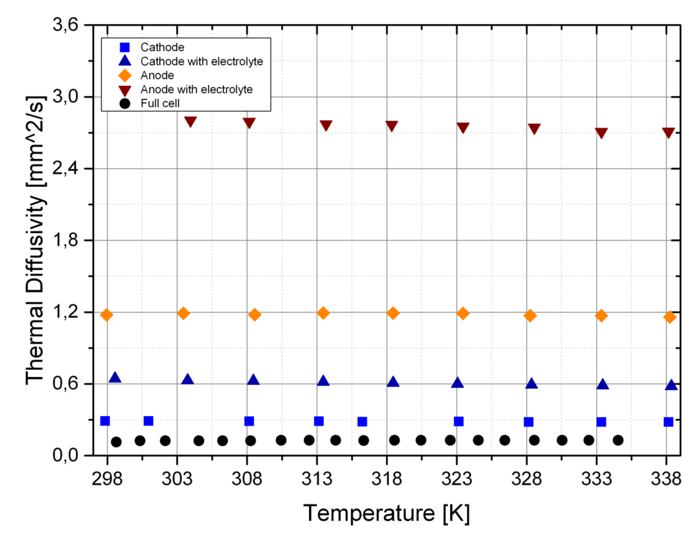

Figure 2: Thermal diffusivity as a function of the temperature for single cell components and material combinations obtained from the LFA measurements.

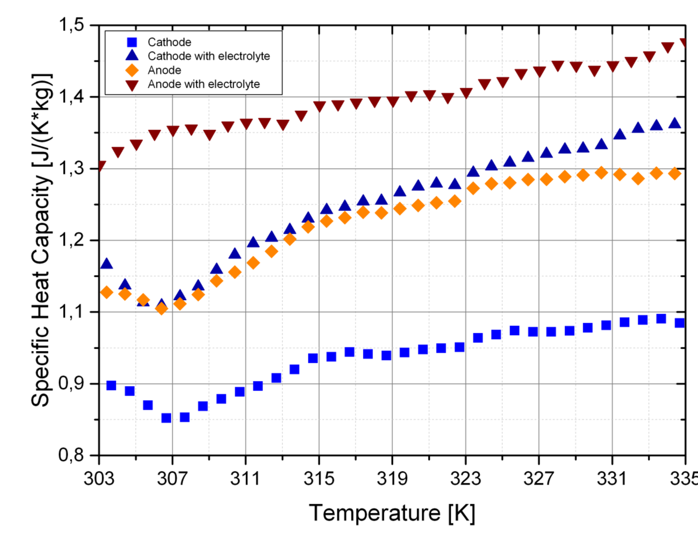

Figure 3: Specific heat capacity as a function of the temperature for single cell components defined using DSC.

Simulation Results

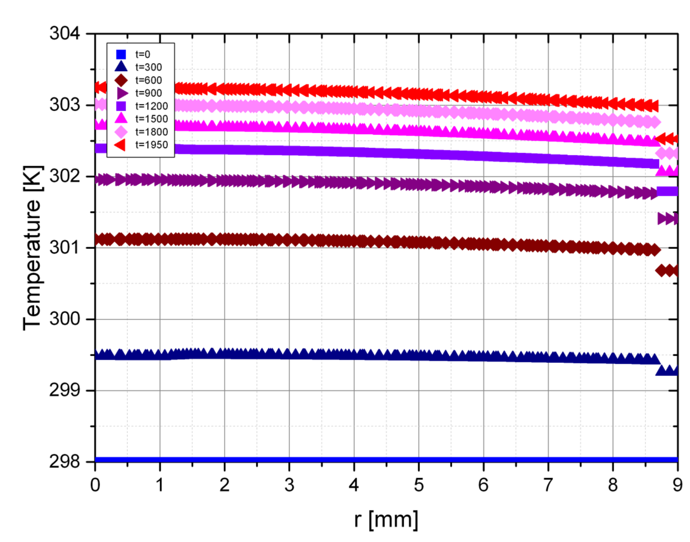

Figure 4: Simulation of temperature as a function of the geometry radius at different discharge times.

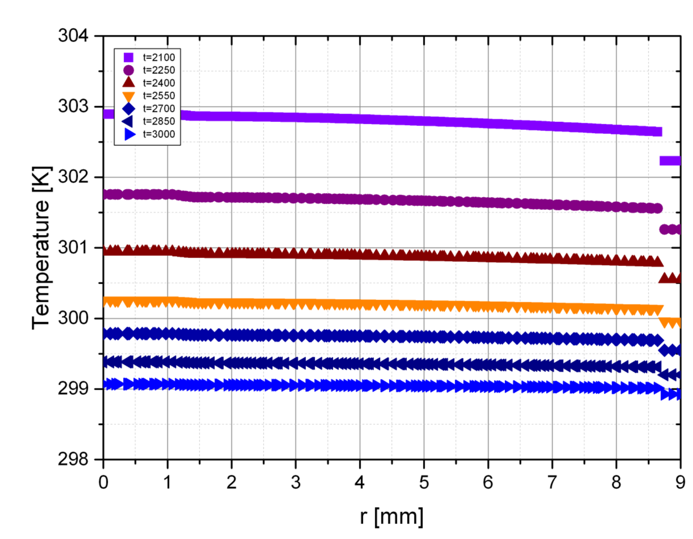

Figure 5: Simulation of temperature as a function of the geometry radius after discharge.

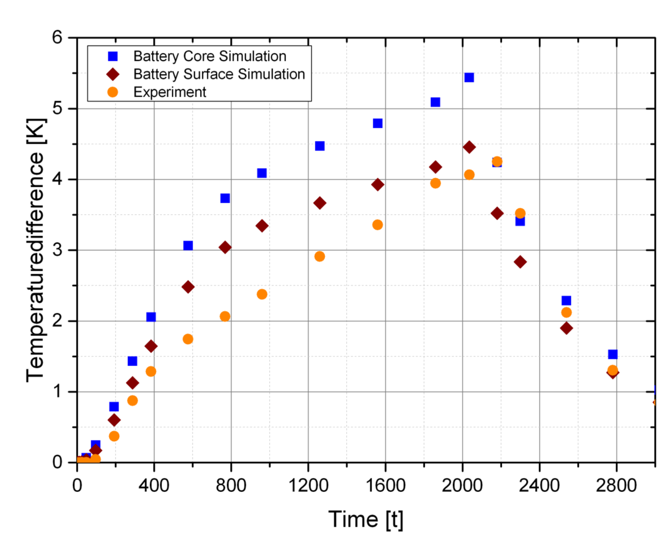

Figure 6: Comparison of simulated and experimental temperature differences between the battery core and battery surface during discharge.

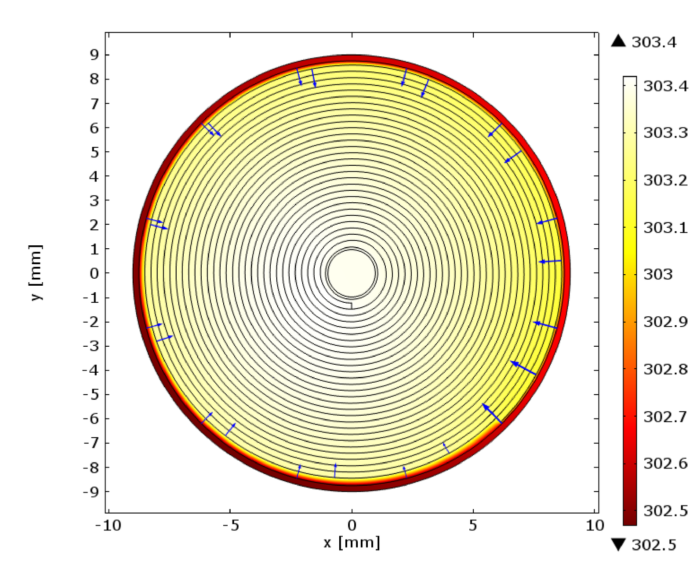

Figure 7: Temperature profile at discharge time=1950s with proportional temperature gradient (arrows).

Conclusion and Outlook

- A two dimensional cell-level thermal model of a Li-ion battery, describing the temperature distribution during discharge in good agreement with the experimental data was developed.
- A temperature gradient within the spiral geometry appears with increasing discharge times.
- The model will be further optimized and used for a comparative study of varying cell geometries and prediction of thermal hotspots.

References

[1] P.M. Gomadam et al., J. Electrochem. Soc. , vol. 150, no. 10, pp. A1339–A1345, 2003
[2] M. Muratori, Ph.D thesis, Politecnico di Milano, 2009.

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