TU Clausthal
Clausthal University of Technology

EST Forschungszentrum Energiespeichertechnologien

STÖBICH technology

The Effect of Fire Protection Layers on the Safety Behavior of High-Performance Lithium-Ion Modules

Alexander Oberland*, Marc Dinse**, Nury Orazov*, Marcel Thiele*, Ralf Benger*
*Clausthal University of Technology, Research Center Energy Storage Technologies, D-38640 Goslar
**Stöbich technology GmbH, D38644 Goslar

1. Introduction

- In the context of changes in mobility, lithium-ion batteries (LIB) are increasingly used in this sector. Furthermore, these batteries are also being used more and more in the energy industry to stabilize the power grid. For many of these applications (e.g. pulse charging), the demands on the battery system in terms of performance and dynamics are very high. In these cases, the battery must be able to withstand increased thermal, mechanical and electrochemical stress, which in particular leads to higher requirements if safe operation and a reduced risk of damage are to be guaranteed with such a battery storage system.
- Due to their properties (e.g. high energy density and undesired side reactions), LIB involve major risks. For example, the contained chemical energy is 8 times the electrically stored energy. [1] This means that in the event of damage, high destruction potential through fire or explosion and thermal spread of the accident to the entire system is possible.
- Fires and explosions in such systems are usually caused by local phenomena, which have electrical (e.g. overcharging and short circuit), mechanical (e.g. local damage to the system) or thermal causes (e.g. local temperature rise). The heat is transferred to the surrounding areas of the battery system and thus causes damage to the entire system.
- It would be good to be able to limit the effects of the accident locally. The result of such containment is the reduction of harmful gases, reduction of fire damage and protection of investments. Possibilities for limitation in case of damage exist at different levels (e.g. housing, module and cell).

2. Method

- Limitation in the experiment carried out at the level of the modules, which are later assembled into a system.
- Module (12p1s) consisting of pouch cells with a capacity of 53 Ah and matching housing (total electrical energy quantity 2.544 kWh).
- In the modified module the bi-packs (two cells) are separated from each other by fire protection layers.

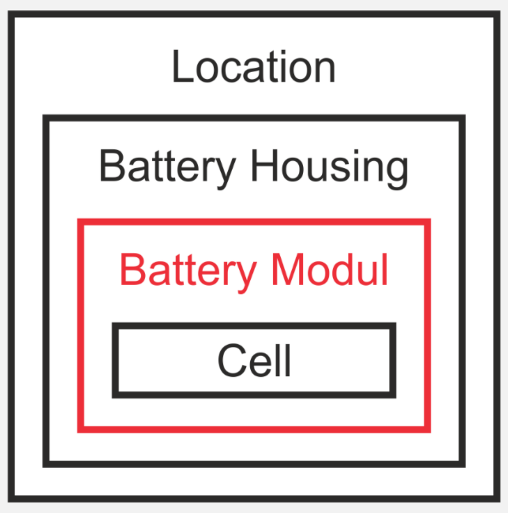
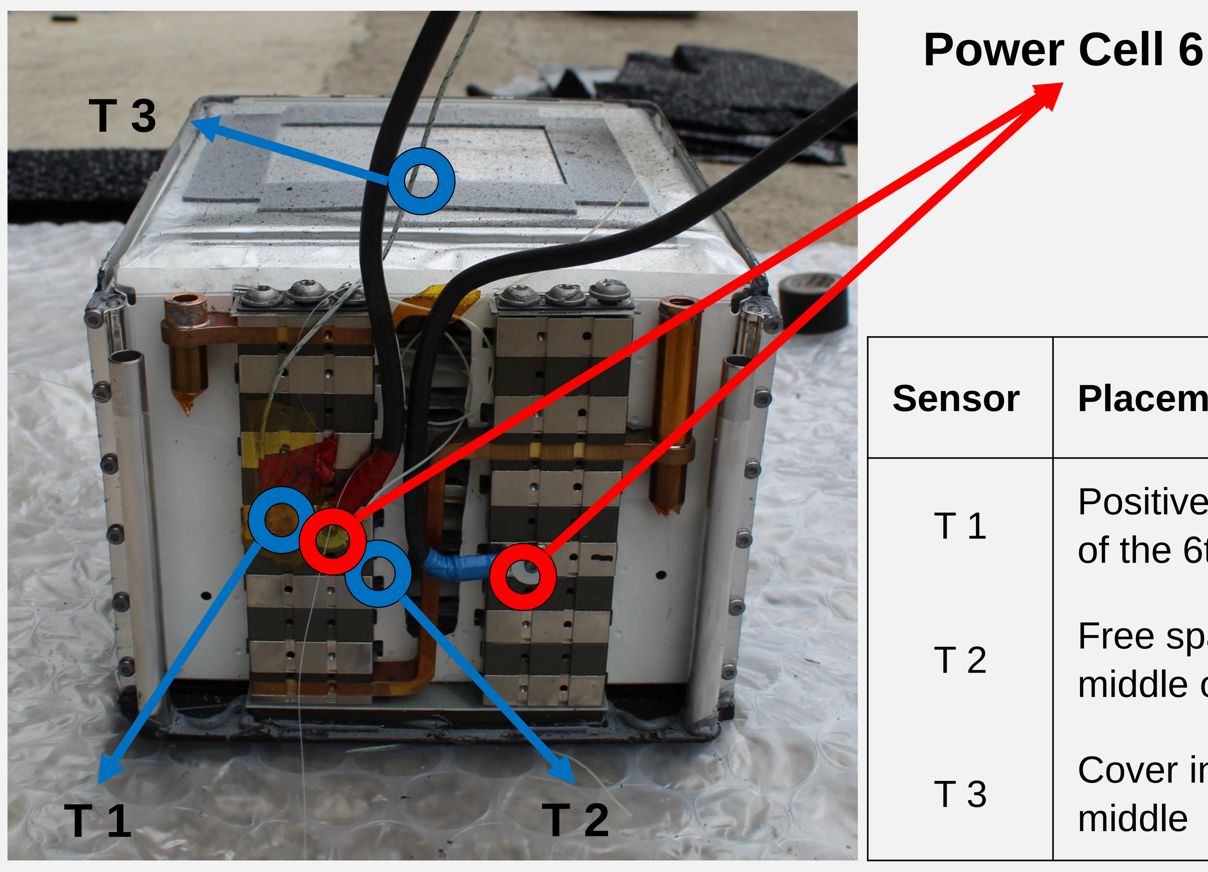


Fig. 1: Protection Level

Fig. 2: Layers

- Fire protection layers consist of glass fiber (support layer), metal-hydrate and thermoplastic binder (cooling layer with a thickness of 3 mm) and a cover (aluminum foil) and are conventionally used as effective fire protection barriers.
- Mineral coolants are used in the cooling layer, which can absorb a considerable amount of energy.
- This is done by evaporation of hydrated minerals and starts at an activation temperature of 95 °C.
- Cell 6 in the middle bi-pack separately overcharged in steps of 5 % with a current rate of 1C in 5 % steps.
- Ignition Module without fire protection at SoC 175 %.
- Ignition Module with fire protection at SoC 180 %.
- Other cells have a SoC of approximately 50 %.



Sensor	Placement
T 1	Positive terminal of the 6th cell
T 2	Free space in the middle of module
T 3	Cover in the middle

Fig. 3: Module with sensors

3. Findings

Module without fire protection

- Ignition of the gases occurs immediately after bursting of the pouch cover
- Maximum temperature in the module (sensors T1 and T2) increases to almost 700 °C
- Module burns for more than 1 hour and several explosions occur
- Significantly more harmful gases are produced over the entire period
- Module is completely destroyed after the accident

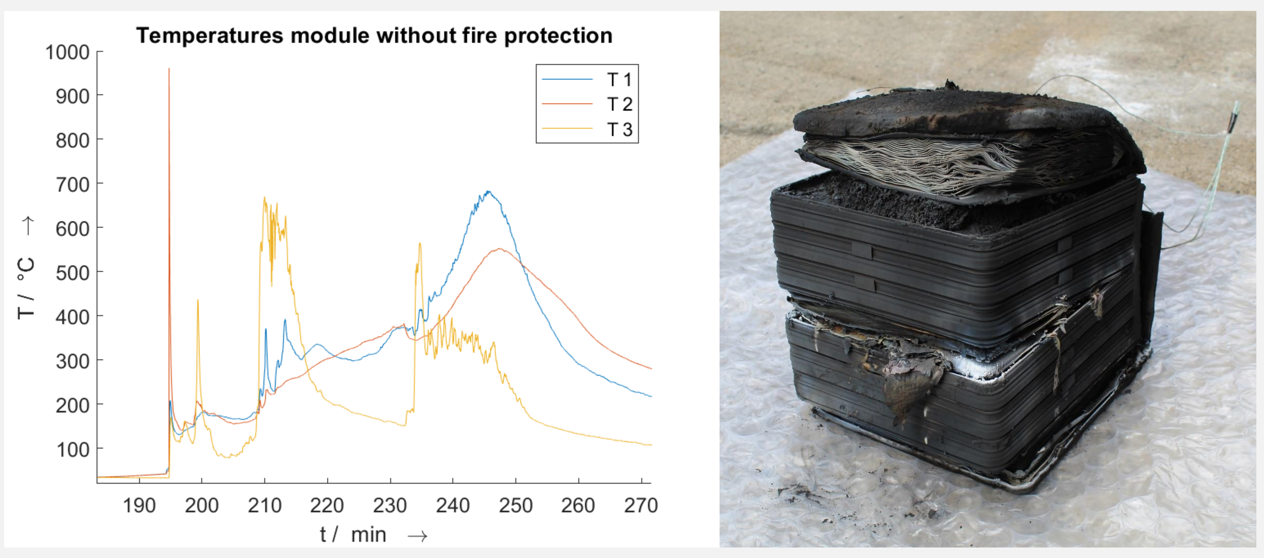


Fig. 5: Temperature developments shortly before and during the accident (left), Destroyed module without fire protection after the test (right)

Module with fire protection

- Ignition of the gas occurs significantly later than in the test with no protective layers
- Maximum temperature in the module (sensors T1 and T2) rise to merely 60 °C
- Only the overcharged cell 6 explodes
- There is no thermal propagation within the module
- Module failure is stopped afterwards (cell voltage of the other cells at 3.5 V to 3.7 V)

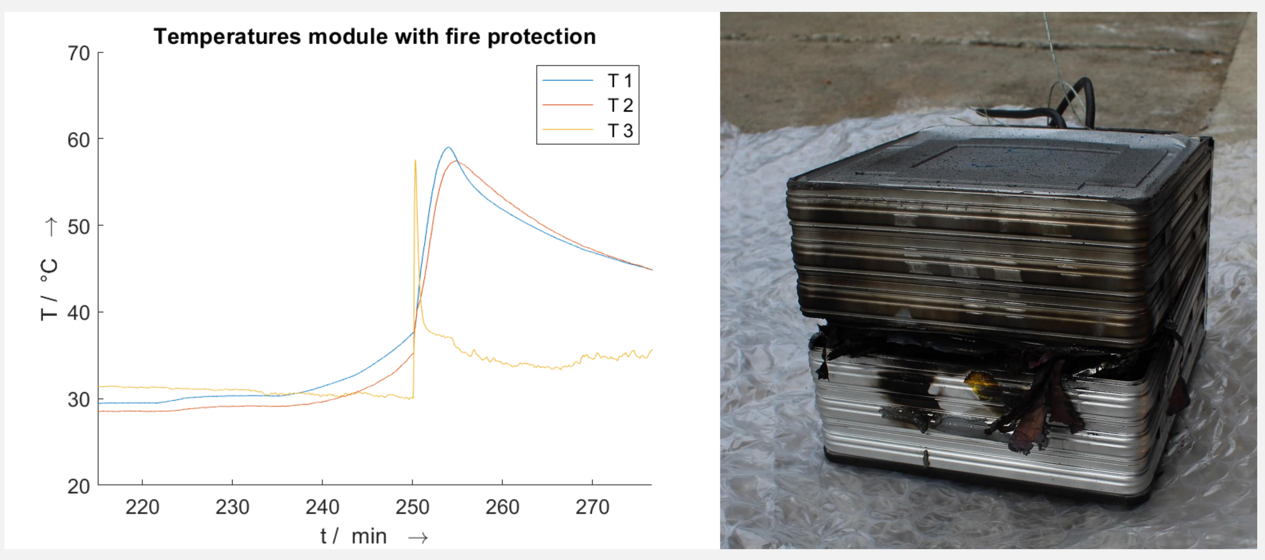


Fig. 6: Temperature developments shortly before and during the accident (left), Module with fire protection after the test (right)

4. Conclusion

- Improved fire protection was achieved by the intermediate layers used.
- Thermal propagation can be prevented locally.
- The rest of the system is only exposed to a significantly reduced temperature rise for a short time.
- In combination with other protective devices (e.g. filters) at other levels of the system, contributes to a significant improvement in safety.

5. Future Work

- Optimal design for different modules (which material and amount of material) depending on energy content and working range.
- Integration of the findings into an overall concept for battery systems for mobile and stationary applications

References:
[1] D. Hoffmann, „Sicherheit von Lithium-Ionen-Batterien: Welche Gefahren gehen von ihnen aus und welches Risiko ist überhaupt vertretbar?“, in Batterien als Energiespeicher. Berlin, 2015, Kap. 134

Acknowledgement:
„MoBat - Modulare Hochleistungsbatteriesysteme in Verbindung mit sicherer Schnellladetechnik" FKZ: 03ET6107

Gefördert durch: Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages

Contact:
Dipl.-Ing. Alexander Oberland
Am Stollen 19A, D-38640 Goslar
Alexander.oberland@tu-clausthal.de