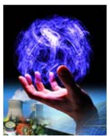

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Electrochemical-calorimetric studies on safety fundamentals of cylindrical lithium ion cells

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Laptop: internal short circuit

One of the most urgent tasks for the extensive introduction of stationary storage technologies and electric mobility is to provide safe and reliable lithium-ion cells. Insufficient heat transfer to the environment during charging and discharging can lead to a loss of battery power but also to uncontrolled reactions (thermal runaway) and ignition to cause an explosion. In this study, commercial cylindrical lithium ion cells were tested under isoperibolic and adiabatic conditions in an accelerating rate calorimeter (ES-ARC) to investigate their performance and thermal behavior. By measuring the overall heat capacity of the cell and the calorimeter constant heat data were determined, which can be used as input for thermal modeling and for a thermal management system.

Boeing Dreamliner: wrong materials choice

Heat generation rate

$$\dot{Q} = \left[I\left(U_{OCP}^{cell} - U^{cell}\right) - IT\frac{\partial U_{OCP}^{cell}}{\partial T} \right]$$

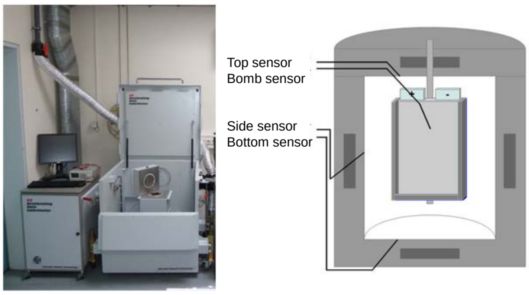
Irreversible heat generation: Ohmic losses and reaction resistances

Reversible entropic heat generation

- $\dot{Q}$ **Heat generation rate (evolved or absorbed)**
- I **Current**
- U_{OCP}^{cell} **Cell equilibrium or open circuit potential**
- U^{cell} **Cell operating potential**

Entropic coefficient $\frac{\partial U_{OCP}^{cell}}{\partial T}$ **and** U_{OCP}^{cell} **are SOC dependent**

Accelerating Rate Calorimeter (ARC)



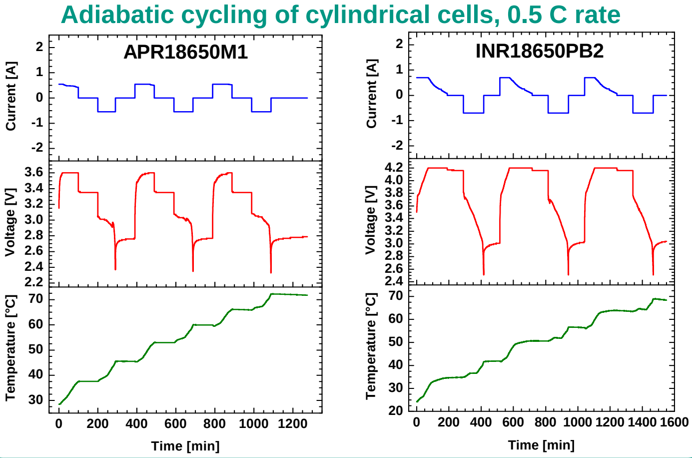
ES-ARC, Thermal Hazard Technolgy

Cell specifications

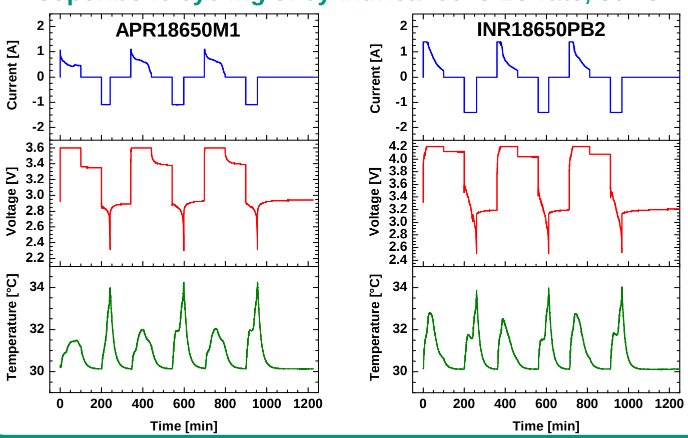
Manufacturer:	A123	Hitachi Maxell
Cell type:	APR18650M1	INR18650PB2
Cathode material:	$LiFePO_4$ (LFP)	$LiMn_2O_4$ (LMO)
Nominal capacity:	1100 mAh	1400 mAh
Nominal voltage:	3.3 V	3.7 V
Voltage window:	3.6 V to 2 V	4.2 V to 2.5 V
Core cell weight:	39 g	41 g

Real conditions (battery pack) **Ideal conditions (single cell)**

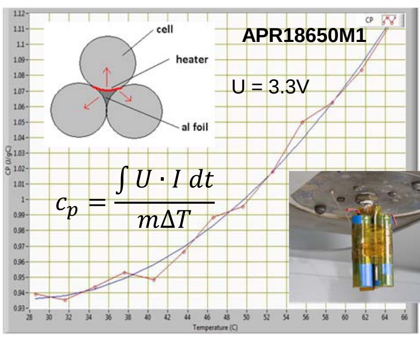
Adiabatic cycling of cylindrical cells, 0.5 C rate



Isoperibolic cycling of cylindrical cells 1C rate, 30 °C



Cp measurements



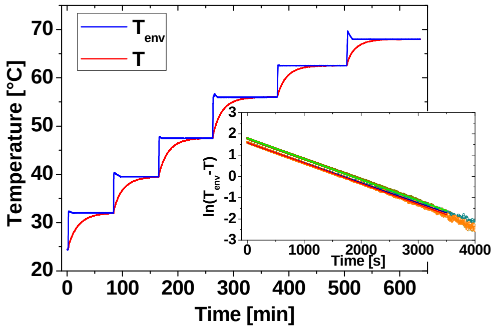
$$c_p = \frac{\int U \cdot I\, dt}{m \Delta T}$$

$$c_p = 1.03468 - 0.00718372 + 0.00013056 \cdot T^2$$

e.g. at 30 °C $c_p = 0.94$ J/g K

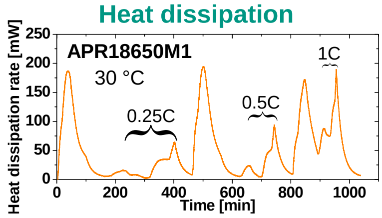
Calorimeter constant determination

dummy cell: cylinder of AlMgSi0.5 EN AW-6060 F22 with same dimensions as 18650 cells



$\alpha_{ARC} = (0.04 \pm 0.001)$ W/K $\qquad q_d = \alpha_{ARC}\,\Delta T$

Heat dissipation



Conclusions/Outlook

- Significant temperature rise even for low charge/ discharge rates especially for adiabatic conditions
- Heat data were determined, which can be used as input data for thermal modeling
- Next steps: - Assignment of heat effects to electro-chemical processes and components
  - Separation of reversible and irreversible heat effects

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