CONCEPT FOR ENHANCED FAILURE DETECTION IN TRACTION BATTERIES

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outline

- motivation
- methodical approach
- detection of accelerated aging
- conclusion

motivation

- enhanced failure detection by the BMS may benefit…
  - systematic minimization of risks in the battery system
  - making better use of battery capacity and performance
  - precise state of health (SoH) and remaining service life (RSL) predictions
  - detection of non-uniform aging characteristics of the individual cells within a pack
  - increased reliability of the vehicle and comfort of the driver by early warning for maintenance

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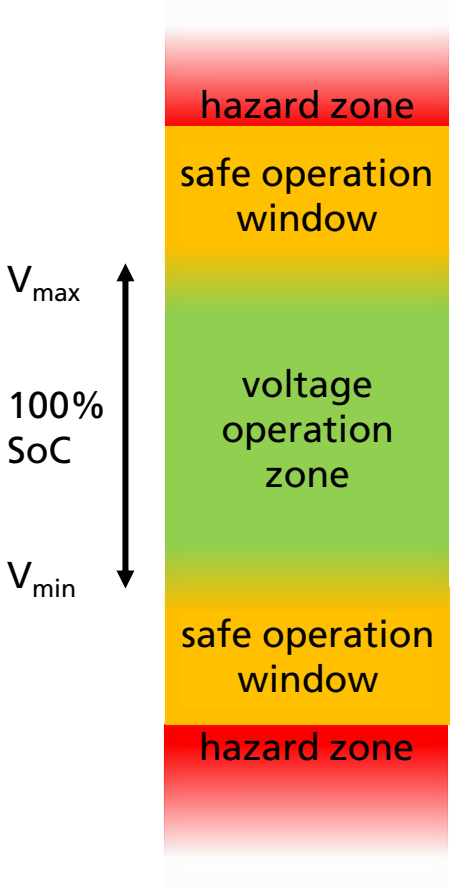
motivation: safe operation window

- cell manufacturer defines narrow limits for ‘voltage operation zone’ to guarantee safety
- battery users need to define operation zone as large as possible to obtain high energy / power density

➡ compromise: safe operation window

- ‘safe operation window’ is not one-dimensional, but also dependent from load current, SoC, temperature and time

➡ causes of cell failure are not entirely understood and need to be analysed in a methodical manner



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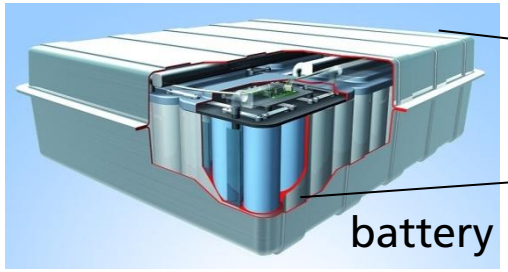
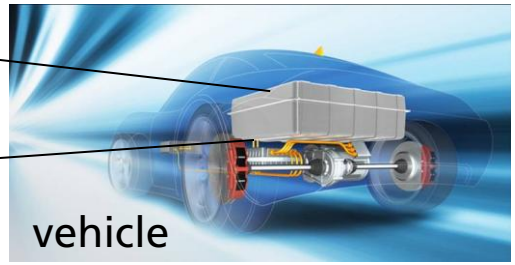
methodical approach





battery risk analysis

functional safety risk analysis

diagnostic functions

battery safety concept e.g. SOW

vehicle safety concept e.g. shutdown on crash

cell require-ments, safety, performance

battery system

BMS requirements HW, SW

cell FMEA: prevent causes detect effects effect sequence

- cell behaviour
- characterization

non safety relevant requirements e.g.: aging, performance,…

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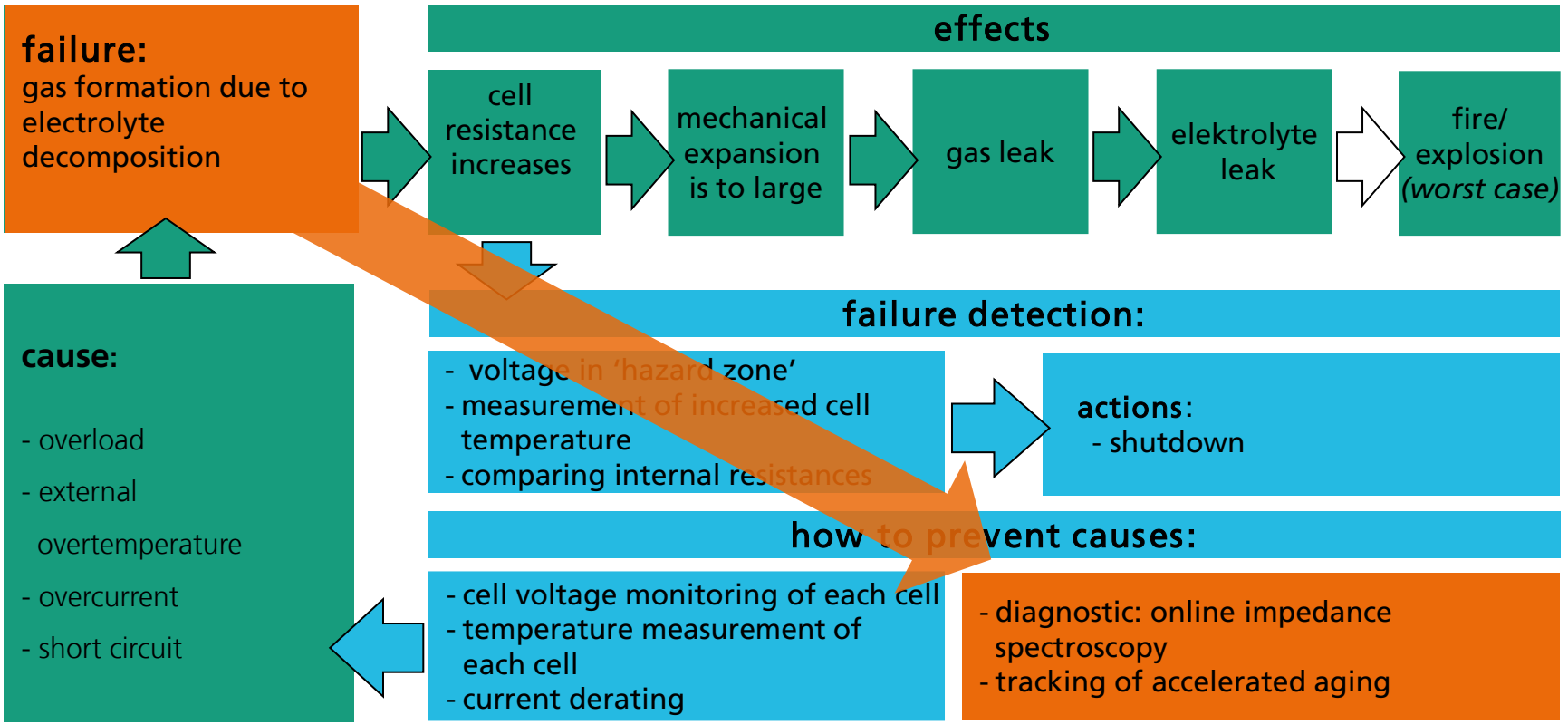
example case cell FMEA: elektrolyte decomposition

- FMEA: failure mode and effect analysis, reflects physical, thermal, mechanical, chemical and electrical failure modes
- safety concept: prevention and detection of failures + reaction mechanisms



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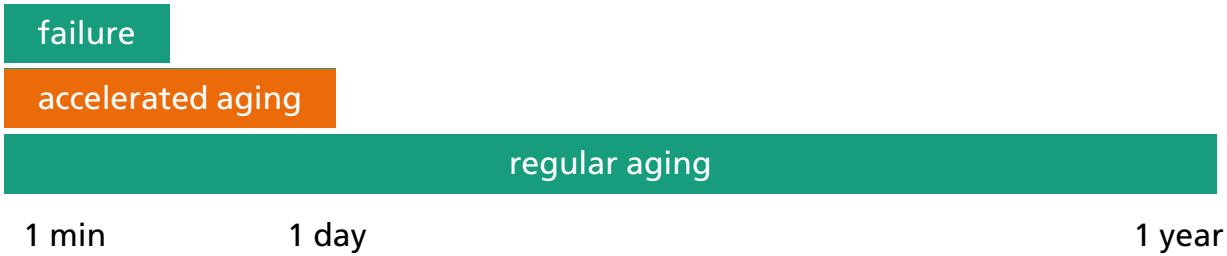
accelerated aging



- failure happens within seconds or minutes (e.g. short circuit or thermal runaway) – battery needs to be shut down
- accelerated aging due to unfavourable environmental conditions or abusive battery operation
- regular aging (calendrical as well as due to cycling) leads to capacity loss and resistance increase as expected by cell manufacturer

accelerated aging may lead to battery failure later on

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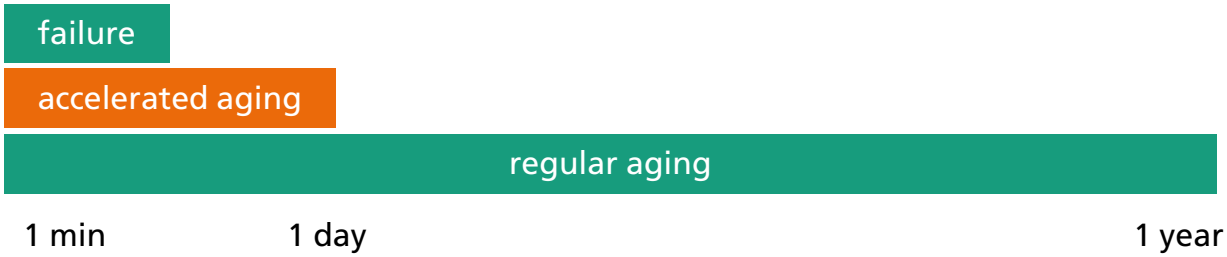
accelerated aging

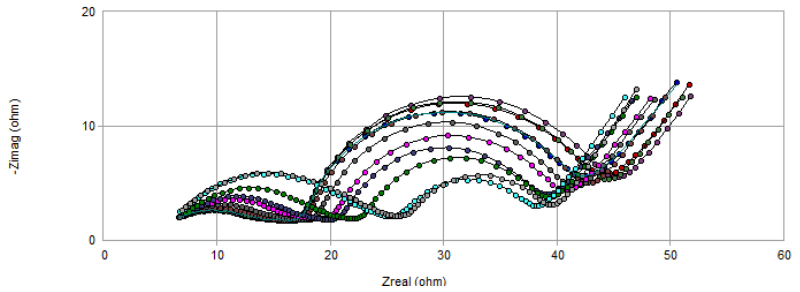


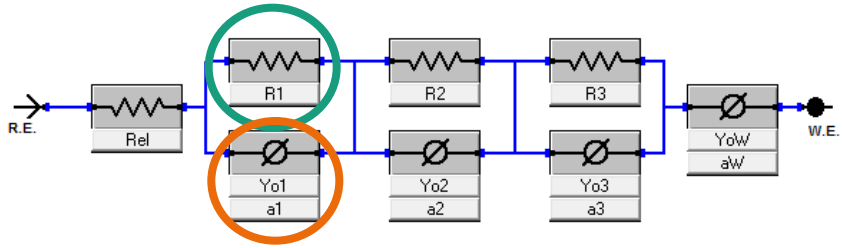
- ideally any cell will behave exactly as described in the datasheet
- cell manufacturer cannot foresee all use cases
- possible causes of accelerated aging
  - low temperature operation
  - operation / storage at elevated temperatures
  - overcharge / overdischarge
  - mechanical stress (external or internal through gas formation)
  - excessive currents
- ➡ investigation in extensive aging-experiments (DSC, TGA, IR, FESEM, porosity, capacity, PITT, IS)

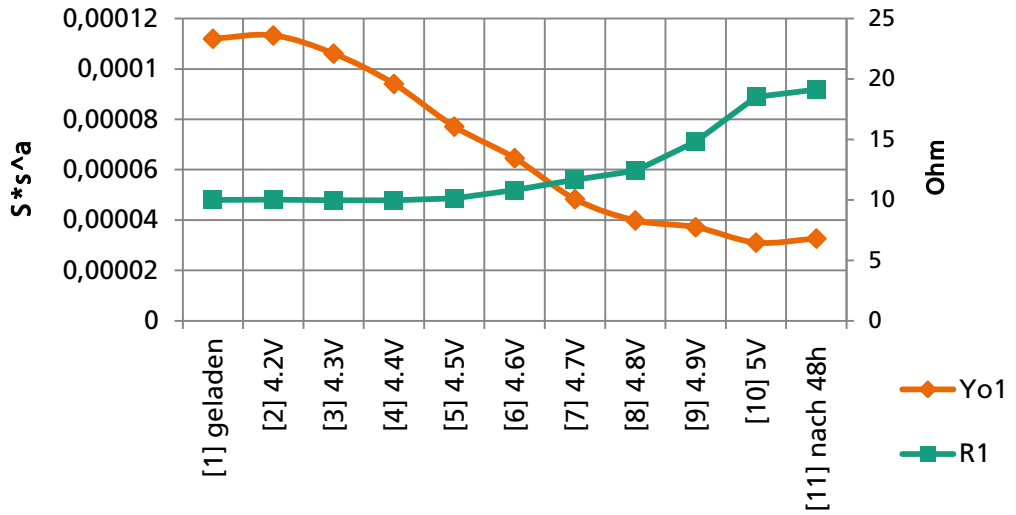
example: overcharging

- lab made coin cell with NCM / graphite electrodes
- stepwise overcharged (4.2 – 5V)
- impedance spectrum measured after each step at 4.15V

- fit of the data to an equivalent circuit diagram
- accelerated aging can be monitored by tracking model parameters







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conclusion

- risk of a sudden breakdown of the vehicle can be minimised by early warning for maintenance
- more efficient battery usage saves costs

- what information should be stated in the datasheet of a cell?
  → standardised ‘safe operation window’ ?

- tradeoff between accuracy and cost of online impedance measurement is challenging
- further research in aging characteristics of different Li ion systems is necessary

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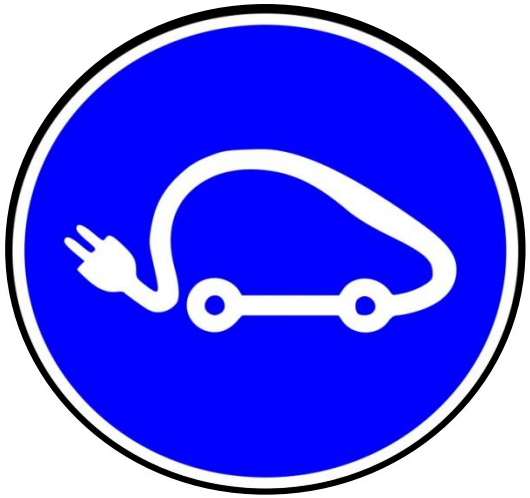

thank you for your attention

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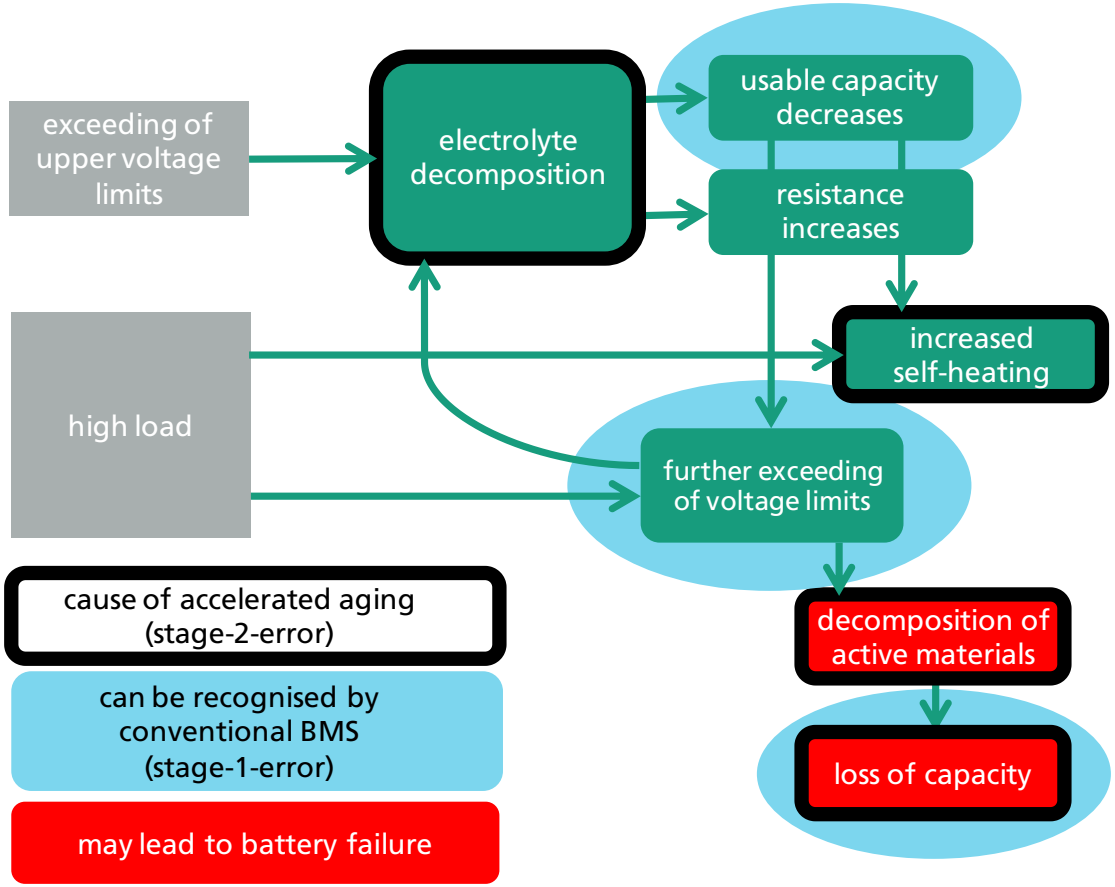
example: overcharging

- propagation of cell states from accelerated aging to battery failure
- example: overcharging



- aging can be quantified by characterising internal resistance using impedance spectroscopy

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