Karlsruhe Institute of Technology

BATTERIETAGUNG 2018

IAM Institute for Applied Materials

Safety Testing using Battery Calorimetry for Thermal Runaway Prevention of Lithium-Ion Batteries

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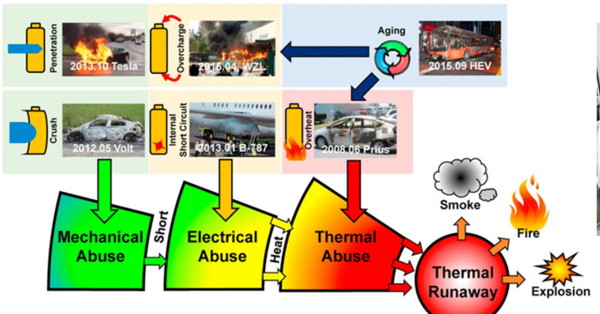
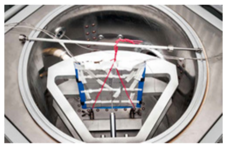
Motivation and Aim

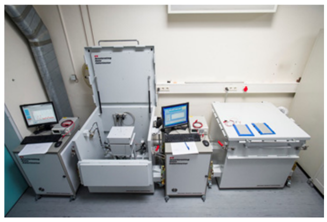


Feng et al., Energy Storage Materials 10 (2018) 246–267

At IAM-AWP: Europe`s Largest Battery Calorimetry Lab



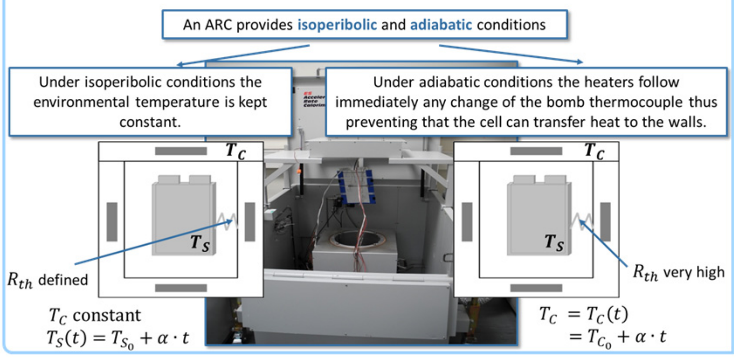
6 Accelerating Rate Calorimeters(ARC)



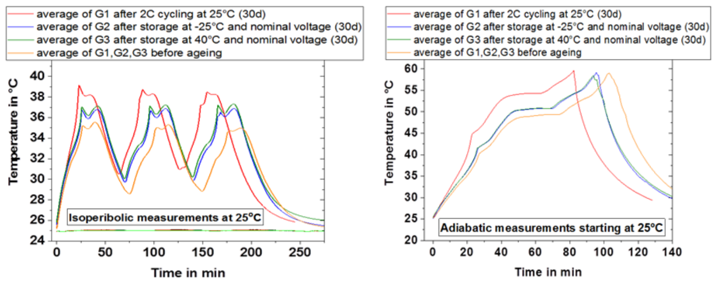
Aim: Improvement of TMS and BMS by determination of quantitative data using battery calorimetry in combination with modelling and simulation

Introduction into Battery Calorimetry

Possible conditions in an ARC



Ageing and SOH prediction

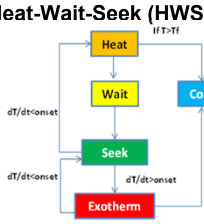


Comparison between fresh 18650 cells and 3 cell groups (each consisting of 3 cells) after cyclic (G1) or calendaric (G2, G3) ageing for 30d: (a) Isoperibolic cycling (b) Adiabatic cycling in the ARC.

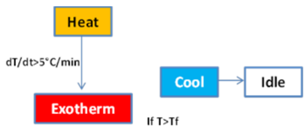
Conclusion: Recording of temperature profile useable as SOH "fingerprint" and as fast method for the characterization of aging processes

Thermal Abuse

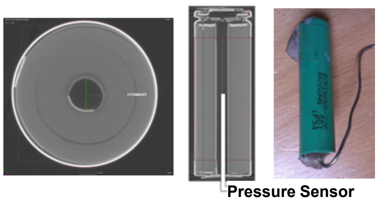
Heat-Wait-Seek (HWS) Method

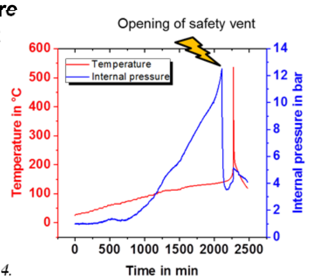


Ramp heating (RH) Method



Internal Pressure measurement



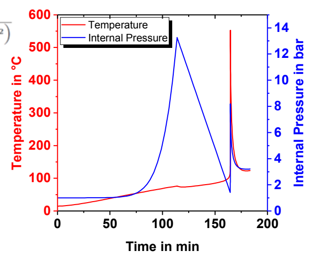


B. Lei, W. Zhao, C. Ziebert, et al., Batteries, **3** (2017) 14.

Conclusion: Internal pressure usable in BMS for thermal runaway prediction

Lumped Matlab ODE Model with venting

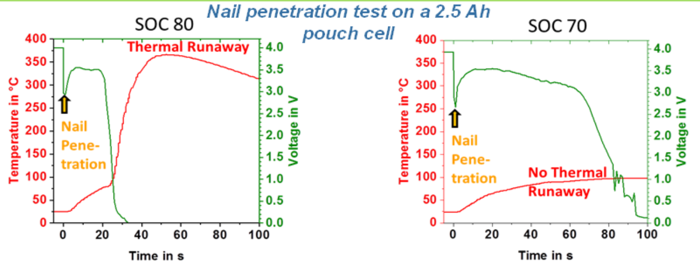
Pressure and temperature during venting	$P_{vent} = \frac{P}{\left(1+\frac{\gamma-1}{2}M^2\right)^{\frac{\gamma}{\gamma-1}}}$ $T_{vent} = \frac{T}{\left(1+\frac{\gamma-1}{2}M^2\right)}$
Static pressure from ideal gas equation	$P = \frac{m_e RT(1-\theta_e - y)}{V_h M_e} + P_{amb}$
Fraction rate and velocity of the electrolyte passing through the vent	$\frac{dy}{dt} = \frac{P_{vent} V_{vent} A_{vent} M_e}{RT_{vent} m_e}$ $V_{vent} = \sqrt{\gamma \frac{RT}{M_e}} M$
Electrolyte venting	$\dot{Q}_{vent} = -m_e h_{vap} \frac{dy}{dt} - m_e c_p T \frac{dy}{dt}$
Venting of ejecta	$\dot{Q}_{ej} = -m_{ej} c_{p,jr} T \frac{dy}{dt}$



P.T. Coman, S. Rayman, R. E. White, J. Power Sources **307** (2016) 56.

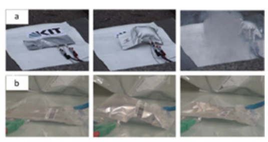
Mechanical Abuse

Nail penetration test on a 2.5 Ah pouch cell

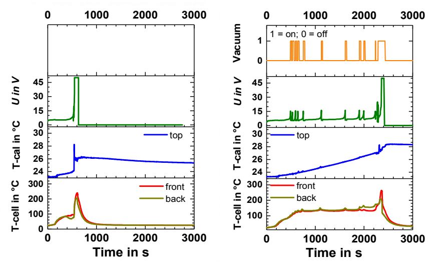


Conclusion: ESC as safety measure in case of mechanical abuse/accident

Electrical Abuse



Cell tests during thermal runaway caused by overcharging at 10 C. (a) Overcharging experiment without prevention. (b) During thermal runaway vacuum is applied by a vacuum pump.



Overcharging of 264 mAh pouch cells without (a) and with vacuum control (b).

A. Hofmann, N. Uhlmann, C. Ziebert, et al., Applied Thermal Engineering, **124** (2017) 539.

Conclusion: Pressure reduction of pouch cells as safety measure for thermal runaway prevention

Summary

Sophisticated battery calorimetry allows to collecting quantitative data on temperature, heat and internal pressure while operating cells under conditions of normal use, abuse or accidents. These data are essential for BMS, TMS and safety system design. Combined with multiscale modelling they provide a powerful tool for thermal runaway prevention.

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