Looking deeper into preservation of lithium-ion battery life for long hibernation period

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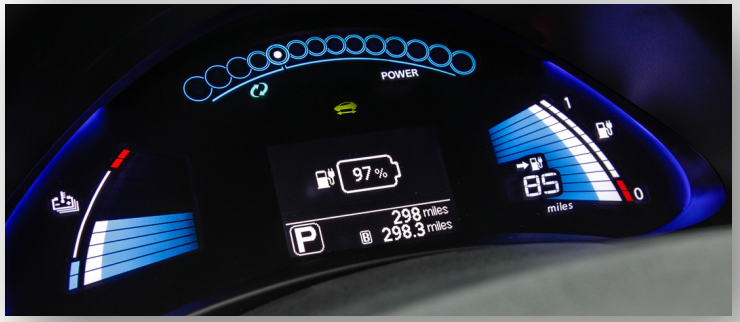
Introduction to Research Problem

- Lithium-ion batteries may spend long periods when they are not used e.g. electric vehicle parked at airport parking, on export transit, even on the way to a different planet

- Lithium-ion battery performance degrades even when they are not used
- How to preserve lithium-ion battery life when they are not being used?

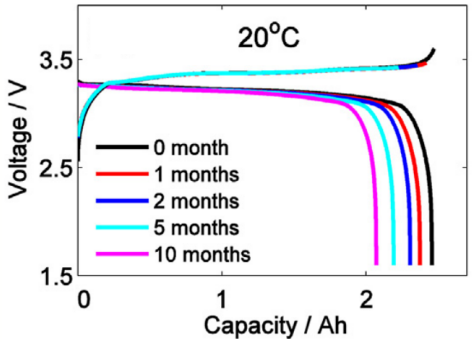
State of the Art

- Current practice is to charge batteries to 30-90 % SoC in consumer electronics before packaging
- For transportation, regulation mandate 30 % SoC
- EV users tend to keep their vehicle at or near 100 % SoC

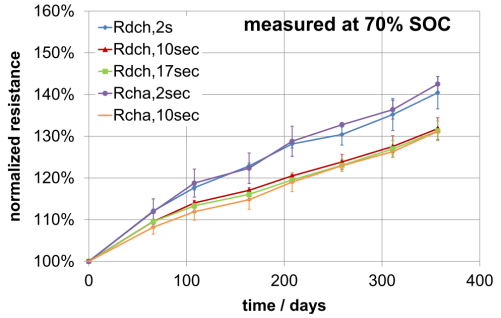


State of the Art

- Battery degrade by 3-5 % for every 12-15 weeks' of storage when stored at ≥ 50 % SoC
- Current speculation – battery degradation is accelerated when stored at very low SoC
- This research investigate battery ageing at very low SoC



Li *et al.* Electrochimica Acta, 2016. **190**: p. 1124-1133



Ecker *et al.* Journal of Power Sources, 2014. 248: p. 839-851

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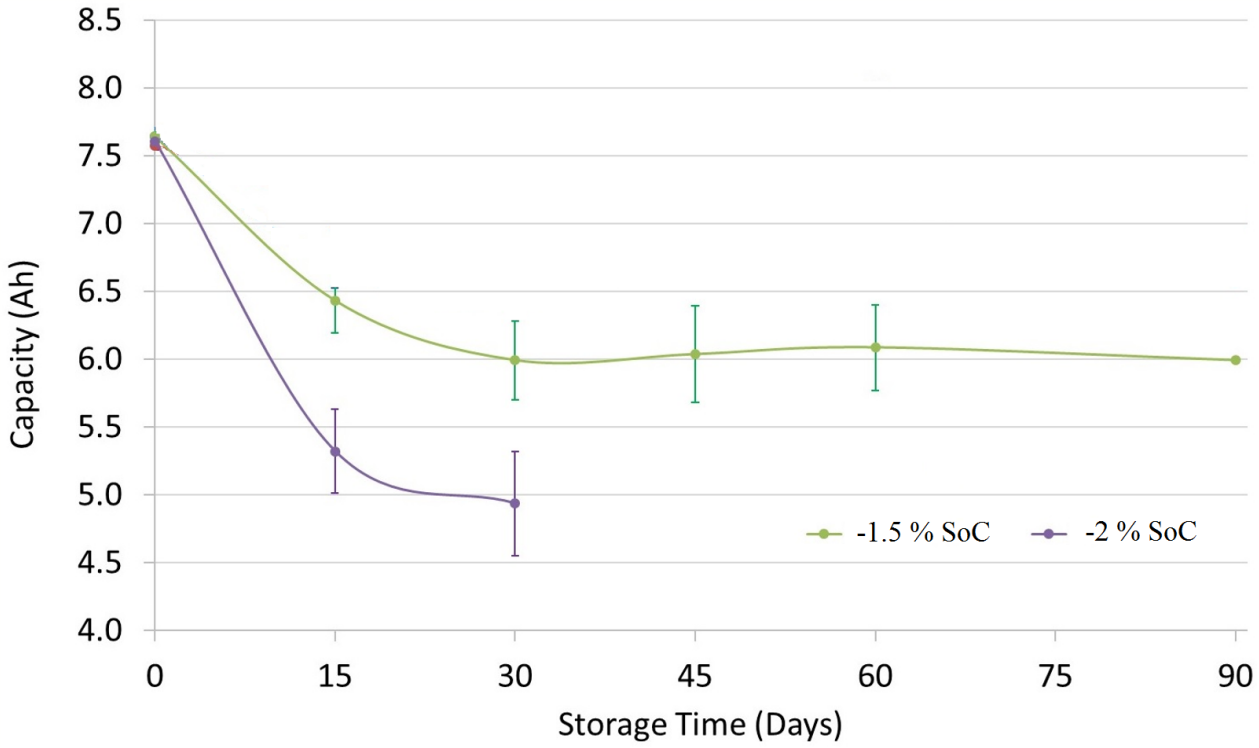
Experiment 1 – Proof-of-Concept

- Calendar life test was performed on 8 Ah LFP batteries
- Battery SoC is adjusted to 0, -0.5, -1.5 and -2 % SoC at stored at 25 °C
  - Below 0 % SoC battery will have little stored energy – safe to transport
  - At -2 % SoC a 300 V battery pack voltage will be <50 V
- Cell capacity was measured every 15 days with 1C current
- EIS testing was performed at 50 % SoC, every 15 days

Results – Change in Capacity -2 and -1.5 % SoC



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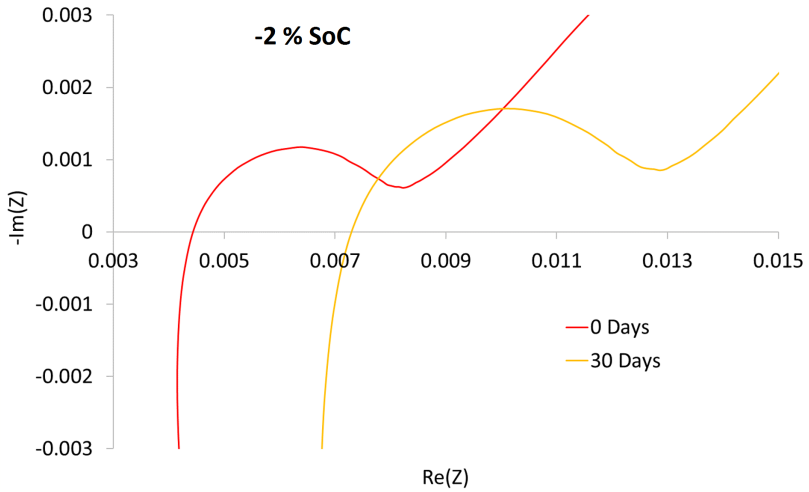
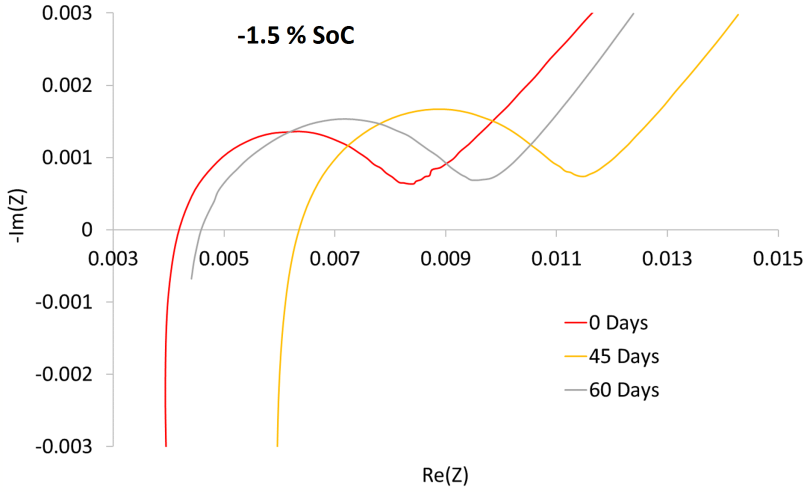
Results – Change in Resistance -2 and -1.5 % SoC



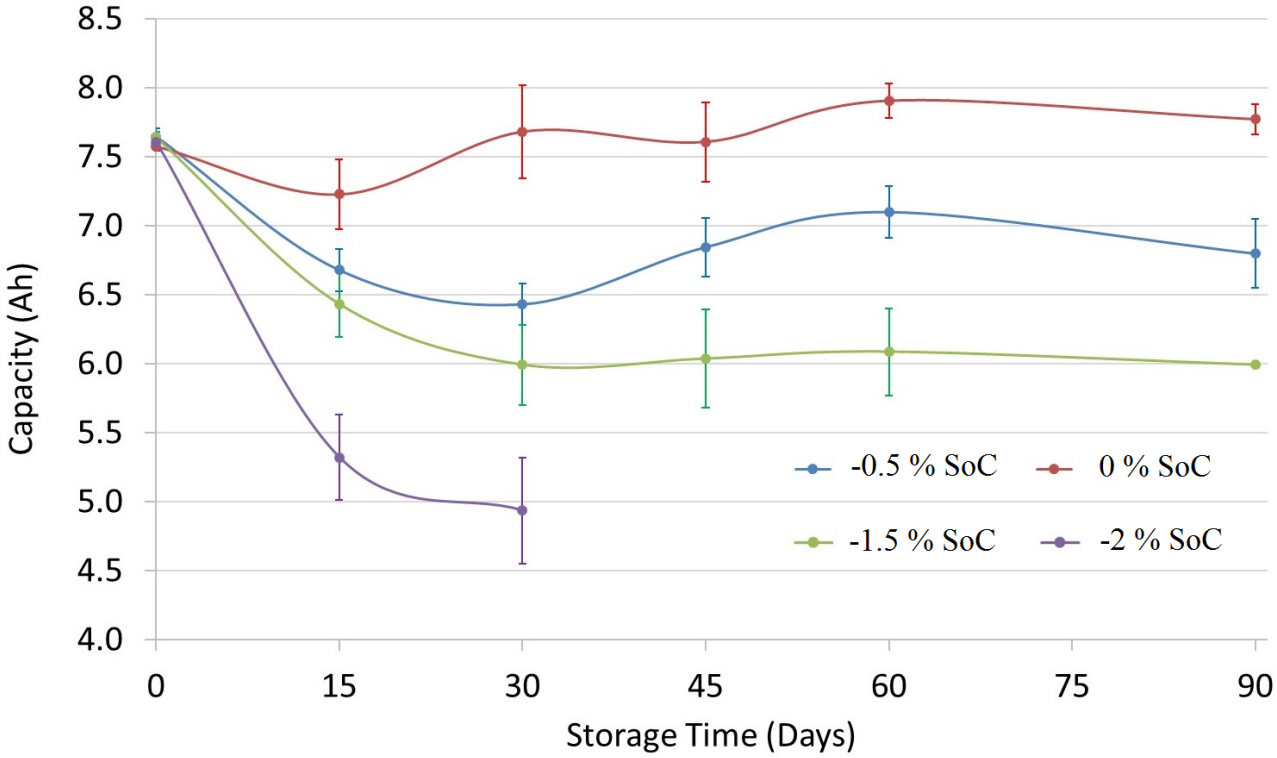


Electrochemical Mechanisms -2 and -1.5 % SoC

- At -2 % SoC copper current collector dissolution may occurs with gas formation
  - ➢ Small trace of copper at negative electrode materials was found from EDS results
- At -2 and -1.5 % SoC decomposition of SEI can happen, leading to both capacity drop and resistance rise (Guo et al. Sci Rep 6, 2016)
- Reversible and irreversible breakdown of $LiFePO_4$ cathode material will happen

(Kassem et. al. JPS 208, 2012, Li et al. Electochem. Acta 190, 2016)

Results – Change in Capacity all 4 SoC



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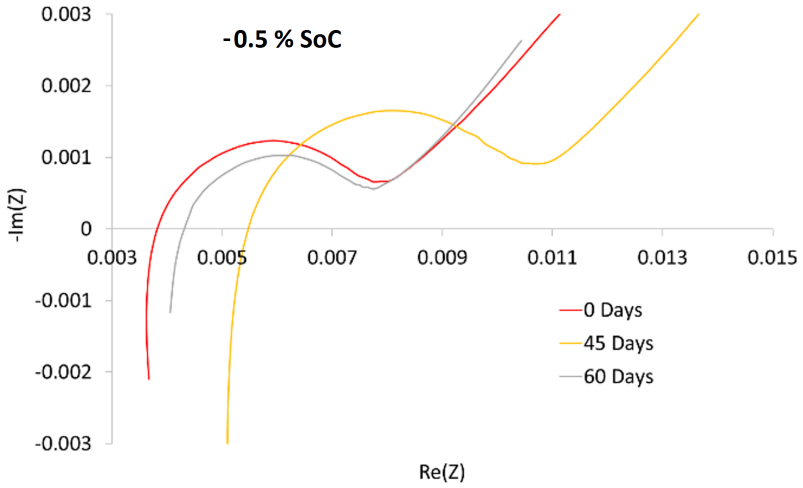
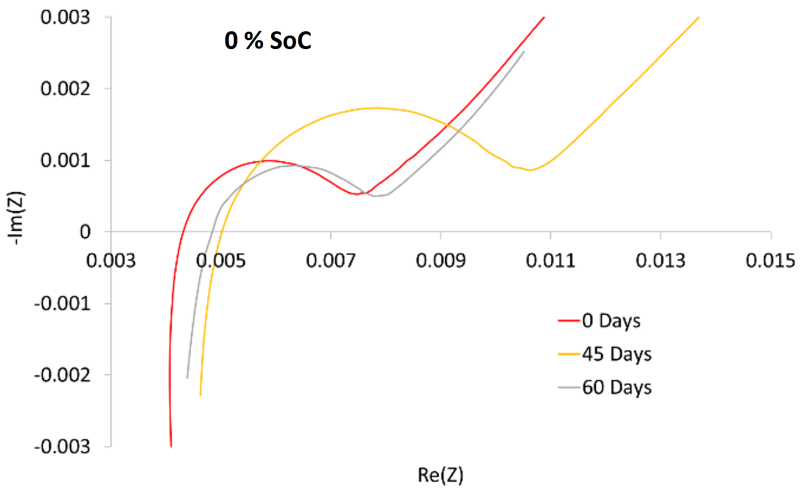
Results – Change in Resistance -0.5 and 0 % SoC





Results – Electrochemical Mechanisms

- At -0.5 and 0 % SoC no copper current collector dissolution can occur (Guo et al. Sci Rep 6, 2016)
- At -0.5 and 0 % SoC slower decomposition of SEI can happen, leading to both capacity drop and resistance rise (Guo et al. Sci Rep 6, 2016)
- Reversible and irreversible breakdown of $LiFePO_4$ cathode material will happen (Kassem et. al. JPS 208, 2012, Li et al. Electochem. Acta 190, 2016)

Summary - Proof-of-Concept

- A stability window exists at low SoC where battery ageing is minimal
- -0.5 % SoC might be used but further evidence required
- Battery cannot be stored below -0.5 % SoC
  - 300 V battery pack cannot be discharged to <50 V

What happens between 0 – 10 % SoC?

Impact

- For automotive
  - Reduce fully charged state when stored for long period
  - Improved safety when in transit (Barai et al. Sci Rep 7, 2017)
- For consumer electronics
  - Keep at low SoC after manufacturing
- For aerospace
  - Hibernate at low SoC

Experiment 2 – long duration calendar ageing test

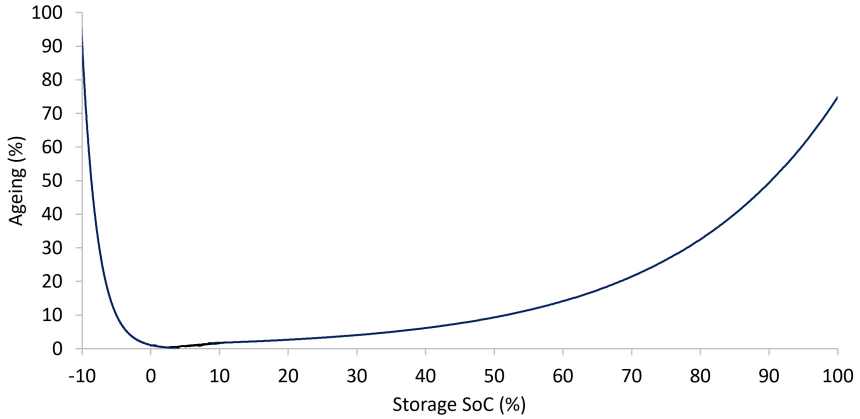
- Extended study involves calendar ageing of cell at 5 different SoC points from 0-10 % SoC and multiple temperature points
- Experiment 2 involves NCA, LFP, NMC and LTO cells
- Capacity, EIS and OCV tests data recorded in regular interval
- Expected to complete by 3rd quarter of 2018
- Experiment 3: at low SoC will battery degradation will be minimized when they are exposed to very low temperature and radiation – open for suggestions

Conclusion

- Battery ageing is minimum when stored at low SoC

- Storing at very low SoC can lead to higher ageing

- Battery is safer to store at low SoC



Questions?

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