

Heat flux sensors for battery monitoring

*greenTEG downsizes battery calorimetry
for battery monitoring in any application*



Zurich, September 2017

greenTEG results: comparable to a \$150K Calorimeter

A gSkin heatflux sensor is:

- 100 Million times smaller
- Fraction of the cost

greenTEG HFS has:

- Improved feature resolution
- Lower noise level
- No offset

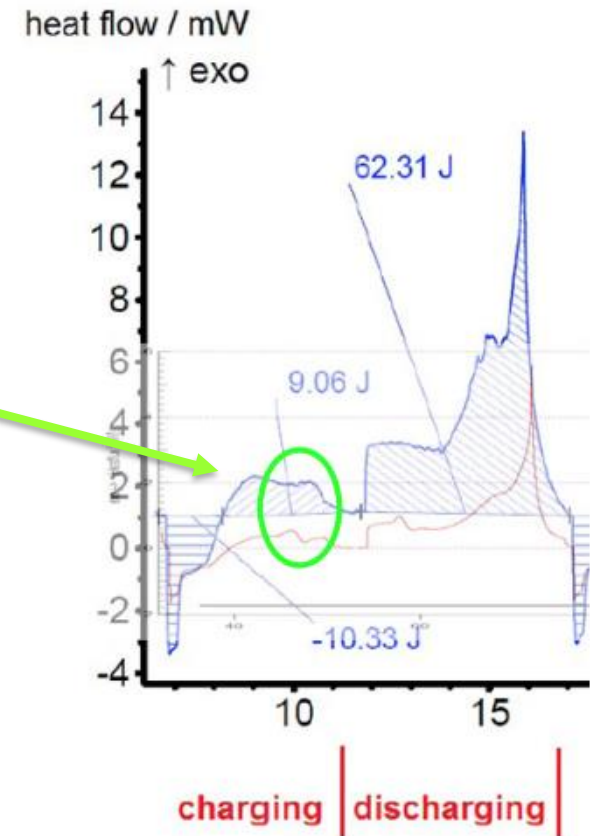
Netzsch MMC27V



greenTEG



**greenTEG enables battery calorimetry
in the real application**



Battery calorimetry on a 45mA coin cell ,
cycling speed: 0.5C;

Red: greenTEG sensor

Blue: Netzsch MMC27V;

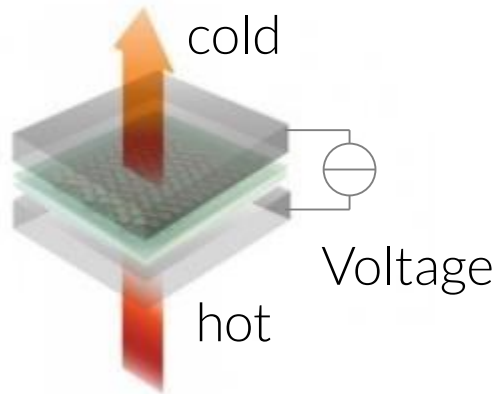
Results from EMPA¹

¹Swiss federal institute of material science and technology

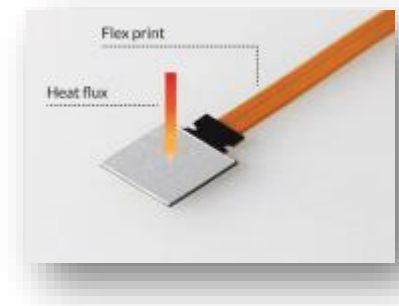
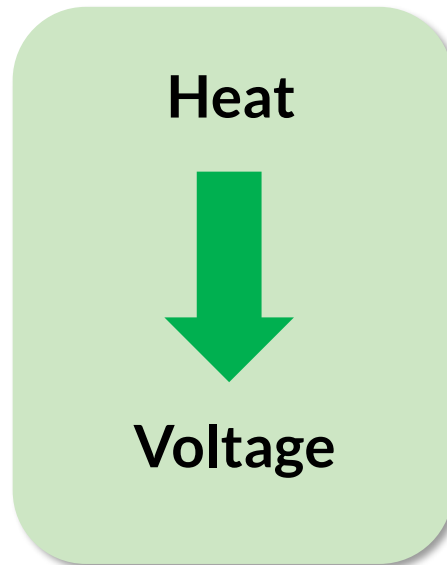
greenTEG – the Seebeck effect explained

greenTEG fabricates thermoelectric sensors which convert heat into a voltage

Heat flux sensor



Principle

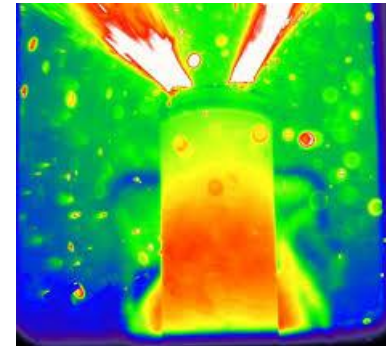


Device

We see many potential applications, such as thermal runaway prevention



Thermal runaway prevention



Thermal management



Status control (SOC, SOH, SOF)



Battery quality control

Deep dive: Prevent thermal runaway



Problem:

- Inner temperature of the battery should not exceed 60° C
- Inner temperature of the battery can not be monitored with surface temperature sensors

Solution:

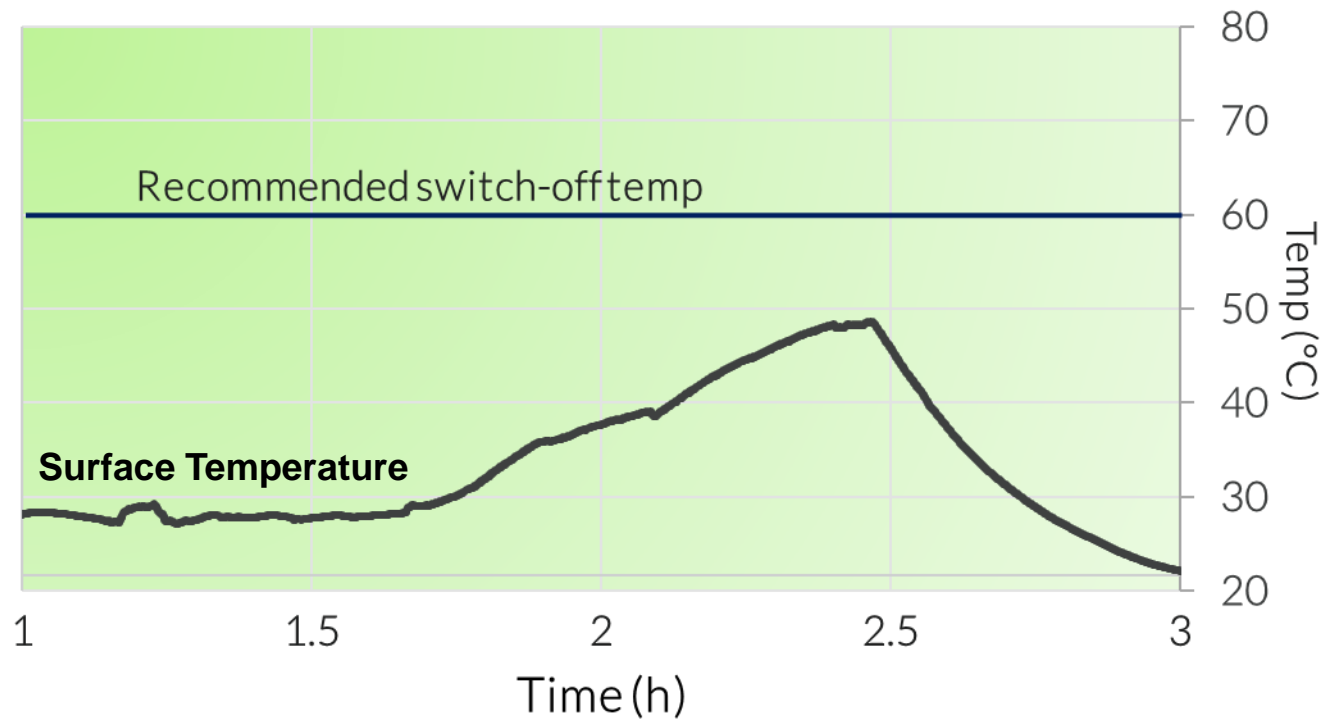
Calculate the inner temperature by combining heat flux sensor signal with surface temperature sensor signal

$$T_{\text{inside}} = T_{\text{surface}} + Q \cdot R$$

R = Thermal resistance

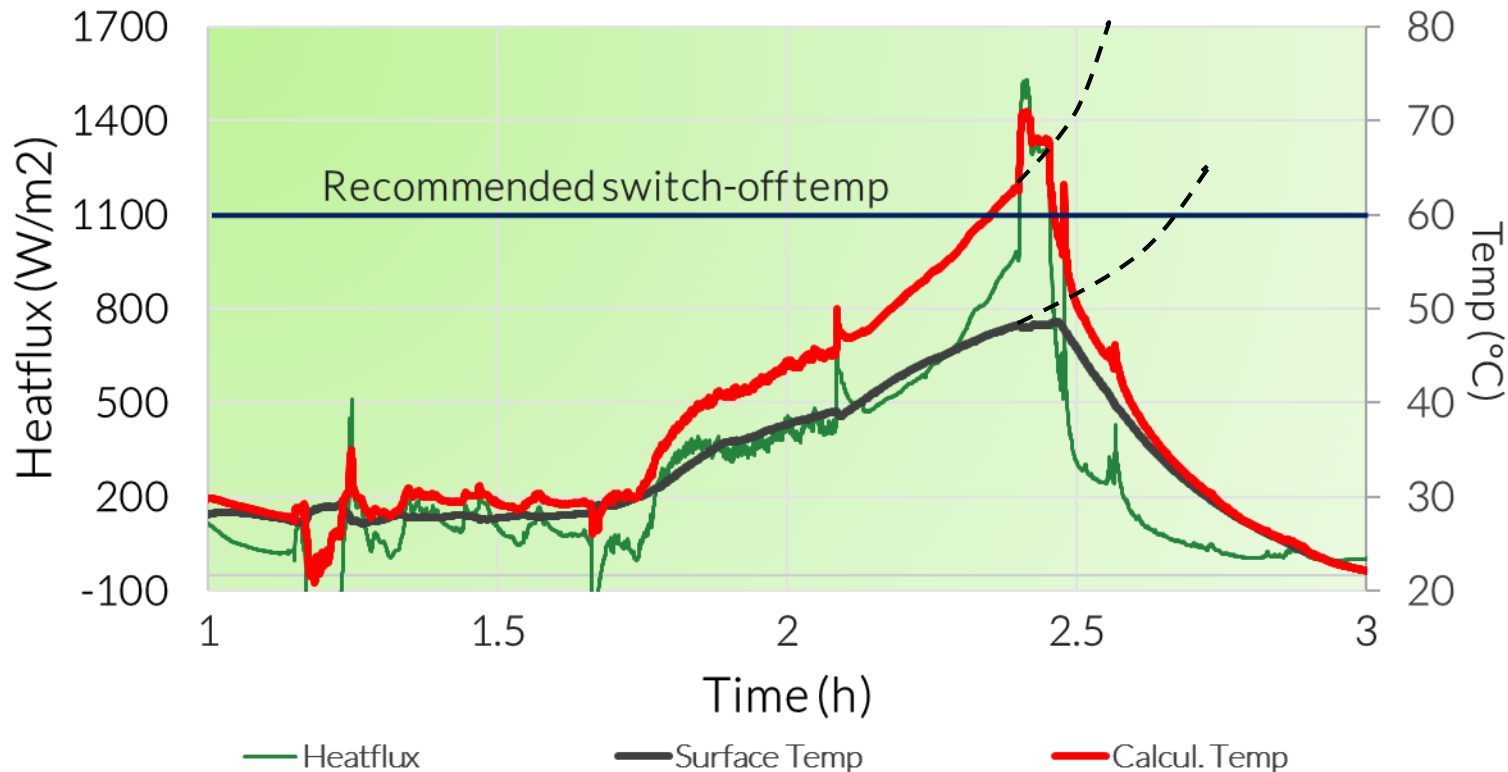
Q = Heatflux

We have generated new insights: To know what's going on inside the battery / battery-pack



Surface temperature only measures 48°C → Everything ok!?

Our enhanced calculation using heatflux data provides new insights inside the battery



The high Heat flux in combination with the high surface temperature reveals a critical inner battery temperature exceeding 60°C.

Without Heat flux measurement this brief temperature excursion is very difficult to detect

Deep dive: Battery status control and quality control

By thermal profiling

With the gSKIN[®], phase transitions of Li-ions in the electrodes can be detected during the normal charging and discharging of the battery

The sharpness, amplitude and position of the peak is a clear indication of:

- Quality
- State Of Health (SOH)
- Intracellular electrode dis-balancing

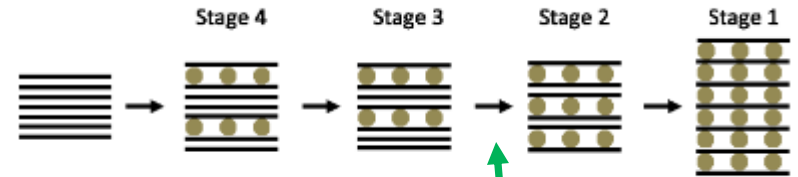
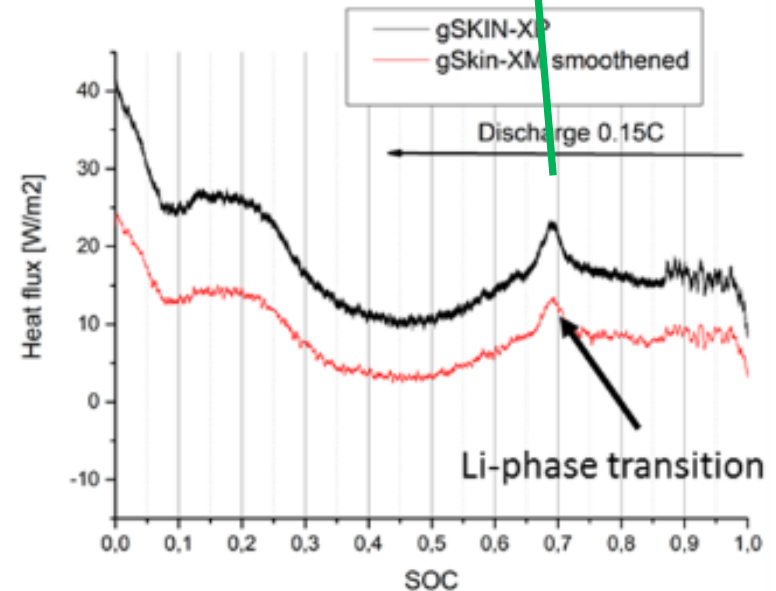
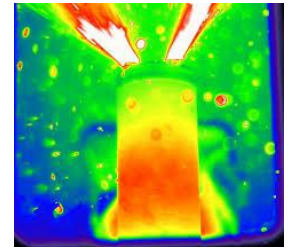


Figure1: Model of ion intercalation into graphite by Rüdorff [1]



Deep dive: Battery Thermal management



Controlled cooling/heating of the batteries is known to:

- Extend Battery life
- Enable fast charging
- Avoid thermal runaway

Today's control is "only" based on temperature sensors

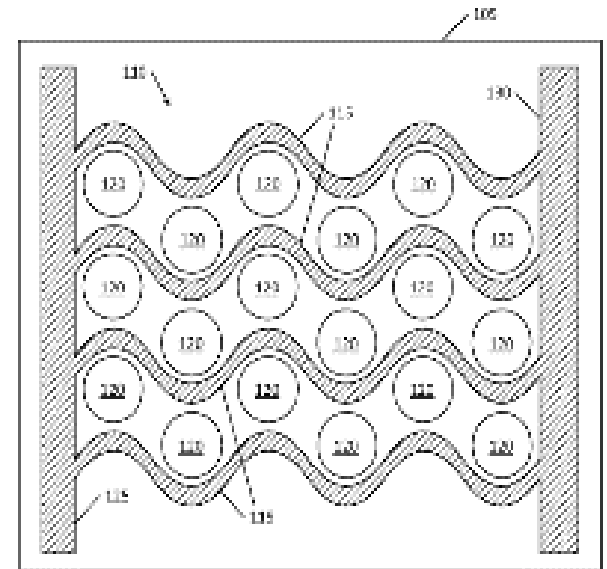
Problem

A temperature sensor is measuring a state and not the dynamics of the system → Not the right tool for control systems (slow, overshoot)

Solution

greenTEG's heat flux sensors react immediately to temperature changes larger than 100uK resulting in:

- Much faster thermal control
- Improved thermal management



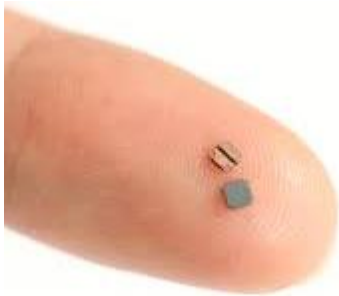
Reference: Patent on water cooled thermal management system from Tesla

greenTEG's technology allows you to measure the thermal dissipation even when water cooled



We are integration experts

greenTEG provides cost efficient solutions for electrical and thermal integration of the sensors



Specifications:

- Sensor size: 2mm x 2mm x 0.4 mm
- Sensitivity: $>1 \text{ uV/W/m}^2$
- Required area: 2mm x 2mm x 0.5 mm
- Standard SMD integration
- Additional packaging for thermal heat path to the battery is required

Heat flux sensors for battery monitoring

Dr. Lukas Durrer, Co-Founder and CTO

greenTEG AG

Technoparkstr. 1 | 8005 Zurich, Switzerland

tel. +41 (0)44 632 54 68 | mob. + 41 79 790 02 16

Email: lukas.durrer@greenTEG.com

