EVS27
The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION
BARCELONA
17th-20th November 2013

Using on-board Electrochemical Impedance Spectroscopy in Battery Management Systems

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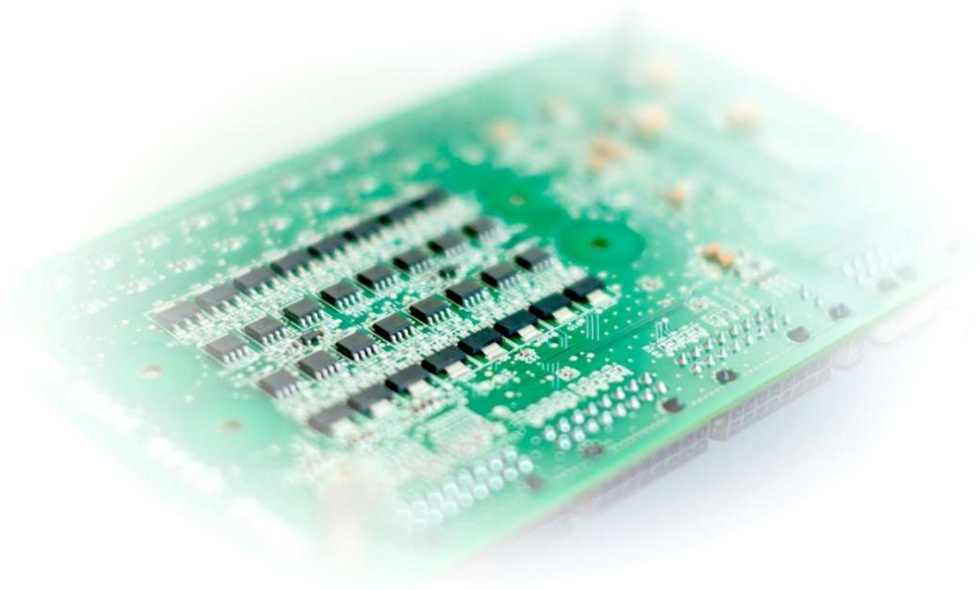

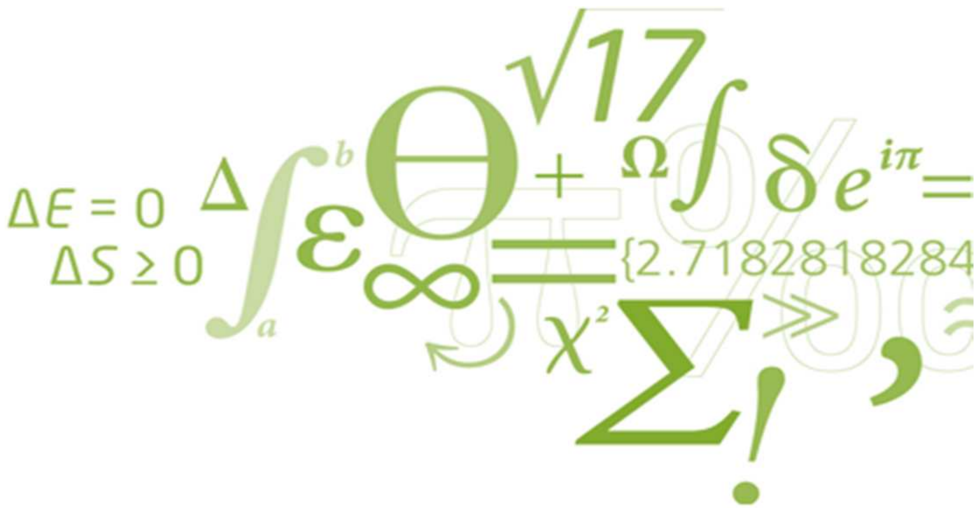

1 LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

2 DTU
DTU Energy Conversion
Department of Energy Conversion and Storage

Organized by Fira Barcelona, avele
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In collaboration with nea, Ajuntament de Barcelona
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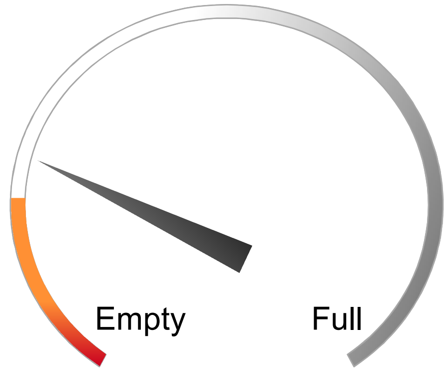
Outline

- Battery measurements and estimations
- Principals of electrochemical impedance spectroscopy
- Real time battery modelling
- Improved battery management
- Early warning detection and battery failure prevention
- Summary

Battery measurements and estimations

Remaining capacity:

- State of Charge (SoC)



Health of a battery:

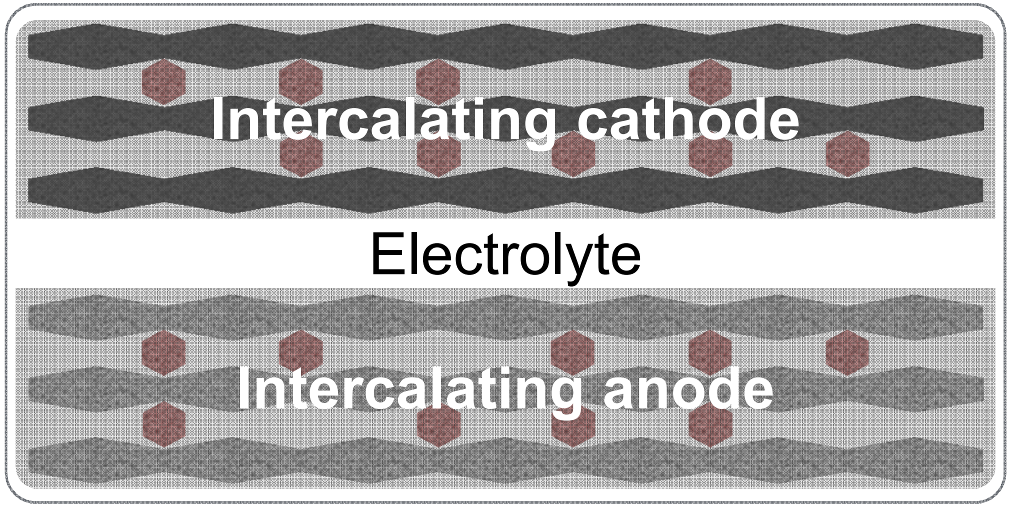
- State of Health (SoH)

$$SoH_{capacity} = \frac{current\ total\ capacity}{rated\ total\ capacity}$$

$$SoH_{power} = \frac{current\ available\ power}{initial\ available\ power}$$

Battery measurements and estimations

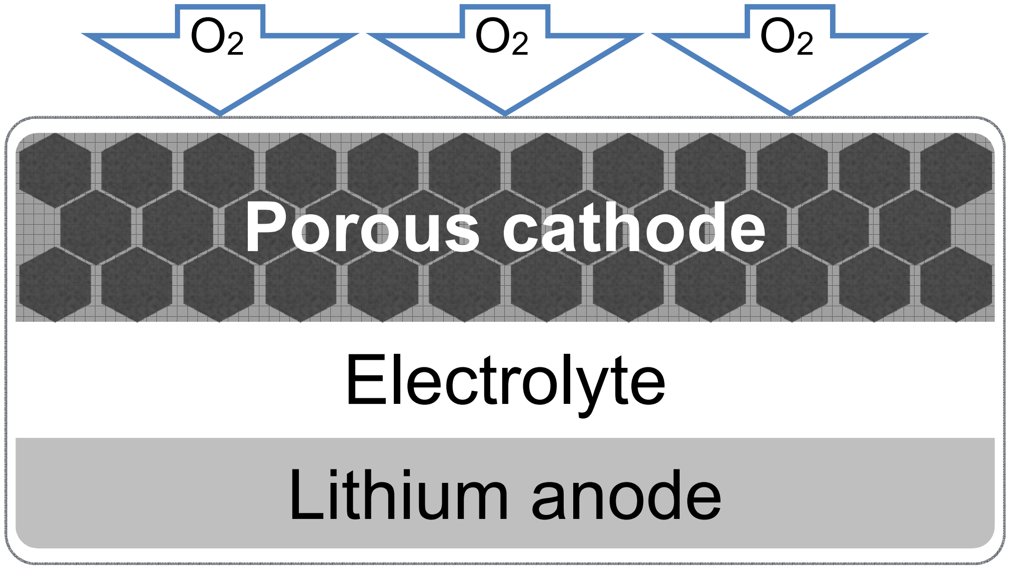
Li-ion fundamentals



- Intercalation materials
- Volume change due to Li^+ ion migration

Battery measurements and estimations

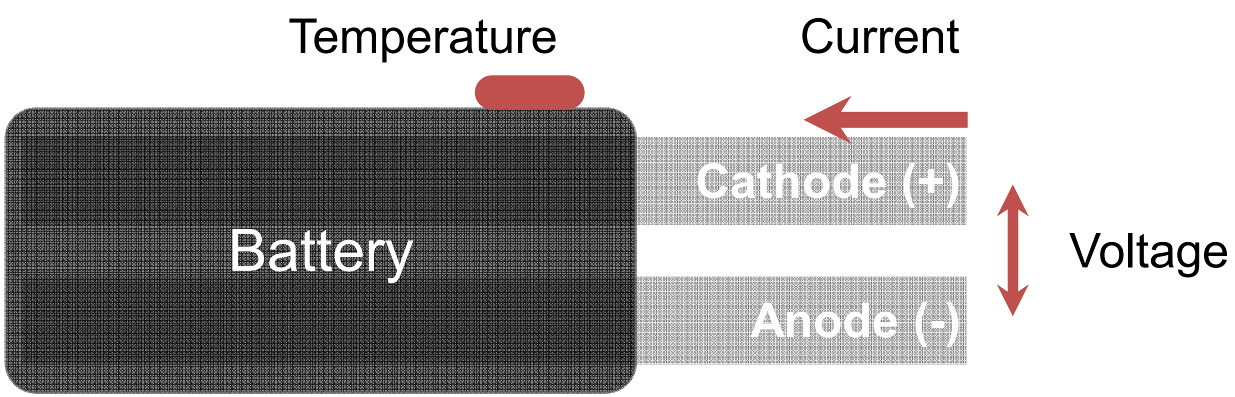
- Li-air fundamentals:
  - Oxygen and lithium-ions
  - Li_2O_2 layer formation
  - Very high specific energy ~5x more than Li-ion



Battery measurements and estimations

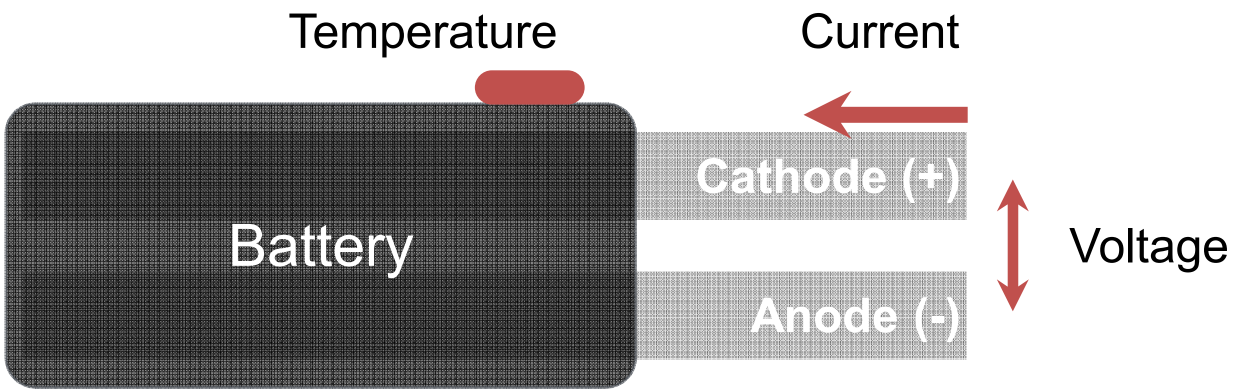
- Parameter estimation based on measurable data
  - Sealed battery seen as "black box"

- Possible measurement points:



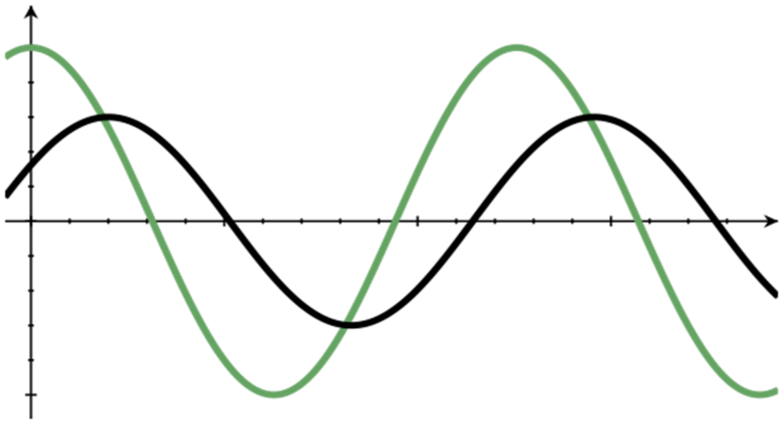
Principals of electrochemical impedance spectroscopy

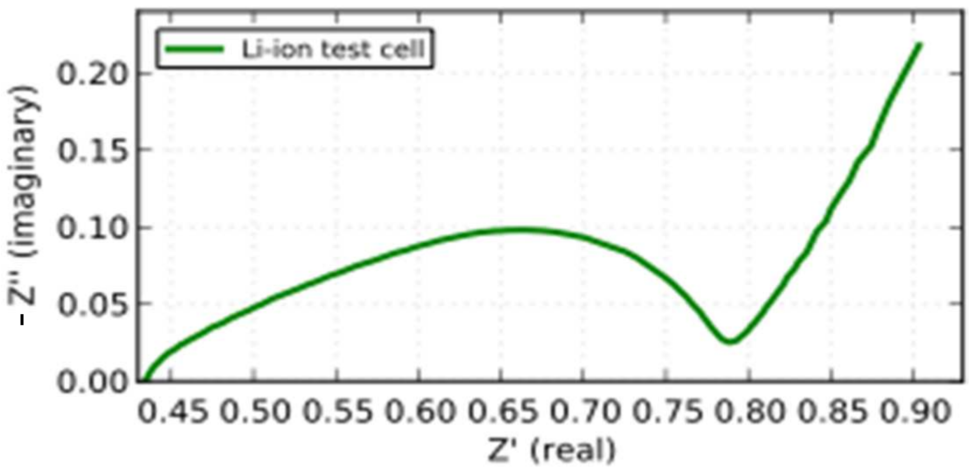
- Another measurement method…



Principals of electrochemical impedance spectroscopy

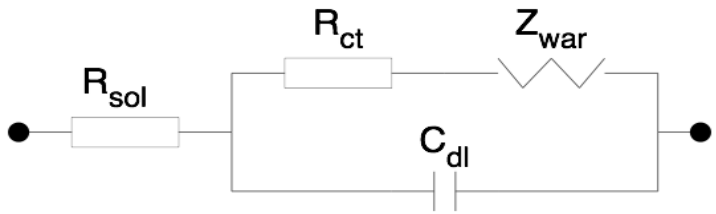
- Light theory of electrochemical impedance spectroscopy

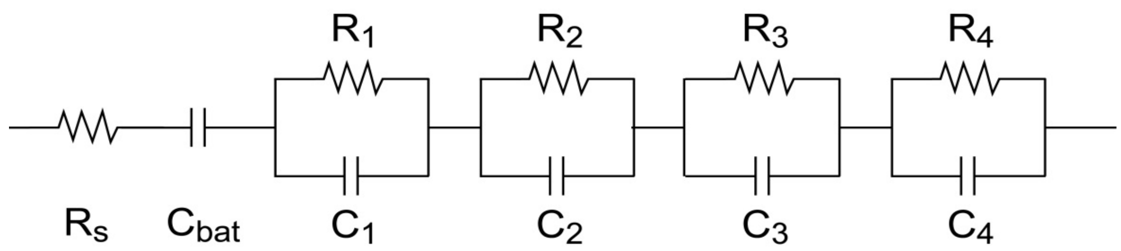




Real time battery modelling

- Equivalent circuits and parameter fitting
  - Physical model vs. perfect fit?



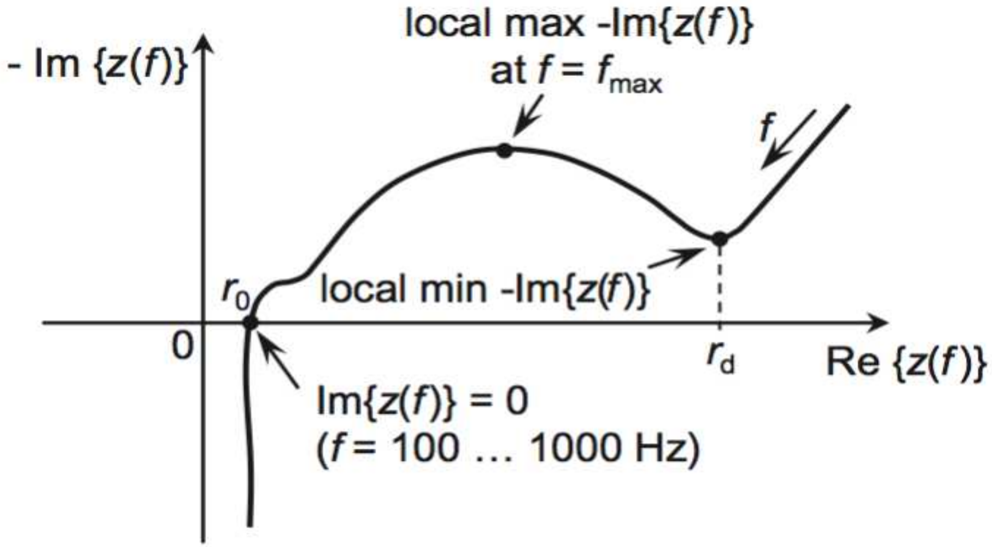


"Selecting an EIS model is 50% science and 50% art"

- Søren Koch, DTU

Real time battery modelling

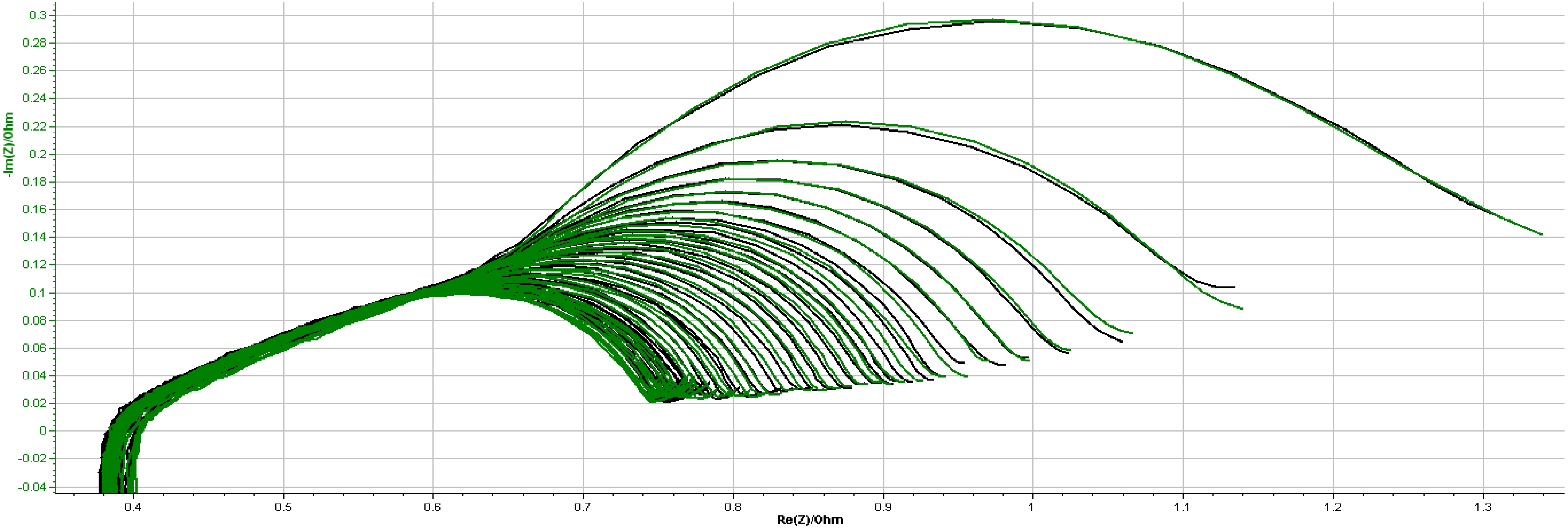
- Real time parameter updates
  - Simple model for easier fitting
  - Characteristic attributes extracted without equivalent circuit.



W. Waag et al., "Experimental investigation of the lithium-ion battery impedance characteristic at various conditions and aging states and its influence on the application", Applied Energy, 102(C):885–897, 02/2013.

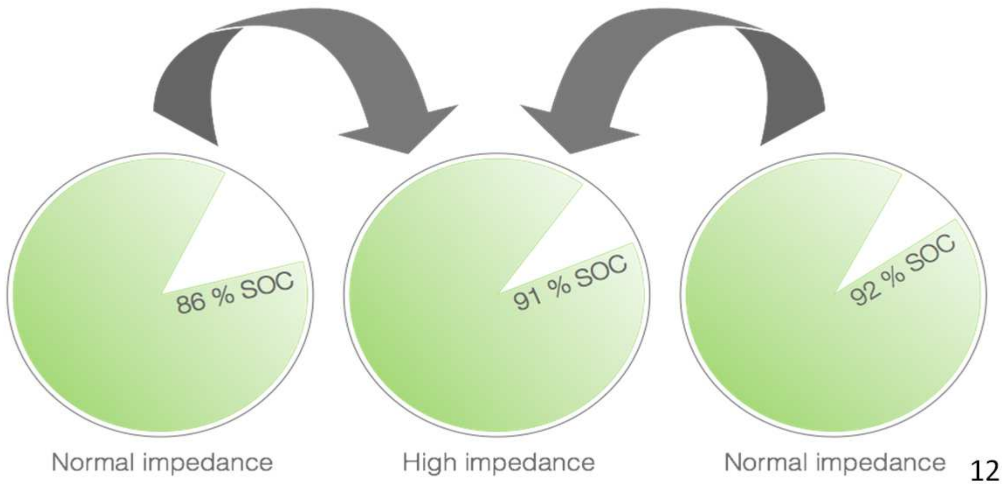
Improved battery management

- Parameter changes as function of internal processes, e.g: SOC, temperature, or ageing.



Improved battery management

- Real-time parameter updates results in increased performance.
  - Balancing batteries with different strategies based on internal impedance data.
  - Unlocks more useful capacity.



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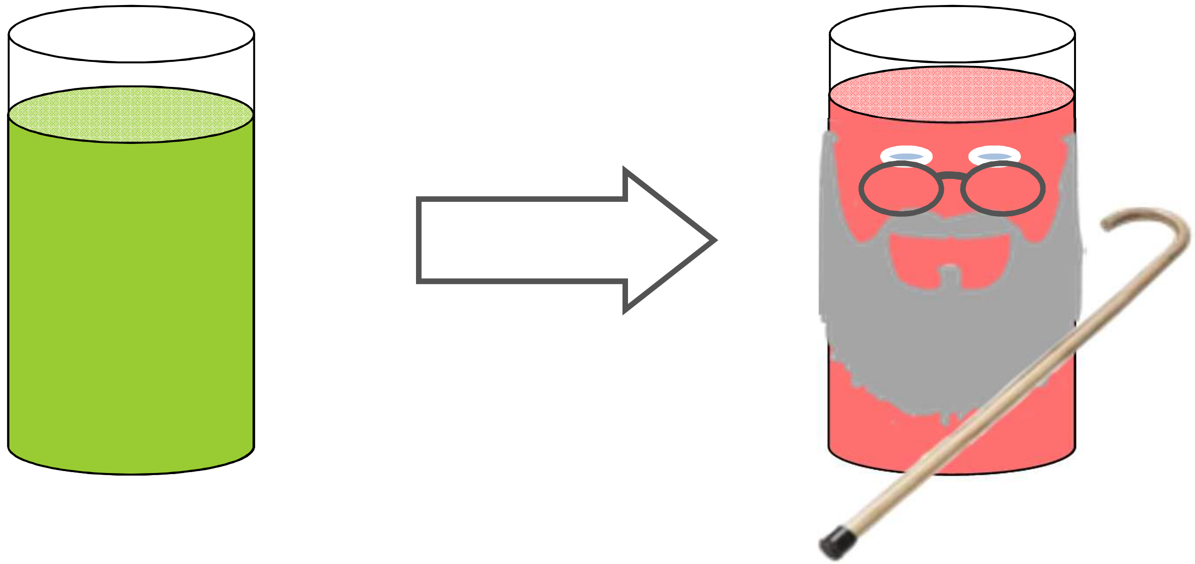
Early warning detection and failure prevention

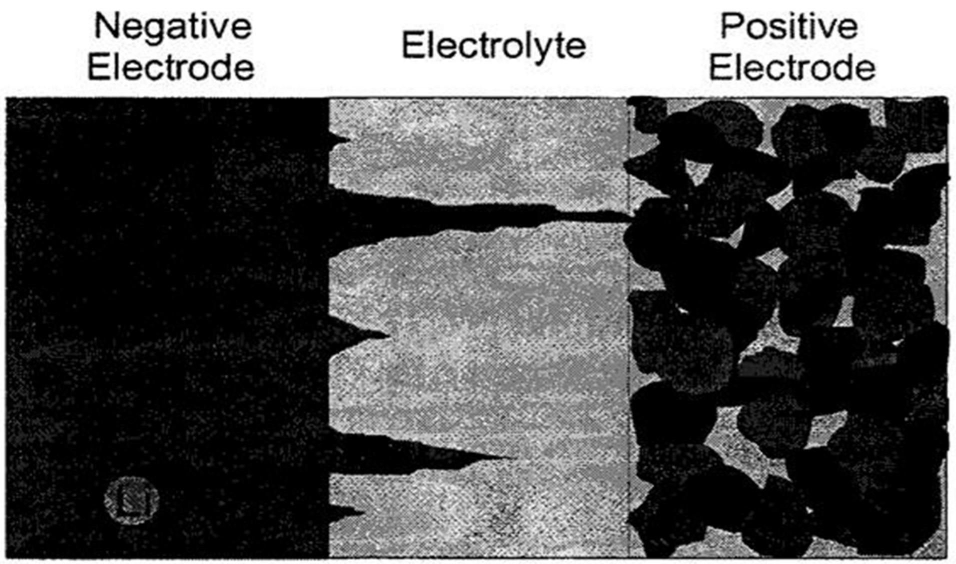
Estimating ageing of batteries

- Through impedance data changes



Early warning detection and failure prevention

- Early warning detection and failure prevention through impedance data
- Detection of internal shorts circuits
- Detection of Li-dendrite formation
- Goal: Detection of thermal run-away



M. Winter, Symposium on Large Lithium Ion Battery Technology and Application (AABC-06), Tutorial B, Baltimore, May 15, 2006

Summary

- Probing batteries using electrochemical impedance spectroscopy.
- Unlocks information on the internal kinetics of a battery.
- Enhance performance through better balancing.
- Track ageing of batteries through impedance.
- Monitor and prevent safety critical events.

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Acknowledgements

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- Colleagues

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