

Degradation Analysis of a Commercial Sodium-Ion Cell after 7000 Equivalent Full Cycles

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Abstract

We investigated the long-term cycling behavior of 81 commercial sodium-ion cylindrical cells with a layered oxide cathode and hard carbon anode, covering more than 7000 equivalent full cycles (EFCs), thereby providing one of the most extensive aging datasets reported for commercial sodium-ion cells to date. We observed that capacity fade was minimal, with highest capacity fade for low SOC cycling conditions. X-ray imaging revealed pronounced deformation only for cells that were cycled at low SOC ranges.

Conclusion

Overall, the observed aging is significantly less pronounced than that reported in the literature for lithium-ion batteries employing graphite anodes and layered oxide cathodes. Even after 7000 EFCs cells retain on average more than 96% of their initial capacity. Notably, we observe a core collapse only in cells cycled at low SOC, which can be attributed to the large volumetric expansion of the hard carbon anode in this SOC range, underscoring the critical need to account for this expansion in mechanical cell design.

Design of Experiment

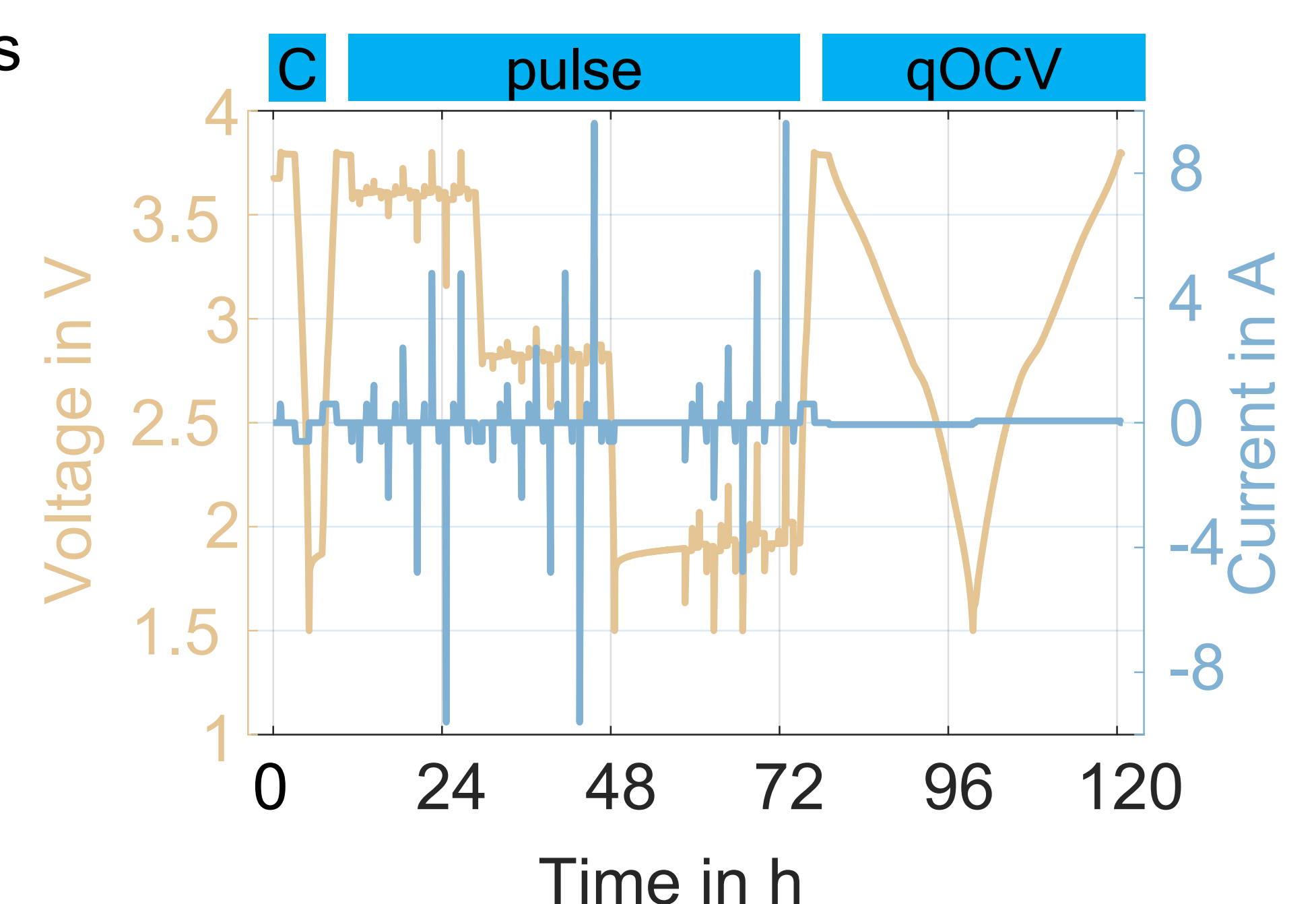
Cell specification	
Nominal capacity	1.2 Ah
Nominal voltage	3.0 V
Voltage range	1.5–3.8 V
Max. charge current	5C – 6A
Max. discharge current	8C – 9.6A
Weight	37 g $\cong$ 97.30 Wh/kg
Internal resistance	≤ 25 m Ω (1 kHz at 50% SoC)
Power density	810 W/kg



Cycling @ 2C/2C, 25 °C

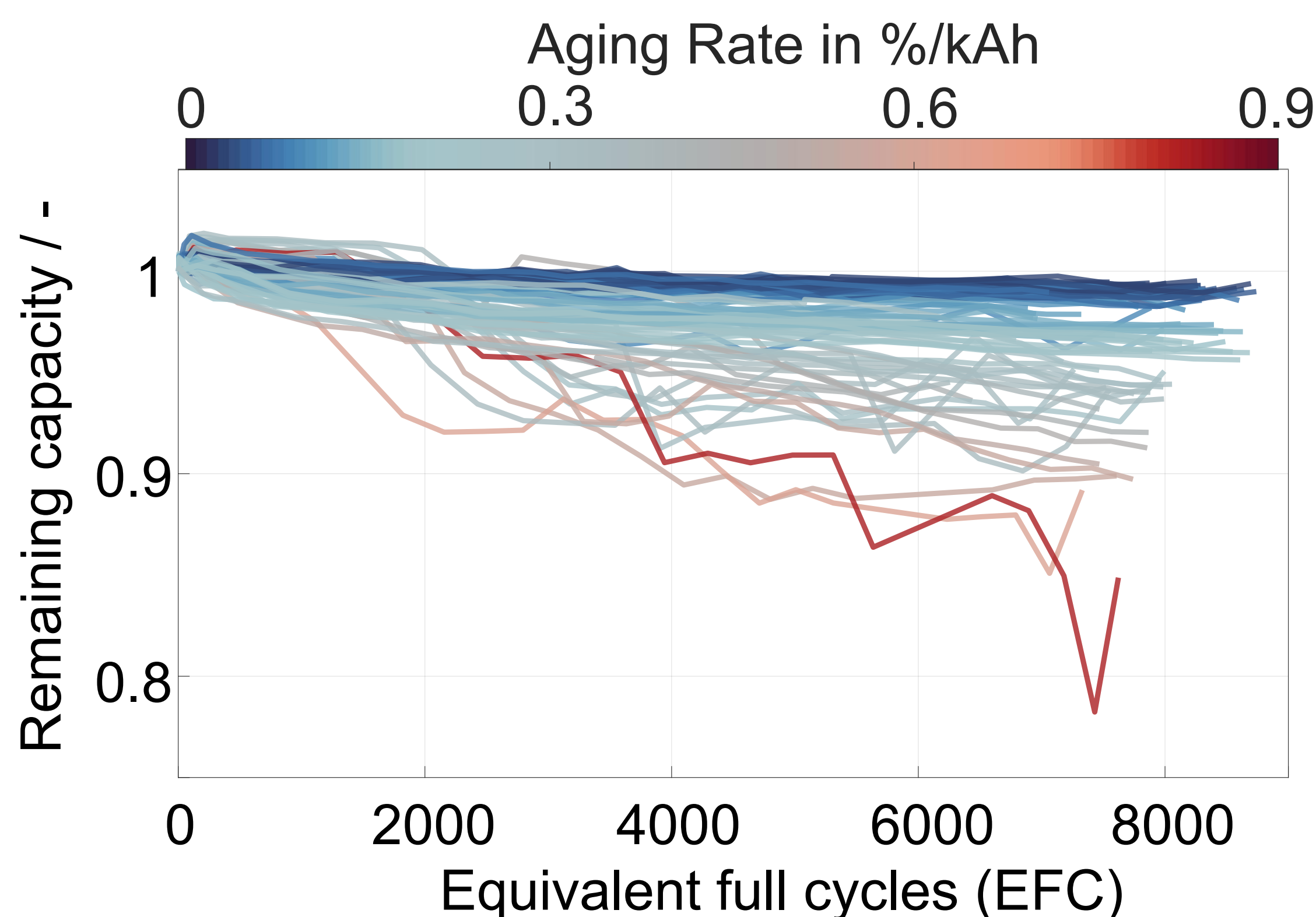
Reference Performance Test

10%-90% SOC	40 cells
30%-50% SOC	8 cells
10%-30% SOC	7 cells
0%-40% SOC	8 cells
70%-90% SOC	9 cells
60%-100% SOC	8 cells

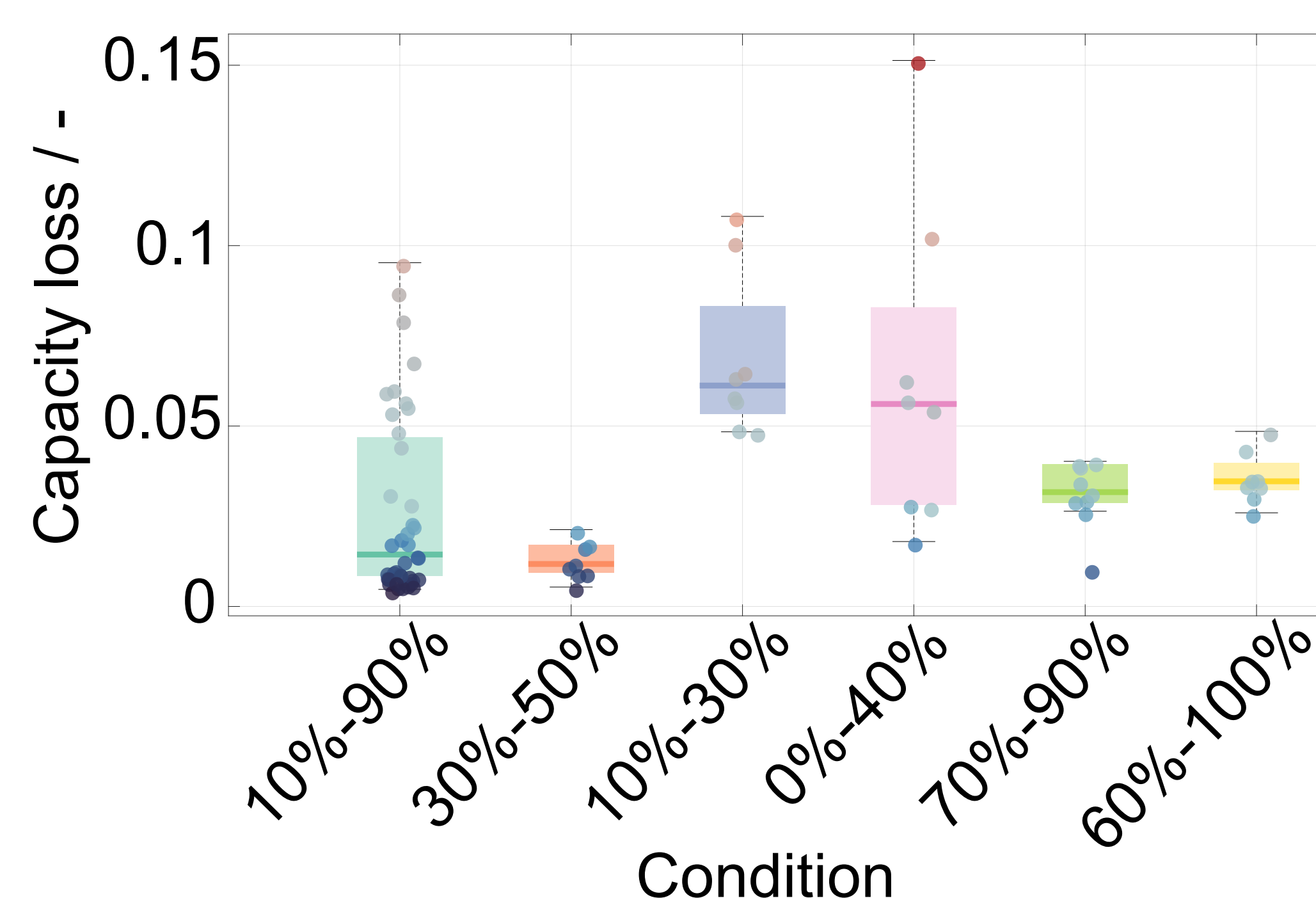


Overview Aging Data

... across all cells



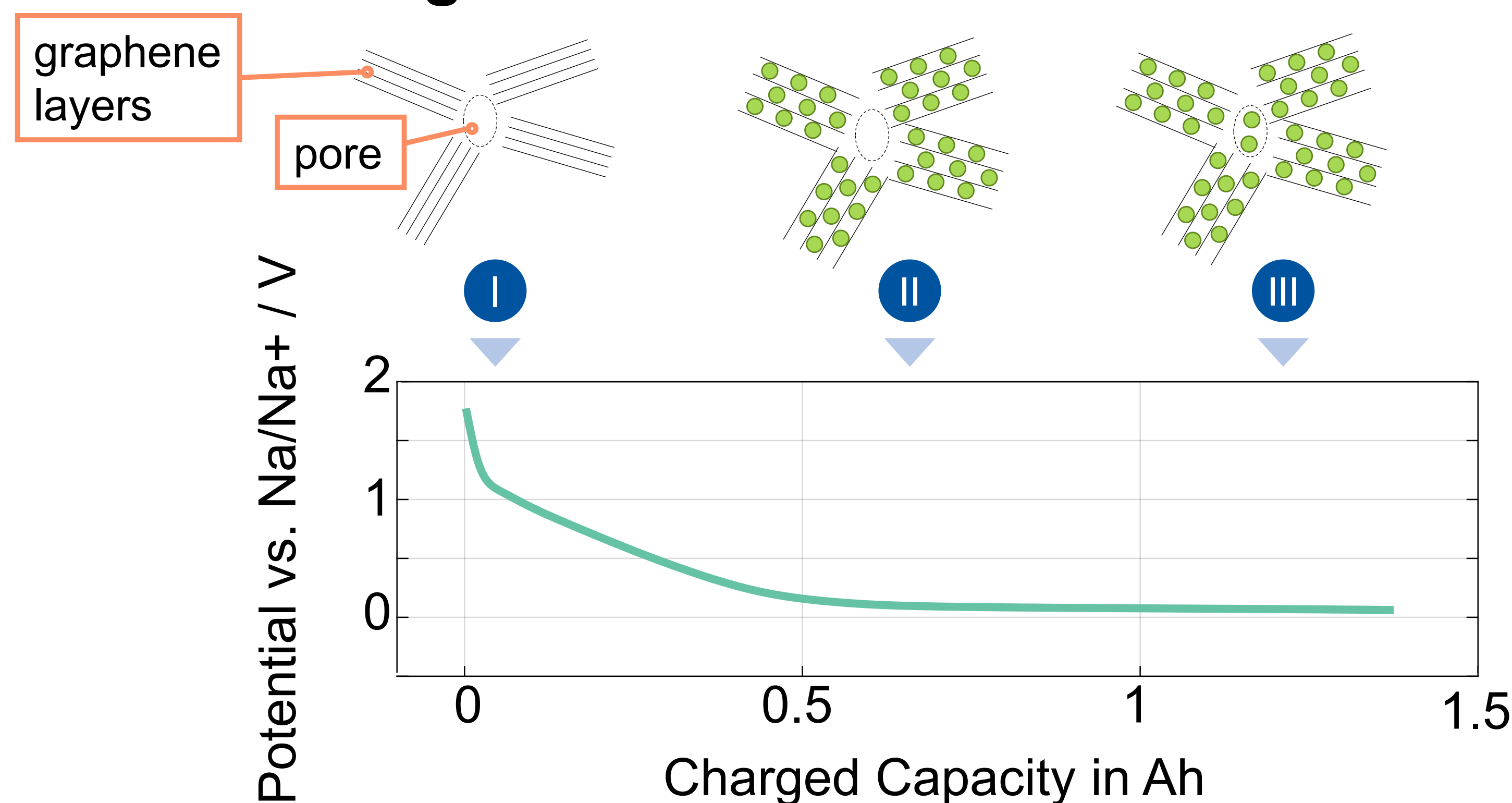
... condition-specific



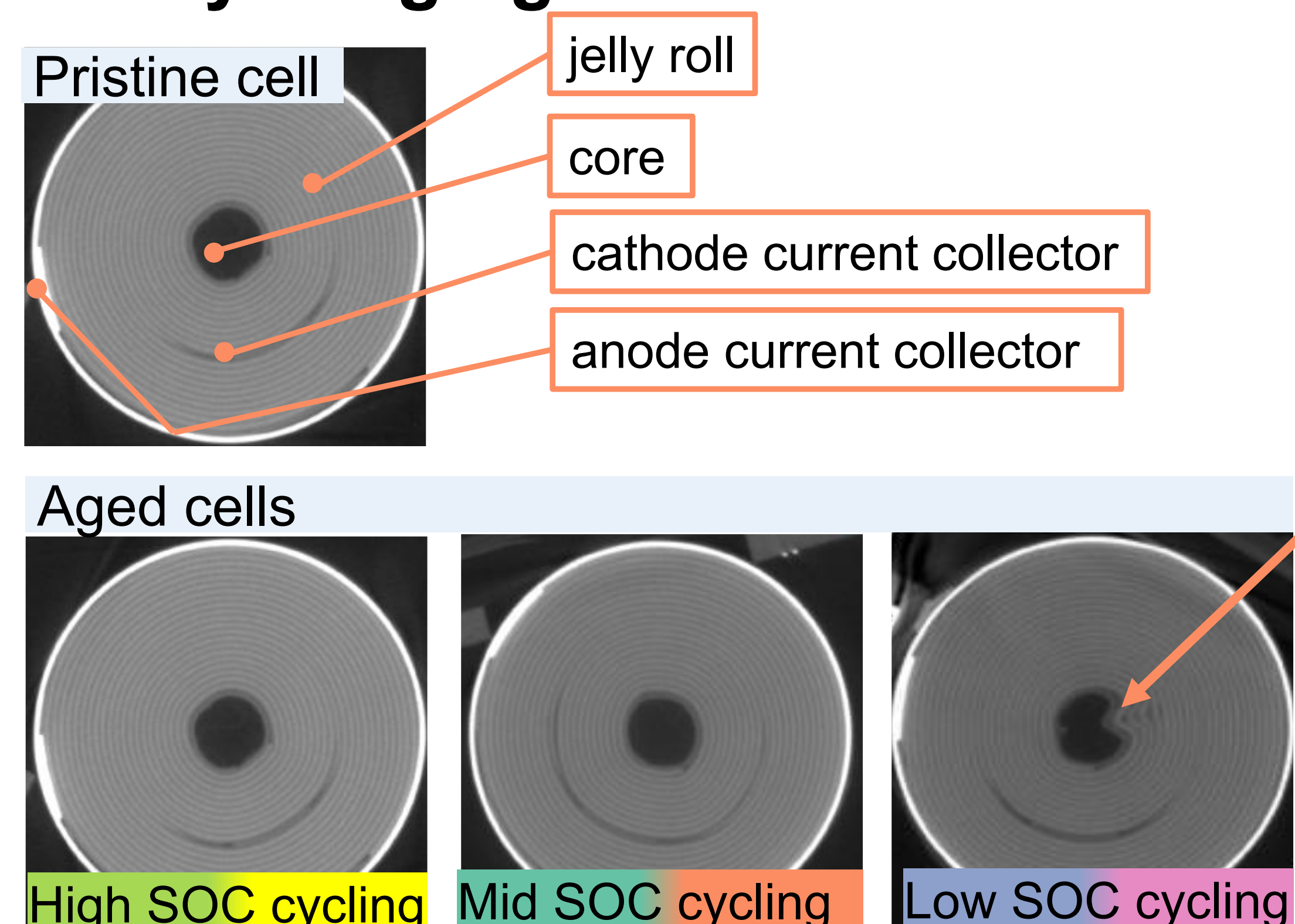
In a nutshell

- Tested cells show minimal capacity fade, on average 3.5%
- High cell-to-cell variations
- Lowest capacity fade for mid SOC cycling
- Highest capacity fade for low SOC cycling

Sodium storage mechanism in hard carbon



X-Ray Imaging



Core collapse visible only for cells cycled in low SOC region due to mechanical degradation and highest volume expansion

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Acknowledgements

This work was financially supported by the German Federal Ministry of Research, Technology and Space (BMFT) within the "SIB:DE FORSCHUNG" project (03XP06271). The authors are responsible for the content of this publication.

With funding from the:



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