An Investigation of the Effect of Storage Temperature on Secondary Battery Shelf Life through Electrochemical Impedance Spectroscopy (EIS)

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Introduction

This research aims to demonstrate the difference in the battery capacity in Remaining Useful Life (RUL), focusing on how these conditions influence battery performance. To assess the electrochemical performance of both fresh and aged batteries, repeated charge-discharge cycles will be conducted. Moreover, This investigation aims to identify the storage conditions that significantly affect battery lifespan. Additionally, it seeks to explore the differential impacts of these conditions on batteries with varying levels of remaining capacities.

Method I

Electrochemical Impedance Spectroscopy (EIS)

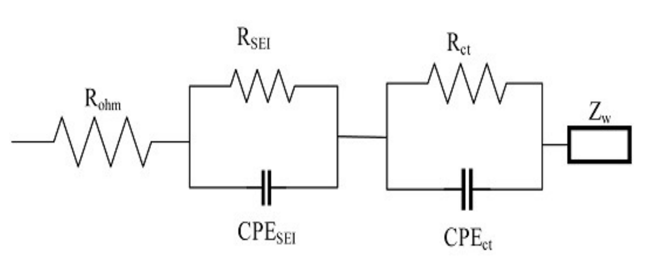

Fig. 1 Randles Model

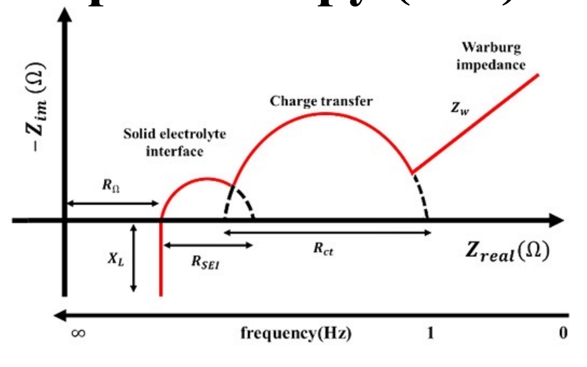

Fig. 2 Analysis method of nyquist plot of Randles Model

Electrochemical Impedance Spectroscopy (EIS) will be utilized to investigate thermal performance degradation, with a special emphasis on alterations at the electrode/electrolyte interface. The Randles model is used to perform EIS. The Randle model (Fig. 1) is an equivalent circuit model used to analyze the internal electrochemical state of the battery It typically consists of several components.[1]

Method II

Accelerated Battery Life Test

Accelerated Battery Life test involves cycling the battery with a high C-rate discharge and charge profile, aimed at simulating an accelerated life test. The sequence of discharge and charge steps is designed to quickly evaluate the battery's capacity and energy retention capabilities, simulating real-life usage patterns in a compressed time frame.[2]

Result

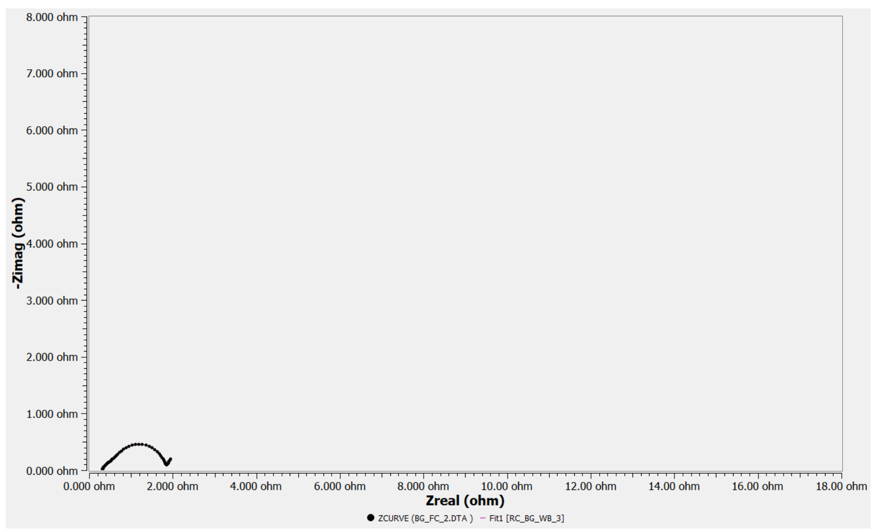

Fig. 3. EIS test (Fresh Cell, Scaled)

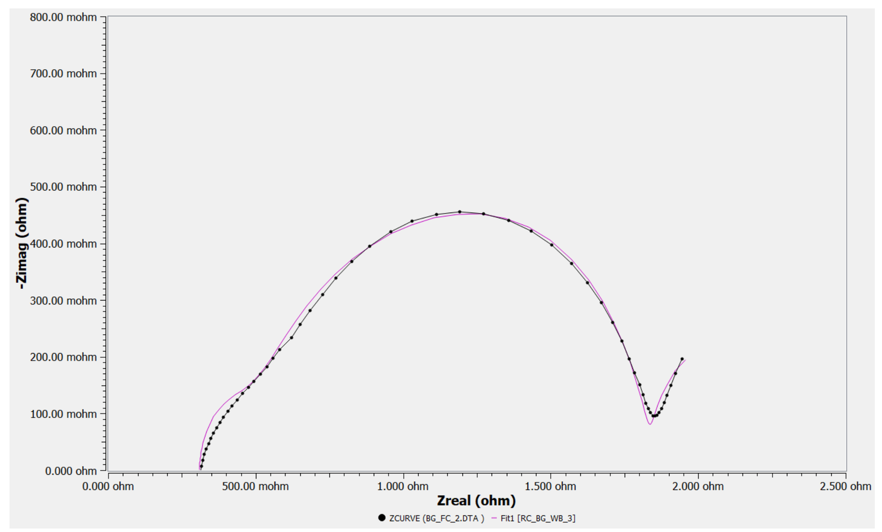

Fig. 4. EIS test (Fresh Cell, Zoomed)

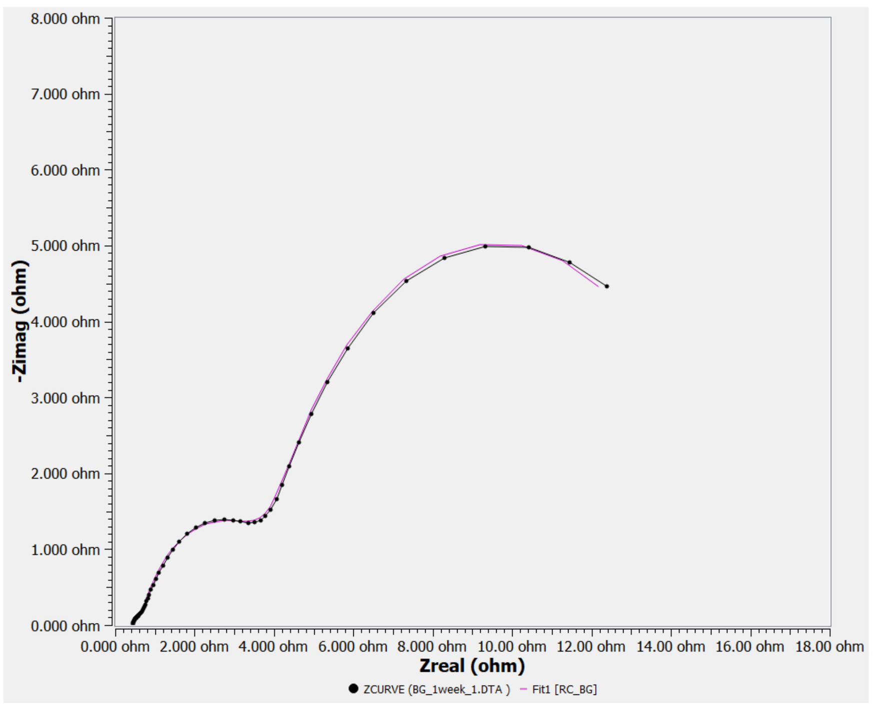

Fig. 5. EIS test (1-Week, Scaled)

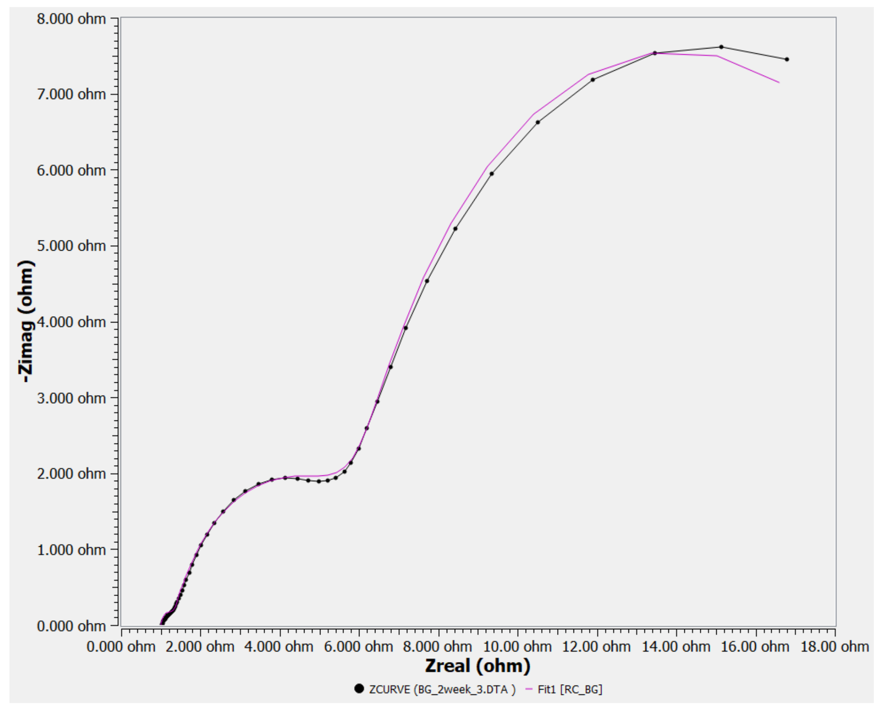

Fig. 6. EIS test (2-Week, Scaled)

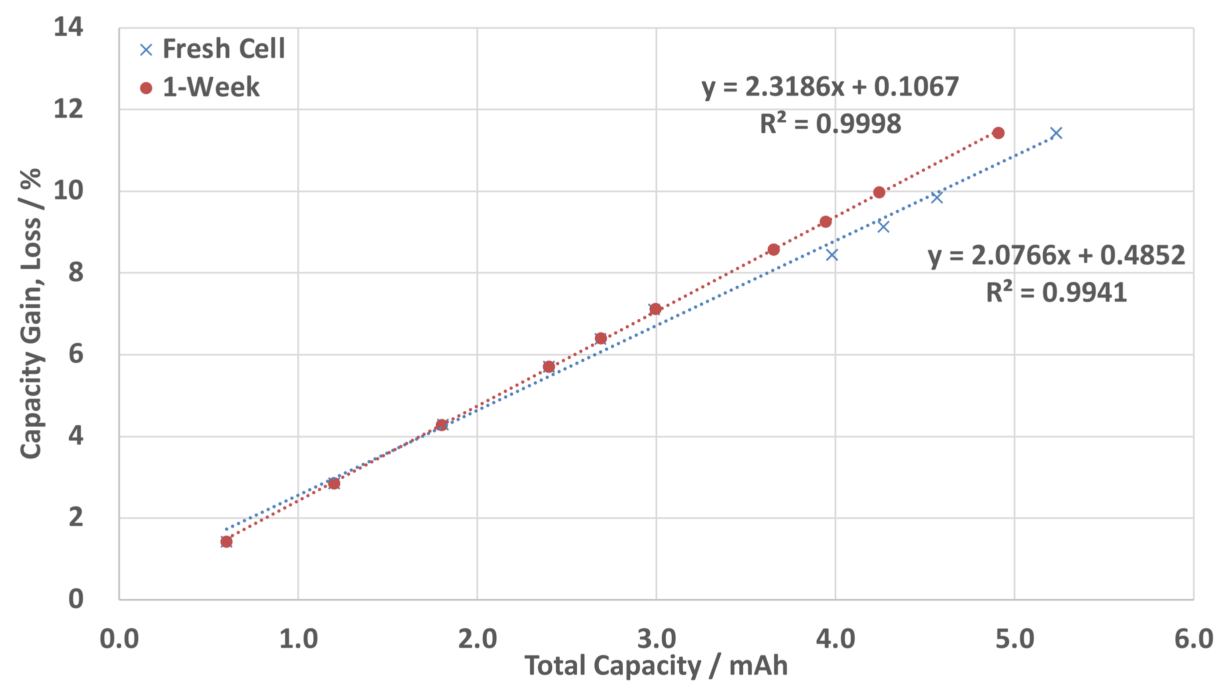

Fig. 7. Accelerated Battery Life Test

	Capacity Gain, Loss / %	
	Fresh Cell	1-Week
3C DC1	-1.429	-1.429
1.5C DC1	-1.429	-1.429
Rest	0.000	0.000
3C DC2	-1.442	-1.430
1.5C DC2	-1.415	-1.429
Rest	0.000	0.000
1C C1	0.683	0.688
.5 C1	0.713	0.723
.33C C1	1.340	1.447
Rest	0.000	0.000
1C C2	0.683	0.688
.5 C2	0.713	0.714
.33C C2	1.583	1.457
Rest	0.000	0.000
Sum	0.000	0.000

Table. 1. Capacity Gain & Loss

Definition of Capacity Loss & Gain:
The increased/decreased ratio of capacity in each step to show a tendency of a battery's capacity.

Conclusion

- Ohmic resistance (R_{ohm}) increased by 2.5 times due to a decrease in electrolyte (because of a decrease of ion conductivity) as the battery is degraded by heat.
- Both Solid Electrolyte Interphase (R_{SEI}) and Charger transfer resistance (R_{ct}) increased, and the total capacity decreased accordingly.
- On accelerated battery life test, the 1-week battery had a higher charge/discharge capacity rate in total than fresh cell implying the cell had been damaged
- These two test results indicate the resistors and impedance inside a battery, R_{ohm}, R_{SEI}, R_{ct}, and Z_W have been damaged due to exposure to a heat for a long time.

Limitations

- Results of fitting model were not matched exactly to the actual plotted data.
- Warburg impedance (Z_W) was not observed in aged cell due to the EIS measurement has not been extended to sufficiently low frequencies.
- Cells in the oven were not heated evenly due to the equipment's unavailability
- Accelerated Battery Life test's data for 2-week cell could not be obtained due to the battery's damage (safety stop has occurred)

References

[1] M. Lee, S. Han, J. Park, and J. Kim, "A Study on the Selection of Failure Factors for Transient State Lithium-Ion Batteries based on Electrochemical Impedance Spectroscopy," Journal of the Korean Society for Precision Engineering, vol. 38, no. 10, pp. 749-756, 2021, doi: 10.7736/JKSPE.021.040.

[2] E. Chiodo, D. Lauria, N. Andrenacci and G. Pede, "Accelerated life tests of complete lithium-ion battery systems for battery life statistics assessment," 2016 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), Capri, Italy, 2016, pp. 1073-1078, doi: 10.1109/SPEEDAM.2016.7525919.

FURI

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