

## Thermal Conductivity, Heat Sources and Temperature Profiles of Li-ion Secondary Batteries

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We measure and report the thermal conductivity of several commercial and non-commercial Li-ion secondary battery electrode materials, with and without electrolyte solvents. We also measure the Tafel potential, the ohmic resistance, reaction entropy and external temperature of a commercial pouch cell secondary Li-ion battery. Finally we combine all the experimentally obtained data in a thermal Fourier model and discuss the corresponding internal and external temperature profiles during charging and discharging.

Electrochemical accumulators and power sources can be both very effective and efficient energy converters. However, as one seeks to intensify both volumetric and specific capacity the heat of these is an inevitable topic in engineering. Moreover, in order to increase performance, the electrodes are necessarily made porous, so that the active specific surface can be increased. In doing so, the thermal conductivity can be lowered by several orders of magnitude. Literature describing thermal conductivity of this property of different Li-ion electrodes is scarce, according to recent reviews e.g. [1], although it is very important.

For the *ex-situ* thermal conductivity measurements we chose commercial electrode materials and for the temperature profile measurements and the electrochemical characterisation we chose a commercial Li-ion pouch cell battery.

The electrode materials that we investigated with respect to thermal conductivity were a commercial cathode material (LiCoO<sub>3</sub>) and a commercial anode material (SLP50). These materials were measured with in an already established procedure [2], both as dry pristine electrode and with a surplus of an electrolyte solvent. The commercial battery was characterised by classical charge and discharge cycling at different current rates. These experiments were performed in a temperature regulated cabinet with a thermocouple on the battery surface and another in the ambient air. Thus all information required to model the battery's internal and external temperature profiles were collected for the modelling part.

The thermal conductivity of dry and soaked electrode material was found to be  $0.30 \pm 0.01$  and  $0.89 \pm 0.04$  W K<sup>-1</sup> m<sup>-1</sup> for the anode material and  $0.36 \pm 0.003$  and  $1.10 \pm 0.06$  for the cathode material. For all materials examined it was found that adding electrolyte solvent increased the thermal conductivity by

at least a factor of three. For materials with electrolyte solvent, the thermal conductivity was found to be somewhat lower than what is reported in literature [3],[4]. The measurement in the temperature controlled cabinet indicated a Newtonian heat transfer coefficient of 30-35 WK<sup>-1</sup> m<sup>-2</sup>, which is equivalent to half of what can maximally be achieved with air [1]. The experimental results used for obtaining the heat transfer coefficient are shown in Figure 1.

Measuring and combining the surface and the ambient temperatures of an air cooled commercial pouch cell battery at  $\pm 2^\circ\text{C}$ , the electric heat sources, and the thermal conductivity of the electrode components made it possible to estimate internal *and* external temperature profiles at any current density. At 12C charging rate (corresponding to 5 minutes complete charging) the internal temperature differences was estimated to be in the range of 3-4 K, depending on the electrode thermal conductivity. The external temperature drop in air flowing (by forced convection) at the battery surface was estimated to nearly 70K. Thus it is clear that though it is the external temperature gradients that need the most attention with respect to engineered cooling, also internal temperatures become significant at large current rates.

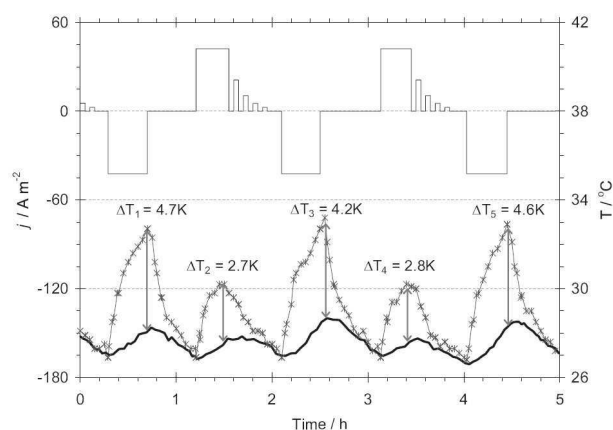


Figure 1. Measured external temperature differences for a pouch cell being charged and discharged at  $\pm 2^\circ\text{C}$ .

### References

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