Temperature Propagation During Cell Stacking Processes for Lithium-Ion Cells

G. Liebig[1], P. Bohn[2], L. Komsiyska[1], S. Vasić[1]

[1]NEXT ENERGY EWE-Forschungszentrum, Oldenburg, Germany
[2]AUDI AG, Ingolstadt, Germany

Abstract

Introduction:
During the fabrication of high-end battery systems, lithium-ion cells pass multiple production processes (Figure 1). Processes such as laser welding exposes the cell to locally elevated temperatures for several seconds.[1] As shown in a previous publication[2] a short-term thermal stress on the cell surface influences the cell behavior (capacity, power fade, safety) significantly and might even irreversibly damage the cell. Thus, we want to analyze and minimize the potential risks during fabrication and increase the cell performance by modeling and simulating the temperature distribution during the cell stacking process.

Use of COMSOL Multiphysics®:
At NEXT ENERGY a three dimensional model of a prismatic commercial Li-ion cell is established (Figure 2). The model is created by using the heat transfer in solids interface and the CAD import module of COMSOL Multiphysics®.

The heat transfer equation (1) is the governing partial differential equation (PDE):
$\rho \cdot c_p \cdot \partial T/\partial t = \mathrm{div}(k \cdot \nabla T)$ (1)

The thermal parameters are the heat capacity at constant pressure c_p, thermal diffusivity α, density ρ and the heat conductivity k. These parameters are connected by the following equation:
$k(T) = \rho(T) \cdot c_P (T) \cdot \alpha(T)$ (2)

The thermal characteristics of the cell components (active layers, current collectors, separator, etc.) were experimentally determined using Laser Flash Analysis (LFA) and Differential Scanning Calorimetry (DSC) in our laboratory. The experimental data was averaged according the parameter attributes, the component thickness and density.
A heat flux boundary condition on the battery surface is specified by using convective cooling by air with a heat transfer coefficient h.
For validation of the model a dummy cell with internal temperature sensors was thermally stressed for 60 s by a heat stamp at several positions with at different heat outputs between 20 W to 50 W.

Results:

The temperature profiles at the selected points in the setup matched the temperature profiles of the collocated points in the simulation model in good accordance. Thus, we are able to realistically predict the temperature distribution inside the battery cell after a short-term thermal stress (Figure 3).
Additional model studies were performed to analyze the temperature distribution inside a cell during different cell stacking processes (Figure 4).

Conclusion:
A short-term thermal stress on the surface of a li-ion cell can have a big influence on the battery performance and the energy efficiency. Therefore, a new simulation model was designed to predict the temperature distribution of a thermally stressed cell and an experimental setup was built in order to validate the model in a test scenario. The experimental and simulated data were in good agreement. We will utilize the model for comparative studies of different thermal stress scenarios. Their results will be related to battery performance and safety considerations.

Reference

[1] M. Yoshio et. al., Lithium-Ion Batteries, Science and Technologies, Springer (2009).
[2] P. Bohn et. al., Performance and the Characteristics of Thermally Stressed Anodes in Lithium Ion Cells, J. Electrochem. Soc., 162 (2) (2015).

Figures used in the abstract

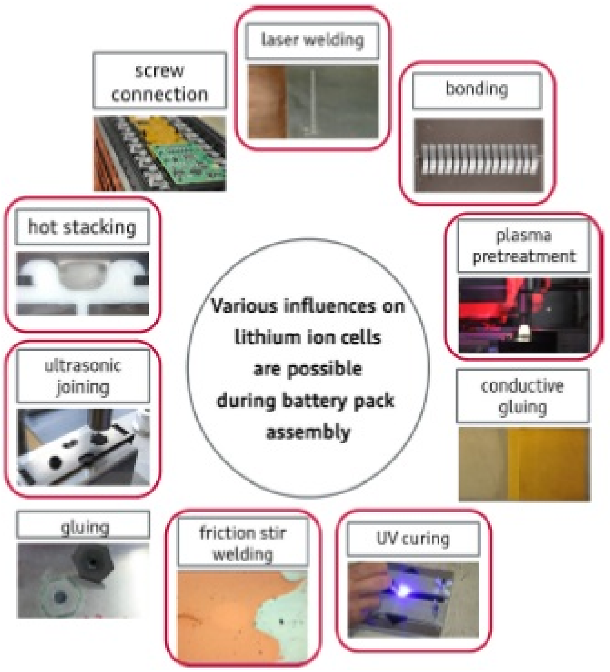

Figure 1: Short term treatments of lithium-ion cells during battery pack assembly

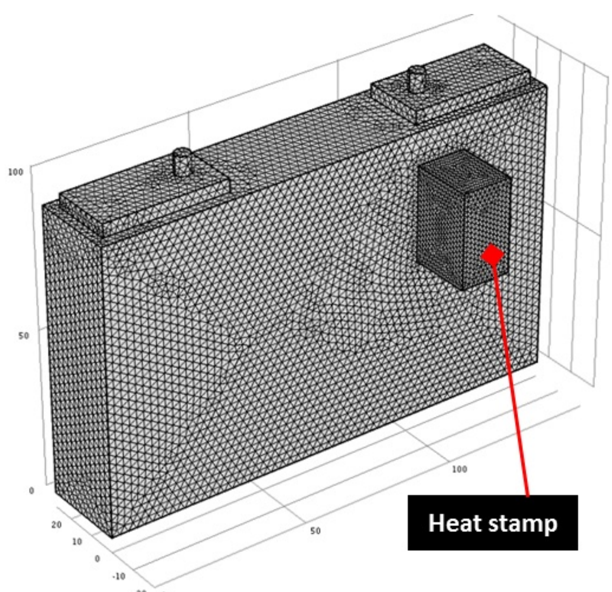

Figure 2: Three dimensional cell geometry of the simulated lithium-ion cell with heat stamp on the housing surface

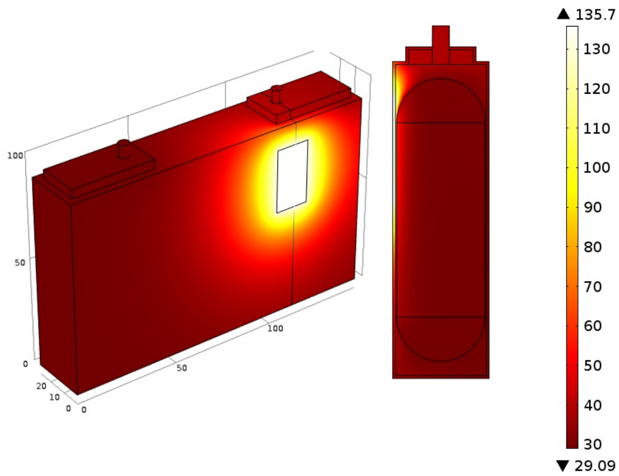

Figure 3: Temperature distribution [°C] in a prismatic cell after a thermal stress for 60 s with a heat stamp at 30 W

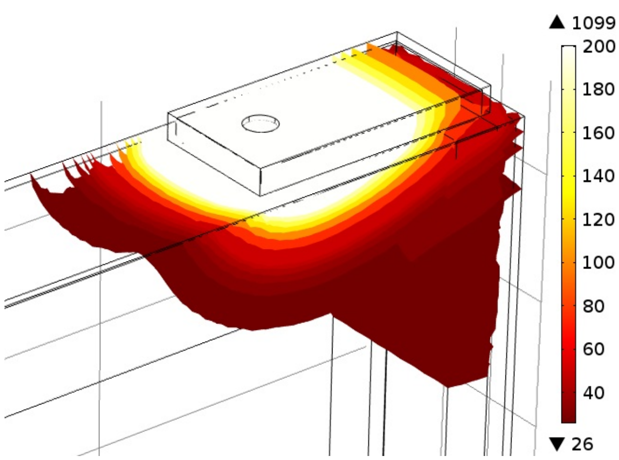

Figure 4: Temperature distribution [°C] in a prismatic cell after a thermal stress for 4 s at 1100 °C to simulate laser welding on the negative pol