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 $\geq 50$ % SoC
- Current speculation – battery degradation is accelerated when stored at very low SoC
- This research investigate battery ageing at very low SoC

![Graph showing battery degradation over time](image1)

![Graph showing resistance over time](image2)
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
Results – Change in Resistance -2 and -1.5 % SoC
Electrochemical Mechanisms -2 and -1.5 % SoC

- At -2 % SoC copper current collector dissolution may occur 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. Electrochem. Acta 190, 2016)
Results – Change in Capacity all 4 SoC
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. Electrochem. 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?

The research presented within this paper is supported by the Innovate UK through the WMG centre High Value Manufacturing (HVM) Catapult in collaboration with Jaguar Land Rover and TATA Motors European Technical Centre.