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In situ equipment condition monitoring of lithium-ion-cells by novel fiber optic sensor systems.

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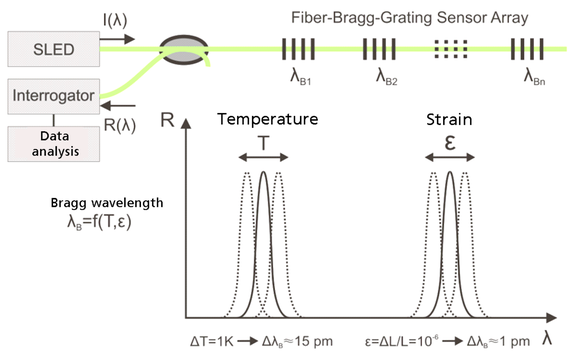
Motivation

- State-of-the-art commercial batteries are monitored by battery management systems (BMS).
- The BMS protects the cells from overpotential, short-circuit current damage and extreme temperatures.
- Some failure mechanisms like thermal runaway cannot be detected by the BMS before they become safety-critical.
- Innovative glass fiber sensors are developed to enable the detection of malfunctions, which cannot be detected by the BMS.

Setup

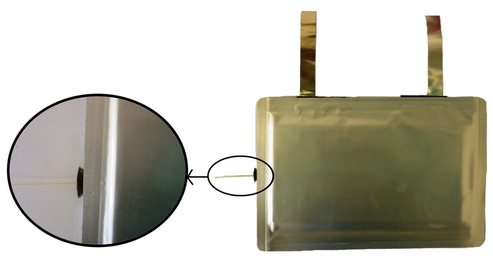
Measuring method

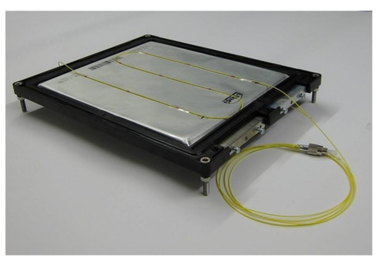
- Bragg gratings are included into glass fibers to measure temperature and strain.
- Bragg grating refracts and reflects light of a specific wavelength.
  - The wavelength can be defined for each Bragg grating during their integration into the glass fiber.
- If the sensor moves or change through temperature, the light refracts in a different way.
  - By these changes the temperature and strain can be calculated.



Integration of the fiber optic sensor systems

- Fiber optic sensor systems can be included into pouch bag cells or be fixed onto them.
- An integrated sensor needs to be included during the production of the cells.
- An externally attached sensor can probably be added to all commercial pouch bag cells.
- The sensors can measure the temperature and strain on definite points inside or outside the cells.



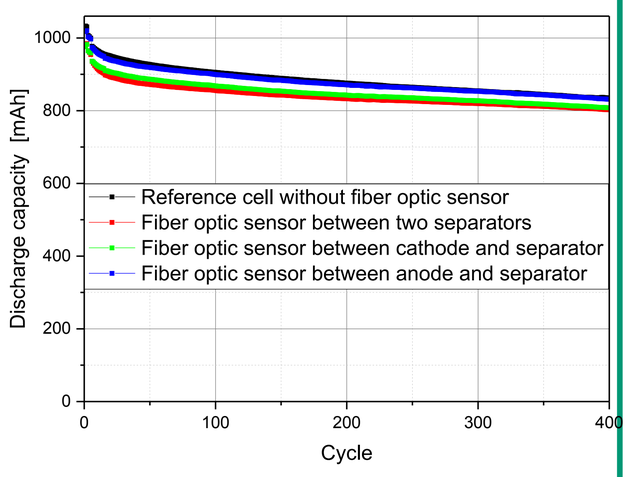


Results

Integrated Sensor: Influence on the cell performance

- First tests were done with a LFP/graphite system and a cell capacity of 1Ah.
- The fiber optic sensor system was integrated at three different positions in the center of the cells:
  - between two separators.
  - between cathode and separator.
  - between anode and separator.

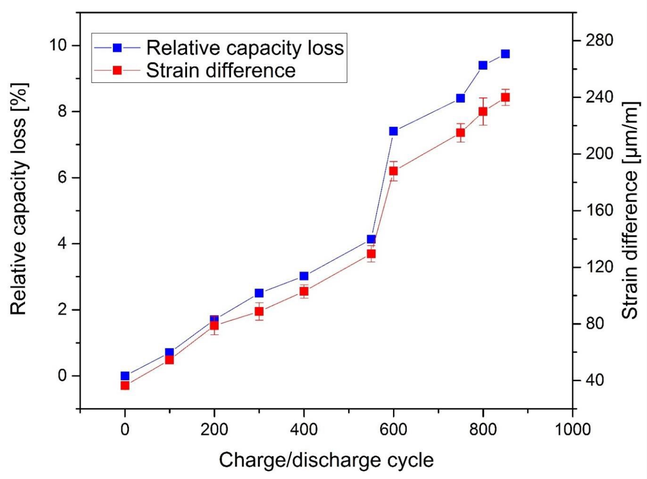
⇒ No influence of the fiber optic sensor system detected.



External Sensor: Measurement of the capacity loss through strain difference

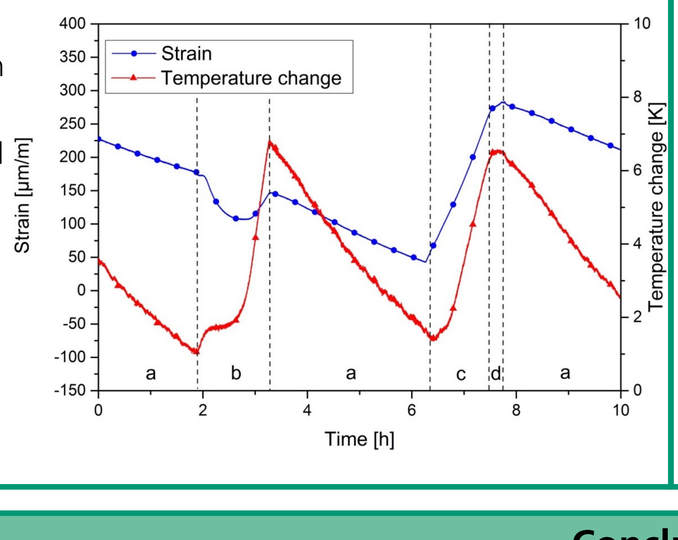
- The fiber optic sensor system was attached onto a pouch bag cell.
- The cell was cycled with 1C charge / discharge.

⇒ Measurable correlation between strain difference and relative capacity loss could be detected.



External Sensor: Temperature and strain measurement

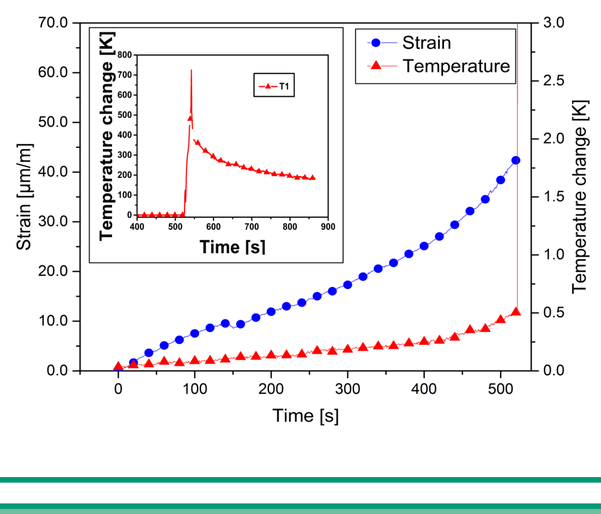
- The fiber optic sensor system was attached to a commercial 40Ah pouch bag cell.
- Temperature and strain were measured during cycling with 1C.
- The diagram is spitted into 4 parts:
  - Rest (a)
  - CC - discharge (b)
  - CC-charge (c)
  - CV-charge (d)



External Sensor: Early detection of thermal runaway

- A temperature measurement of an overheating cell is shown in the diagram.
- The strain has a non-typical behavior and increases fast, while the temperature has a low increase, until the thermal runaway takes place.

⇒ With this data an early detection of a thermal runaway is possible.



Conclusion

- Measurements of temperature and strain of pouch bag cells are possible with fiber optic sensor systems.
- No negative influence on the cell performance, caused by the integrated fiber optic sensor system, was detected.
- Fiber optic sensors can improve the safety through additional measurable parameters.
  - First tests show the possibility to prevent thermal runaway with the fiber optic sensor systems.

Acknowledgment

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