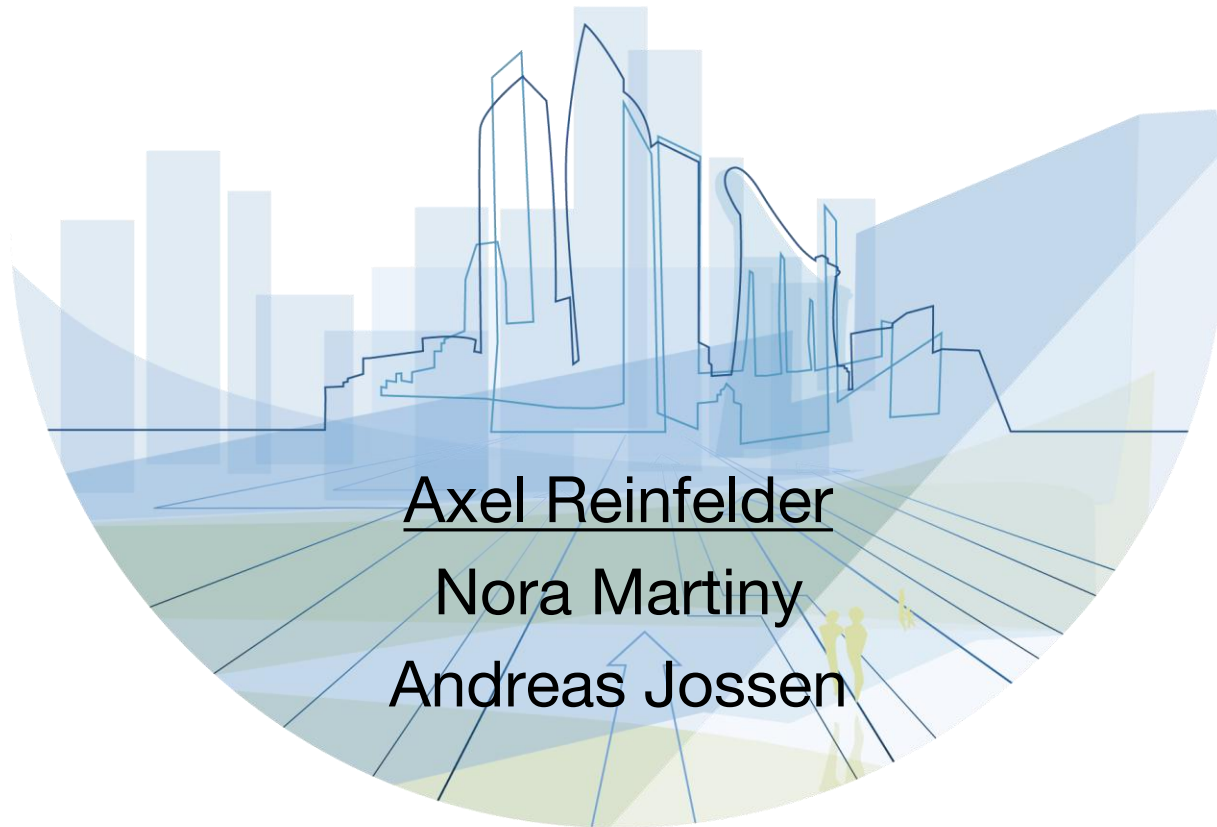


Thermal In-Cell Measurement for Li-Ion Pouch Cells



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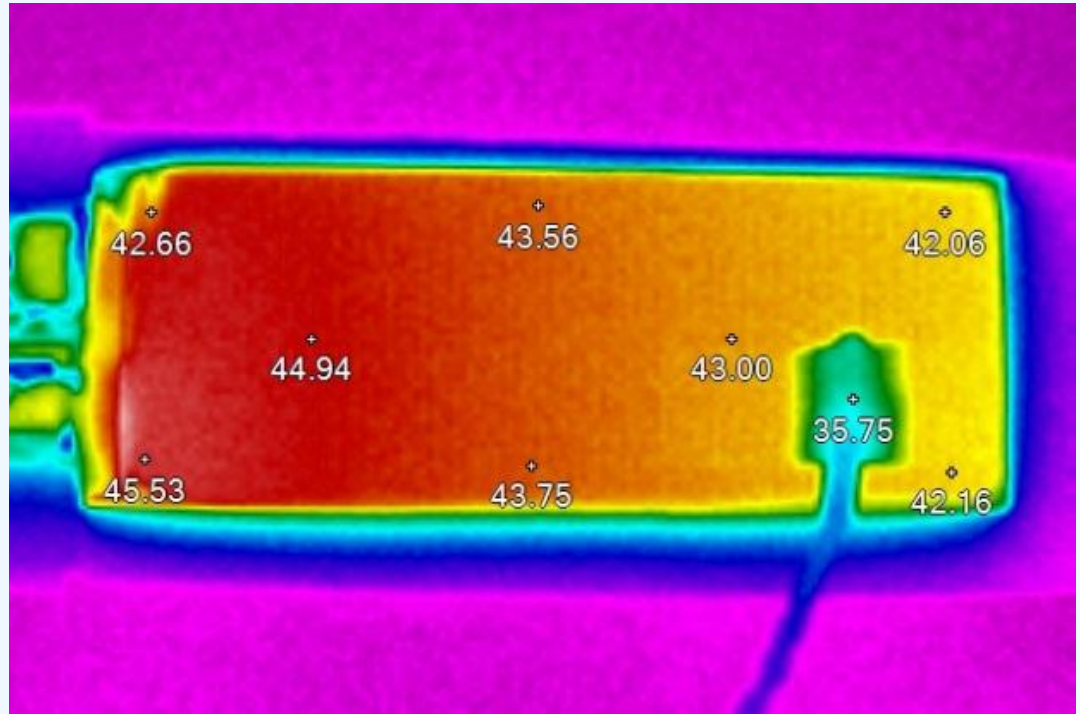
Agenda

1. Motivation
2. Technologies
3. Sensor Production
4. Tests and Results
5. Conclusion & Outlook

Motivation

Temperature Measurement

- General safety concerns
- Special climate conditions in Singapore
- Early failure recognition

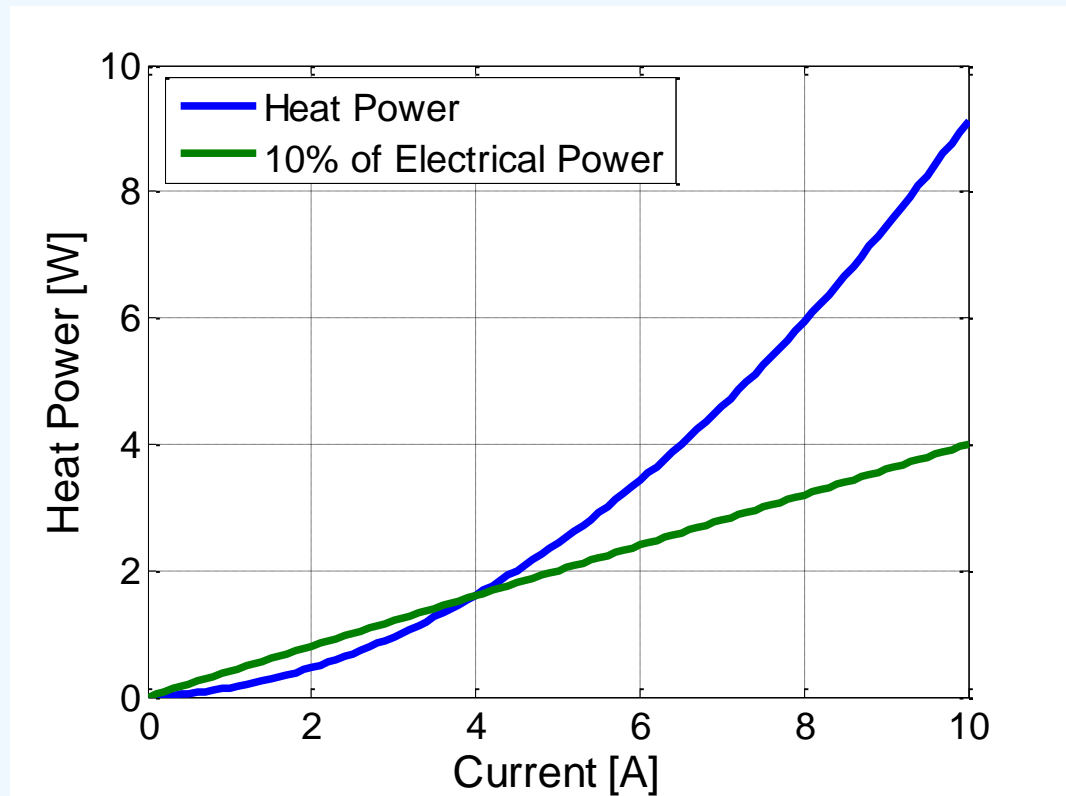


In-Cell Measurement – Heat Sources

- Internal Resistance
- Reversible Heat Effect
- Polarisation Surge

Overall Heat Power:

$$H \approx 0.085 \cdot I^2 \frac{\text{W}}{\text{A}^2} + 0.06 \cdot I \frac{\text{W}}{\text{A}}$$



Motivation

In-Cell Measurement – Heat Transfer– Example 18650

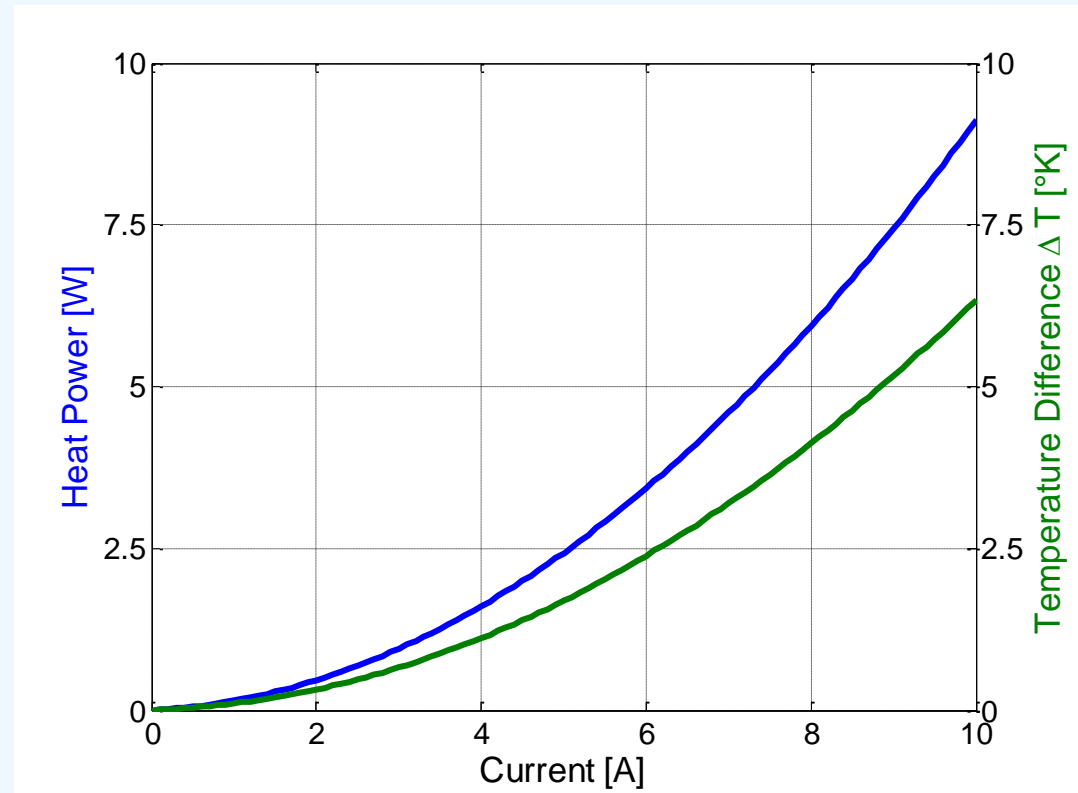
- Conduction
- Convection
- Radiation

- Inside the cell: Only heat conduction:

Thermal Resistance:

$$R_{th} = 6.9 \cdot 10^{-1} \frac{\text{K}}{\text{W}}$$

- Outside the cell: Convection and Radiation



In-Cell Measurement

- Estimation of time needed until internally generated temperature can be measured at the surface. (Fraden, Handbook of Modern Sensors, 2004)

$$t = -C \cdot R_{th} \cdot \ln\left(1 - \frac{1}{R_{th} \cdot H} (T_c - T_s)\right)$$

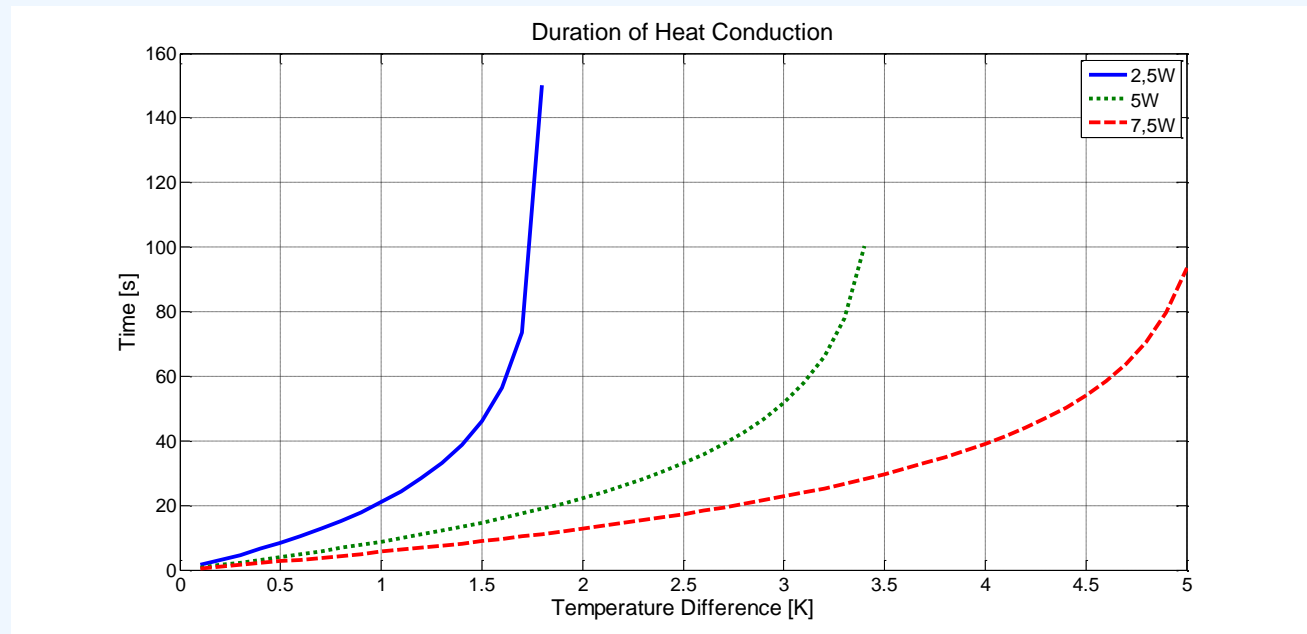
C: thermal capacity

R_{th} : thermal resistance

H: heat power

T_c : in-cell temperature

T_s : surface temperature



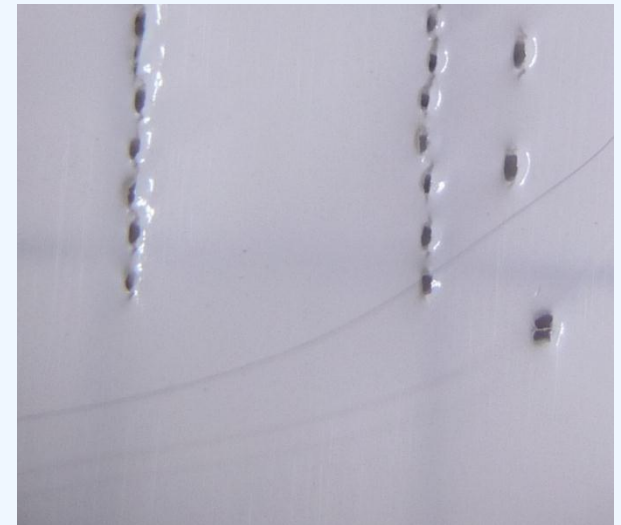
Pre-Conditions for In-Cell Measurement

- Cell chemistry, materials:
Consideration of Electrochemical Potential
Resistivity against HF
- Dimensions:
Sensor thickness should be within the range of cell layer thickness
Separator: 15 μm
Cathode: 40 – 150 μm
Anode: 30 – 60 μm
- Voltage: 3.0 – 4.2 V
- Sensor Technologies:
Thermoelectric Contact Sensor
Fiber Optics
Thermoresistive Sensors

Sensor Production

Wire-based production of a RTD temperature sensor

- 10 μm platinum wire
- Resistance load of $13.5 \frac{\Omega}{\text{cm}}$ at 0°C
- About 7.5cm needed for 100Ω
- As the used wire is a little bit thicker: 9.5cm needed
- 2 designs:
Compact meander, fully sealed, local temperature measurement
- Spread meander, only 4 fixations, average temperature measurement



Sensor Production

Compact meander, fully sealed, local temperature measurement

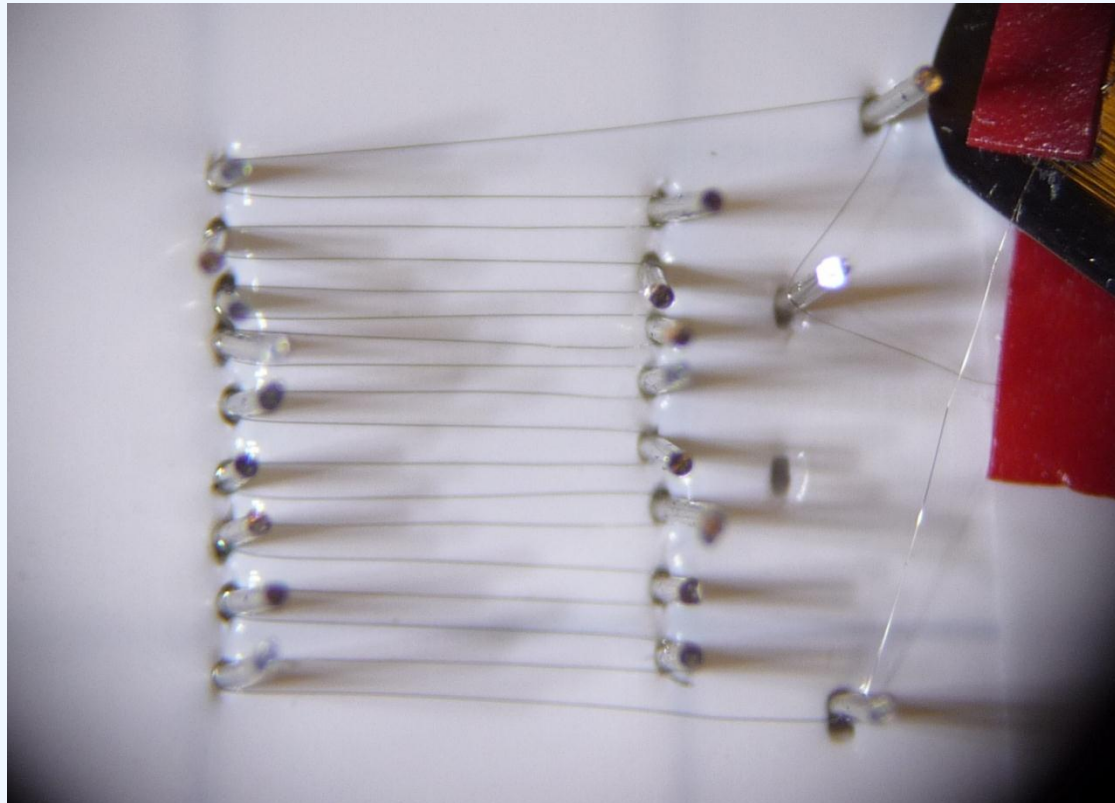
- First step: Meanders are wound around pins with $230\mu\text{m}$ diameter



Sensor Production

Compact meander, fully sealed, local temperature measurement

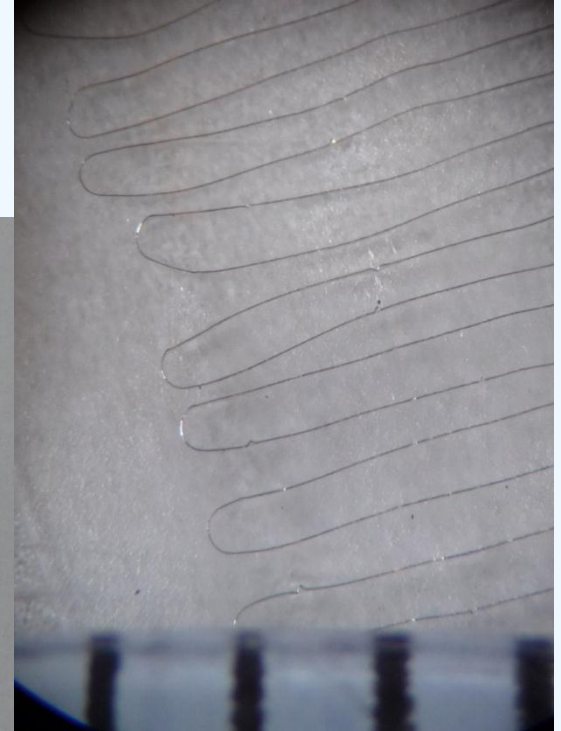
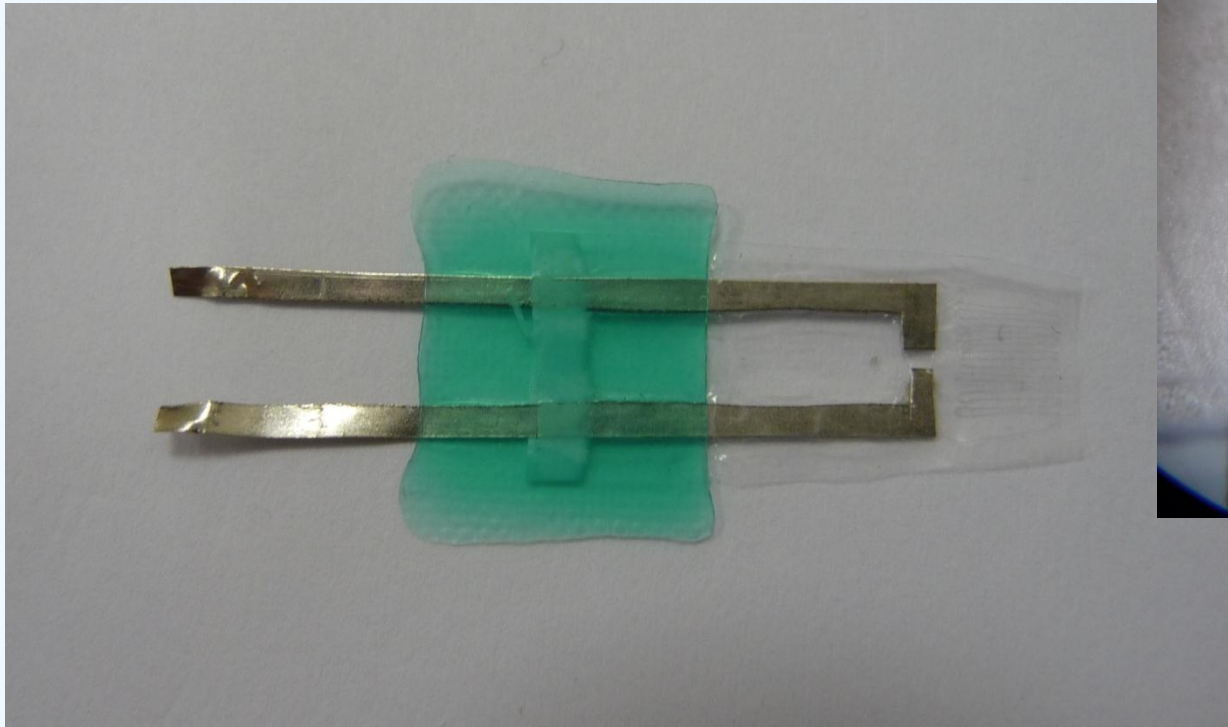
- For production meanders are wound around pins with 230 μ m diameter



Sensor Production

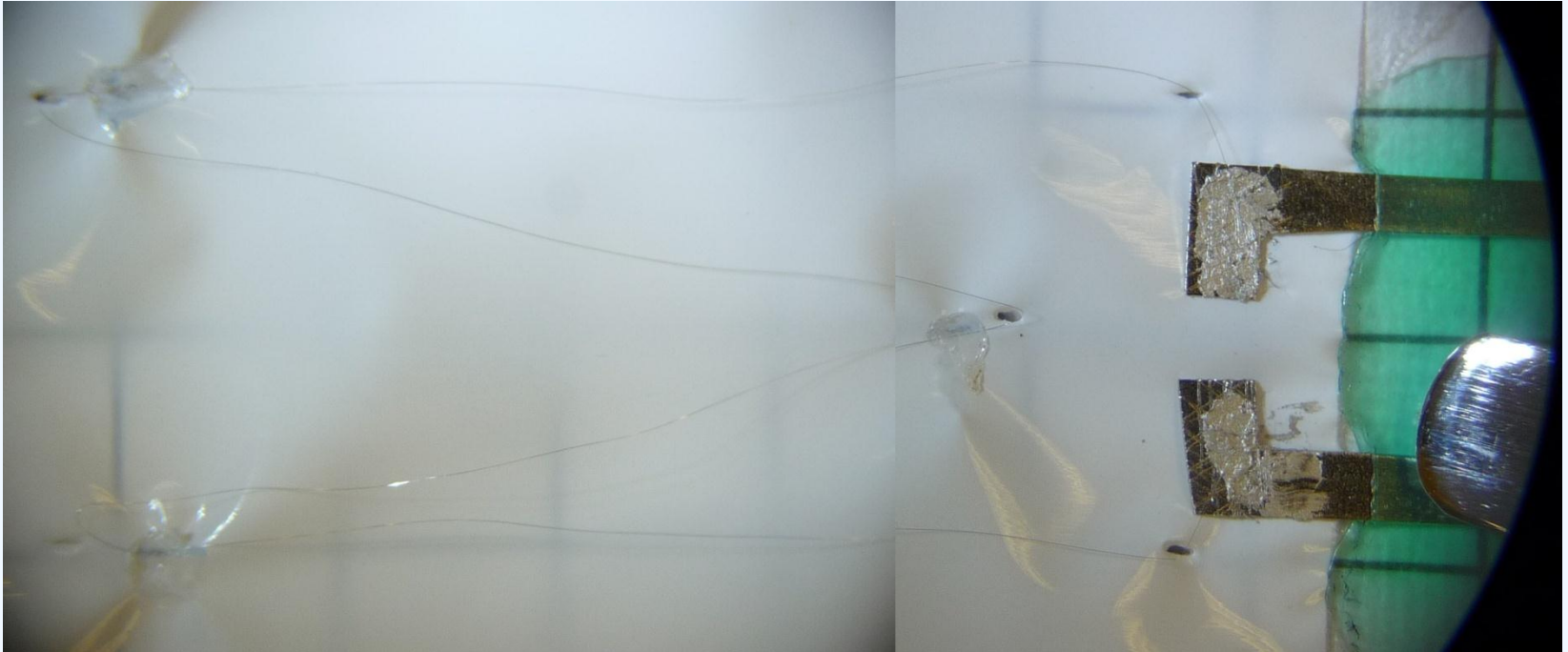
Compact meander, fully sealed, local temperature measurement

- Finished sensor design with a ruler as comparison on the right



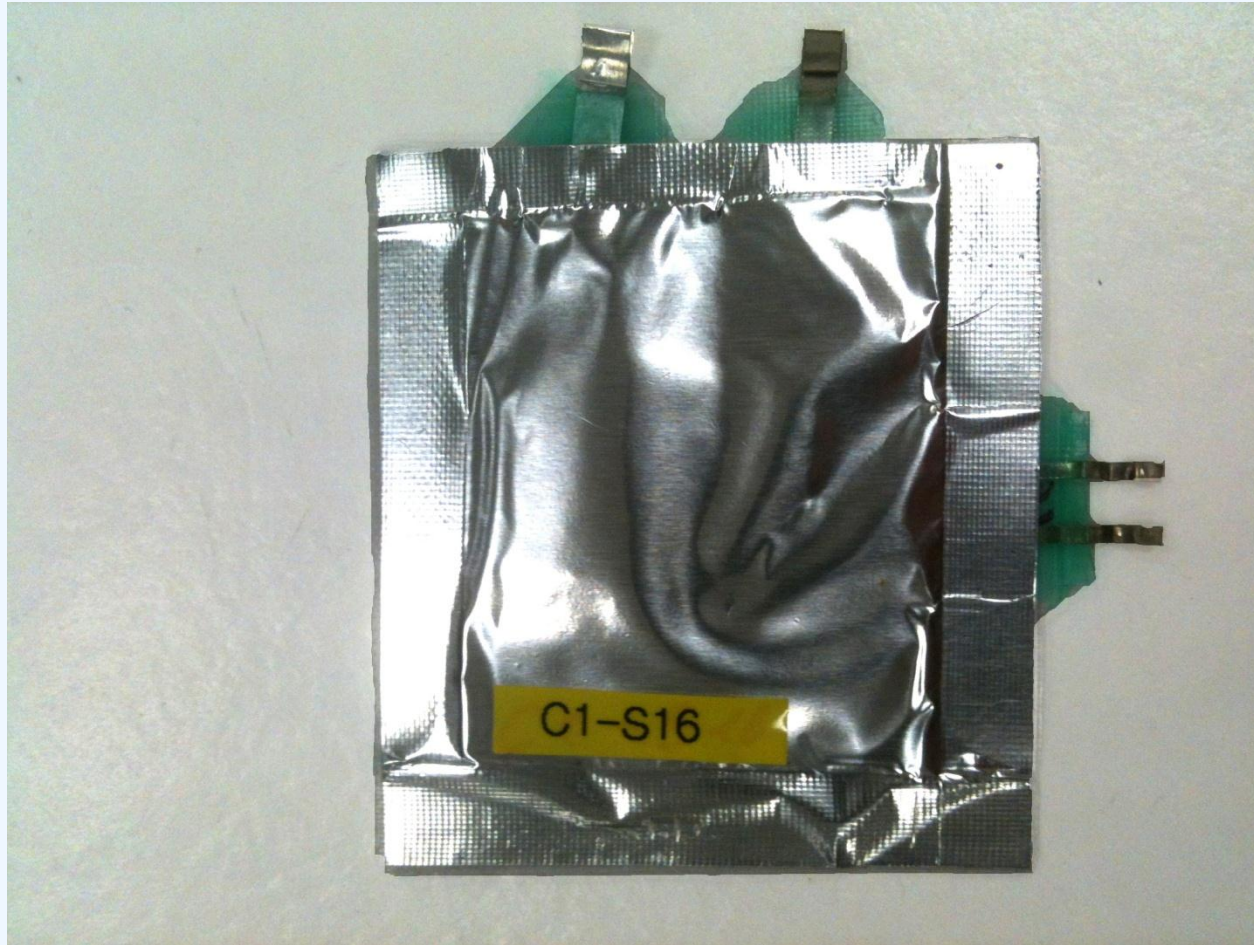
Spread meander, average temperature measurement

- Finished un-sealed sensor, placement directly in electrolyte



Sensor Production

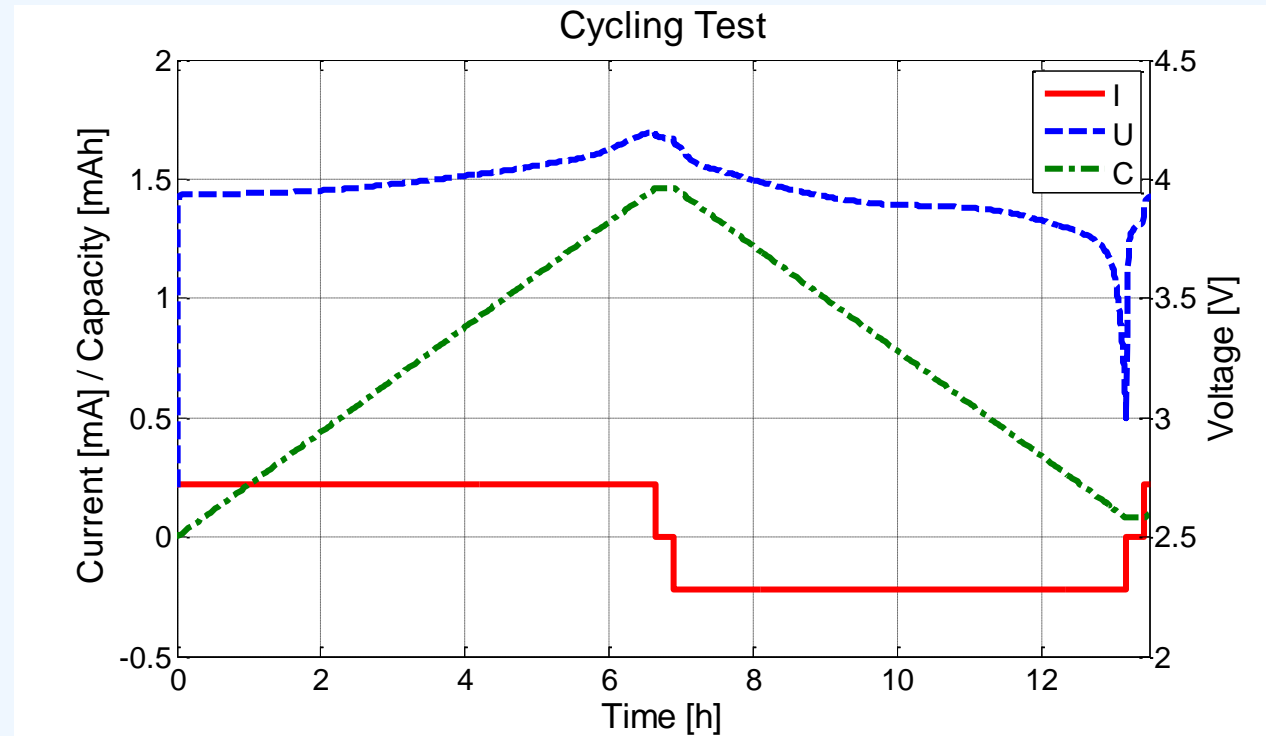
Sensor built in pouch cell



Tests and Sensing Results

Cycling Tests

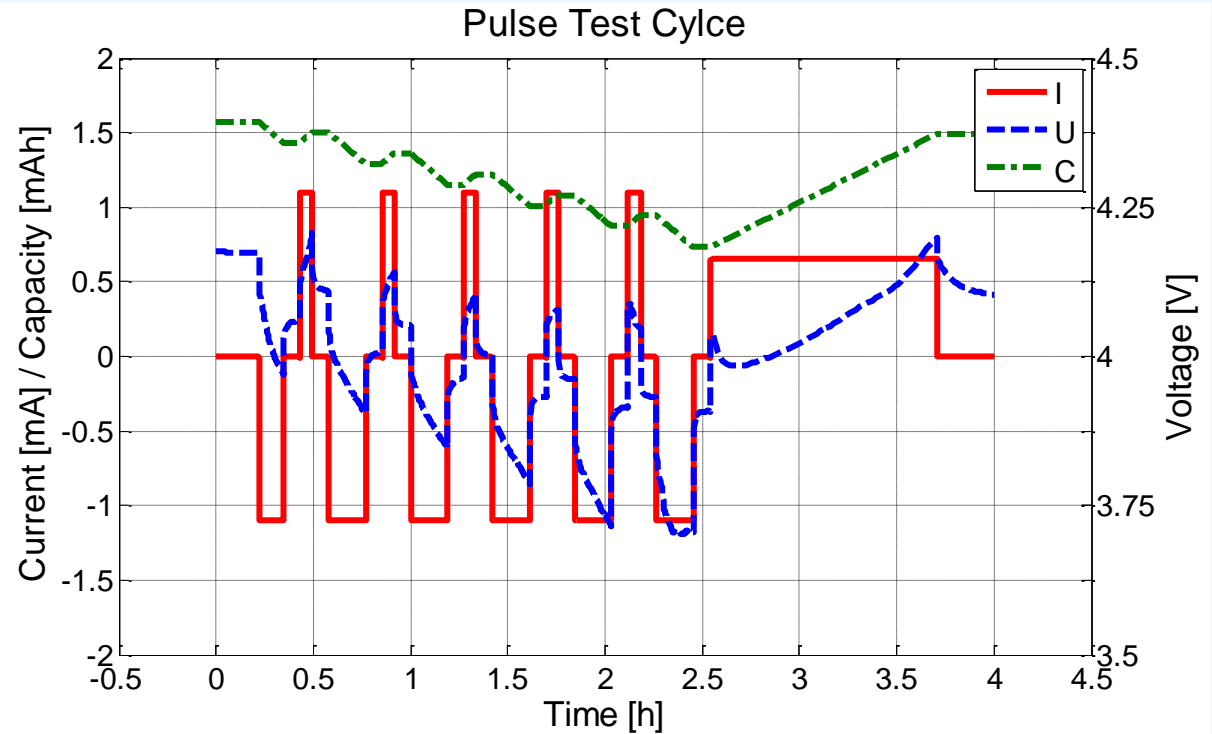
- $C \sim 1.45 \text{mAh}$
- $I = 0.22 \text{mA}$
- $U_{max} = 4.2 \text{V}$
- $U_{min} = 3.0 \text{V}$



Tests and Sensing Results

Pulse Test

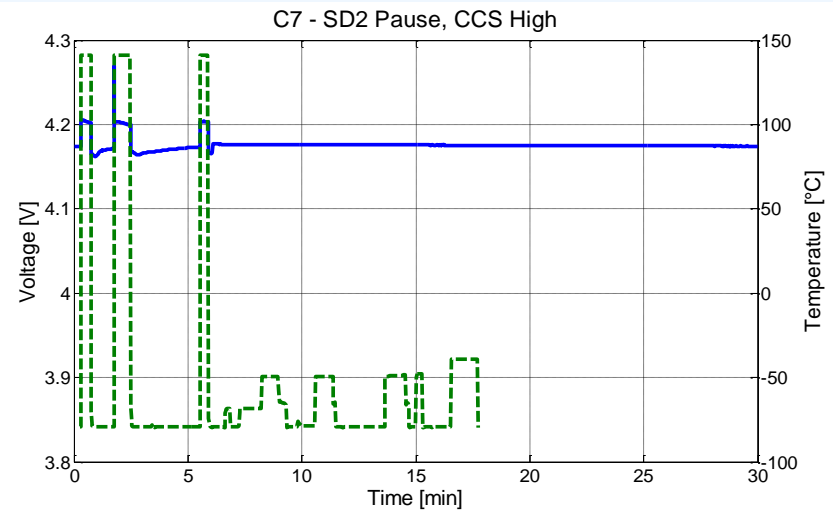
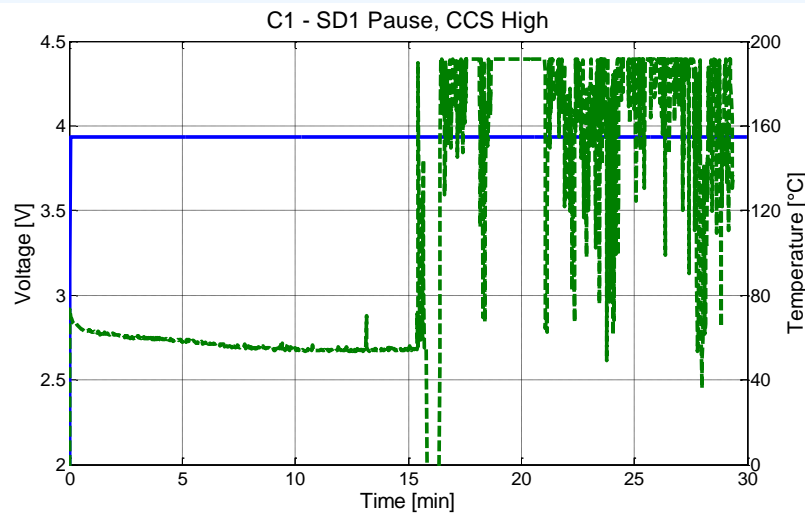
- $C \sim 1.45 \text{mAh}$
- $I = 1.1 \text{mA}$
- $U_{max} = 4.2 \text{V}$
- $U_{min} = 3.0 \text{V}$
- $DoD \sim 60\%$



Tests and Sensing Results

Results – Sensing Potential Higher than cell Voltage

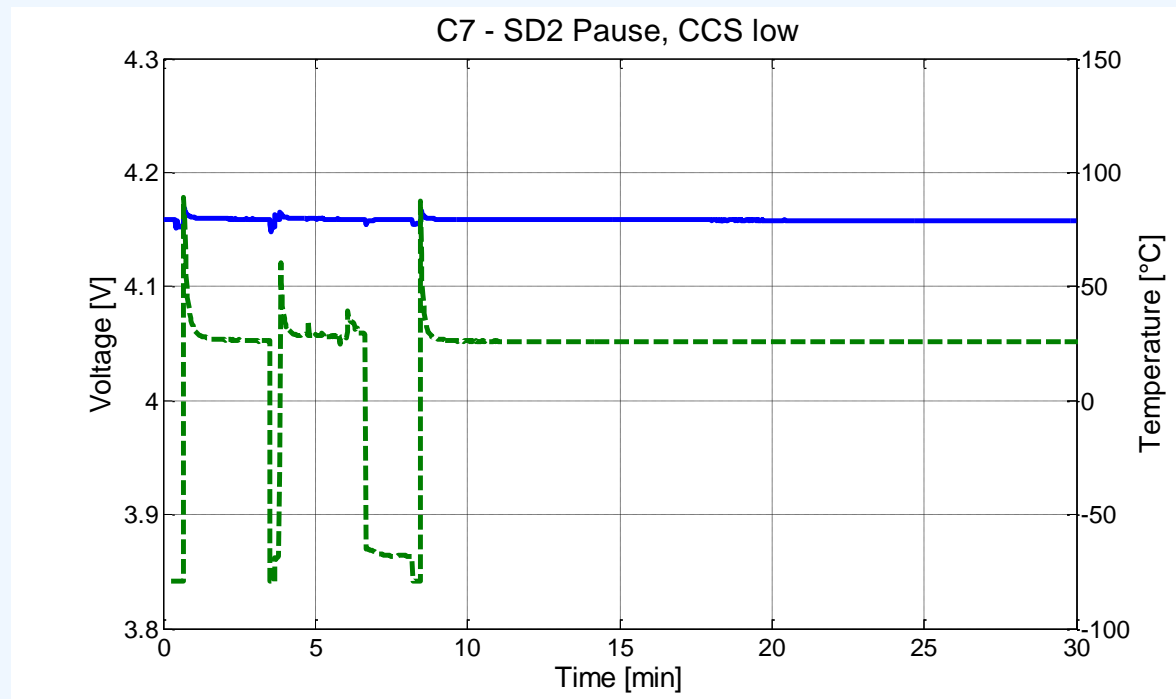
- Feedback from sensor to cell, when the CCS works at a high potential
- No temperature measurement possible



Tests and Sensing Results

Results – Sensing Potential Lower than cell Voltage

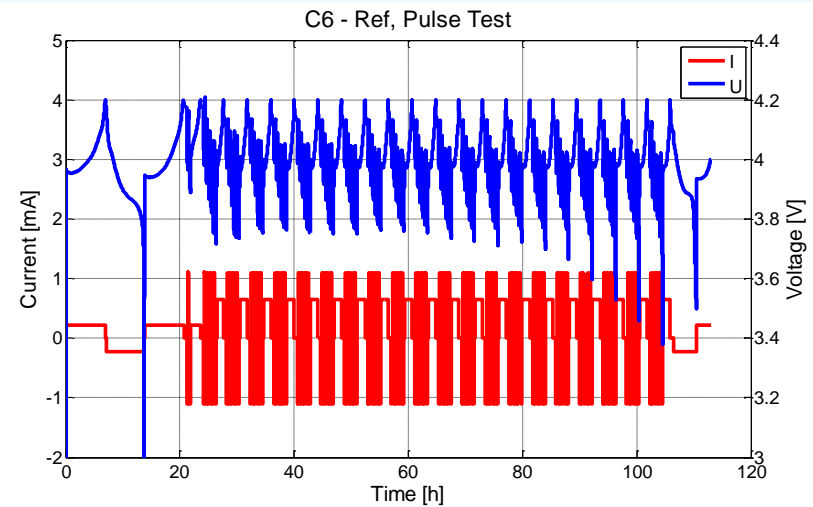
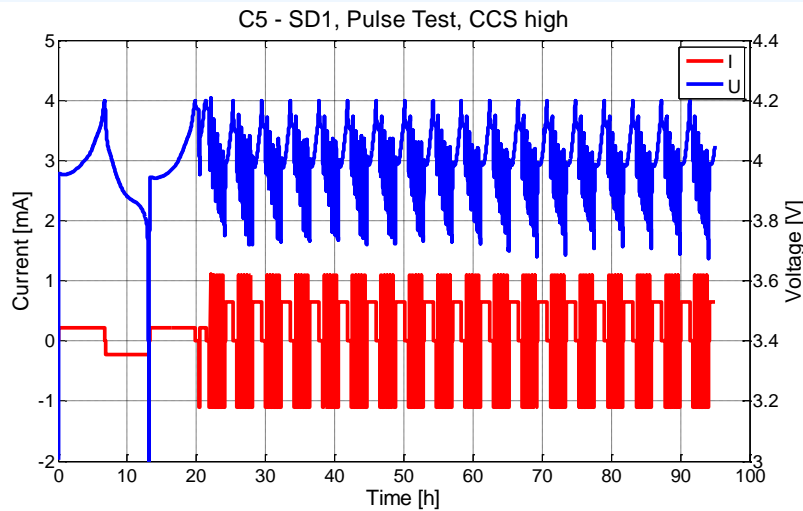
- Small short-time feedback from sensor to cell, when the CCS works at a low potential
- Correct function of sensor



Tests and Sensing Results

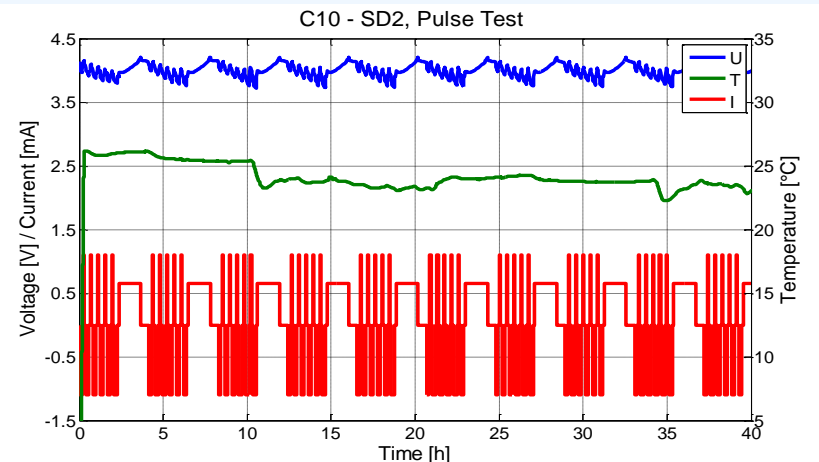
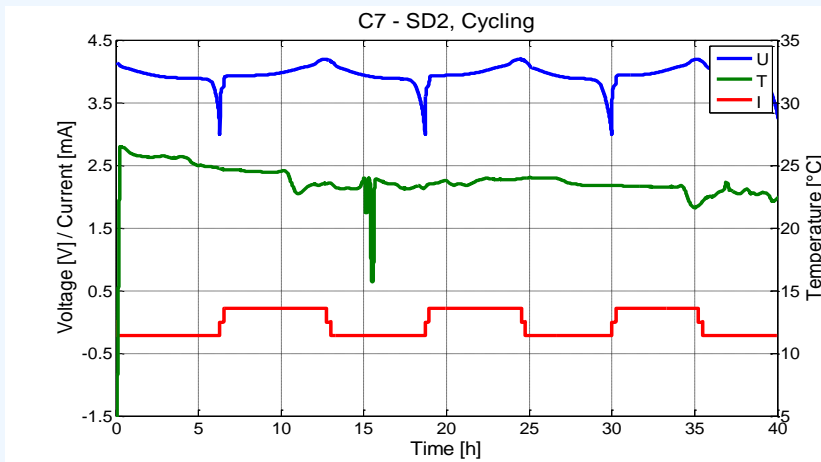
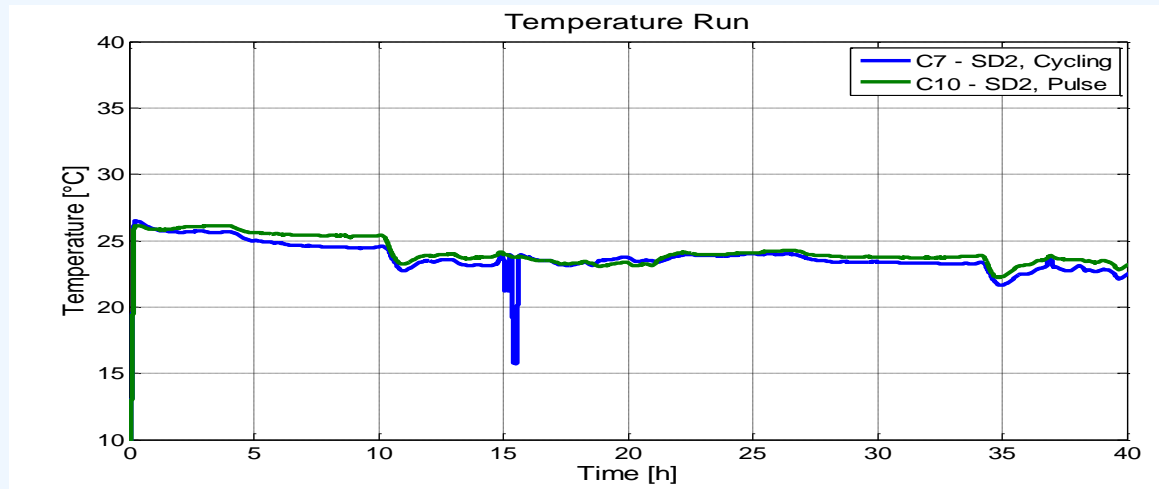
Results – Pulse Test

- No direct medium-term effect on cell behavior – Cell with sensor (left) and without sensor (right)
- Long-term tests with commercial cells desirable



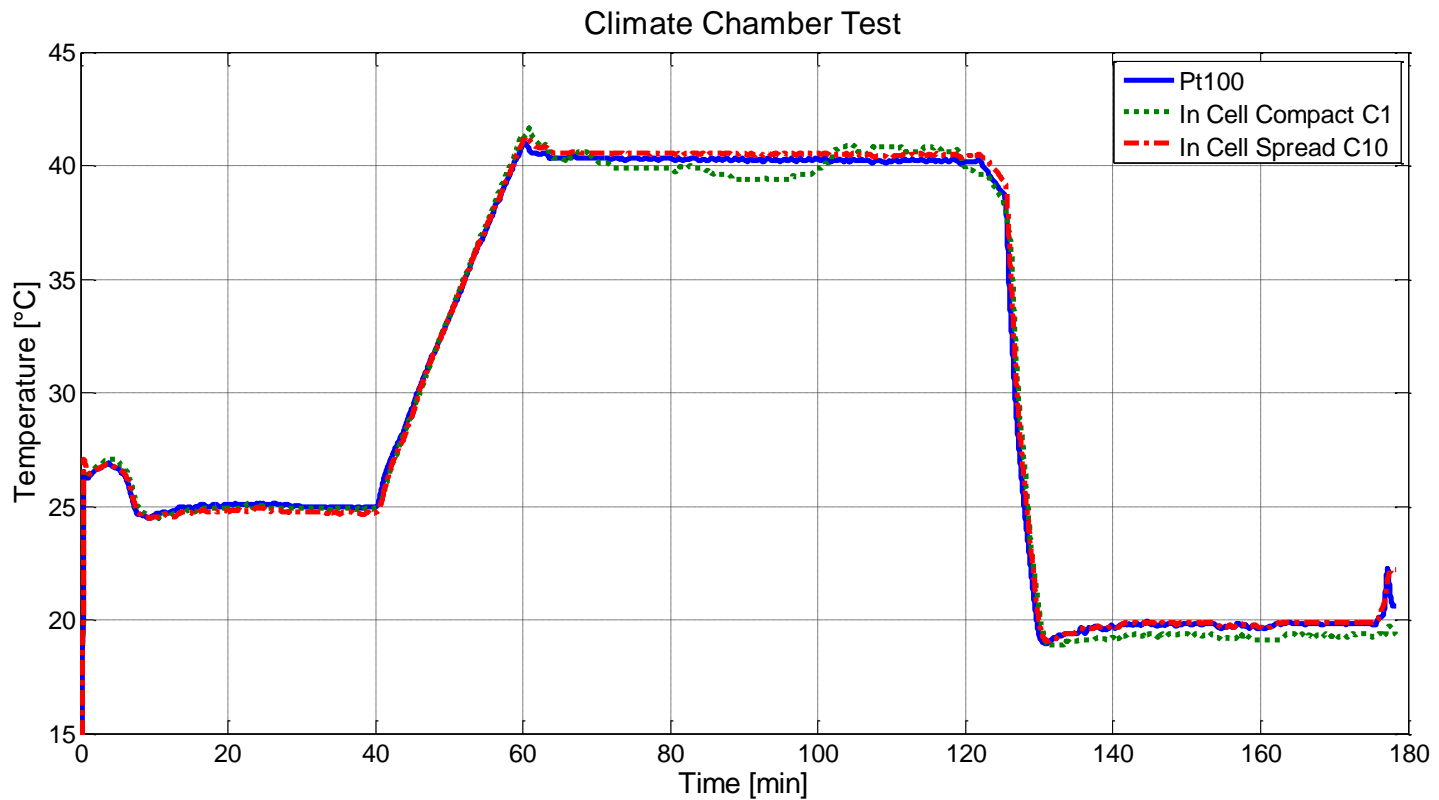
Tests and Sensing Results

Results – Temperature Development at 1/6C and 4/5C



Tests and Sensing Results

Results – Climate Chamber Test



Conclusion & Outlook

Conclusion

- First prototype sensors designed successfully
- Integration in pouch cells possible
- No reactions between sensor and cell measurable
- Temperature differences so far not recognizable due to low C-rates of self-made cells
- Bad reproducibility

Outlook

- Implementation of different types of reproducible thin-film temperature sensors for in-cell measurement
- Implementation in commercial cells for long-term tests and monitoring of temperature behavior at higher C-rates

Aknowlegement

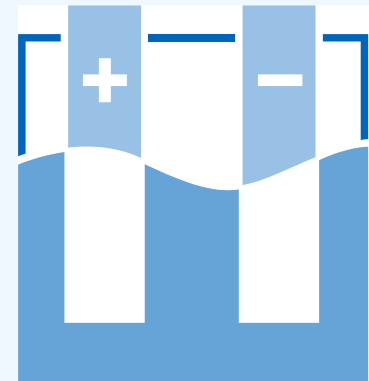
Founding

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Thank you for your Attention!

Any Questions ?

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