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Cycle Life Characterisation of Large Format Lithium Ion Cells

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TUM CREATE, Singapore

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Overview

- Motivation
- Cell ageing
- Experimental
- Results and discussion
- Conclusion and future work

Motivation

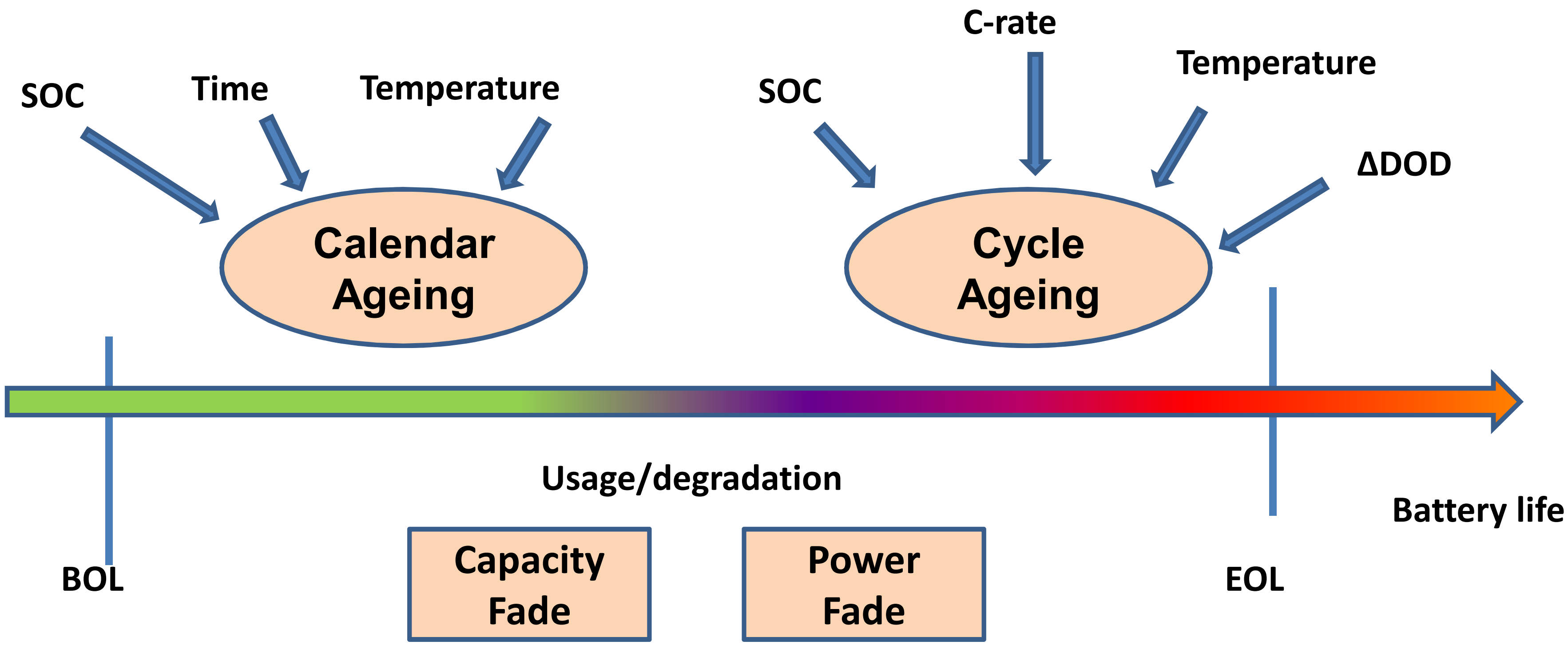
- Large format cells are popular in EV Applications
  - To meet high energy and power requirements
  - Fewer connections and wiring in battery pack
  - Lesser number of cells to monitor
  - Better volumetric space utilisation

- Limited studies have been reported on their ageing mechanism and lifetime prediction

Cell Ageing

BOL Beginning of life : Fresh cell

EOL End of life : Loss of performance and lifetime



Experimental: Cell Details & Test Conditions

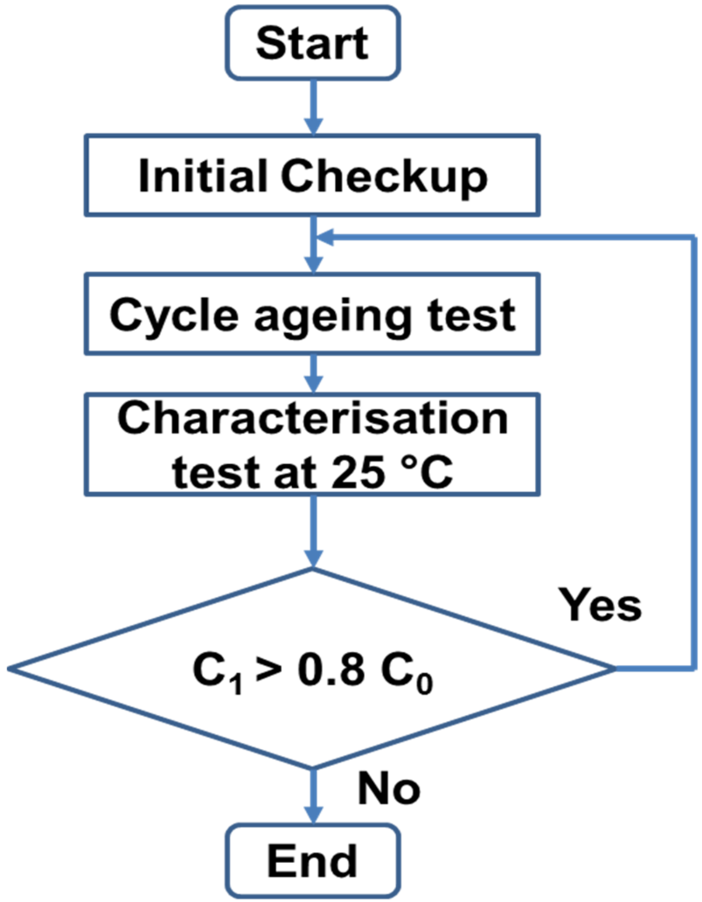
Manufacturer: Dow Kokam High Power 63 Ah
Chemistry: $Li[NiMnCo]O_2$ | Graphite
Nominal Voltage: 3.7 V
Internal Resistance: 0.6 mΩ

C Rate		Temperature (°C)
Discharge	Charge	
1C	1C	25
2C	1C	25
3C	1C	25
1C	3C	25
1C	1C	40

XXX* = 3 cells per test condition to get statistically reliable data

Experimental: Flowchart

- Initial checkup
- Cycle ageing test
  - 100% DOD, CC CV charging, CC discharging
    Upper cut off voltage 4.2 V
    Lower cut off voltage 2.7 V
    Cut off current 3A
- Characterisation test
  - Discharge capacity
  - Hybrid pulse power characterisation (HPPC)
  - Electrochemical impedance spectroscopy (EIS)

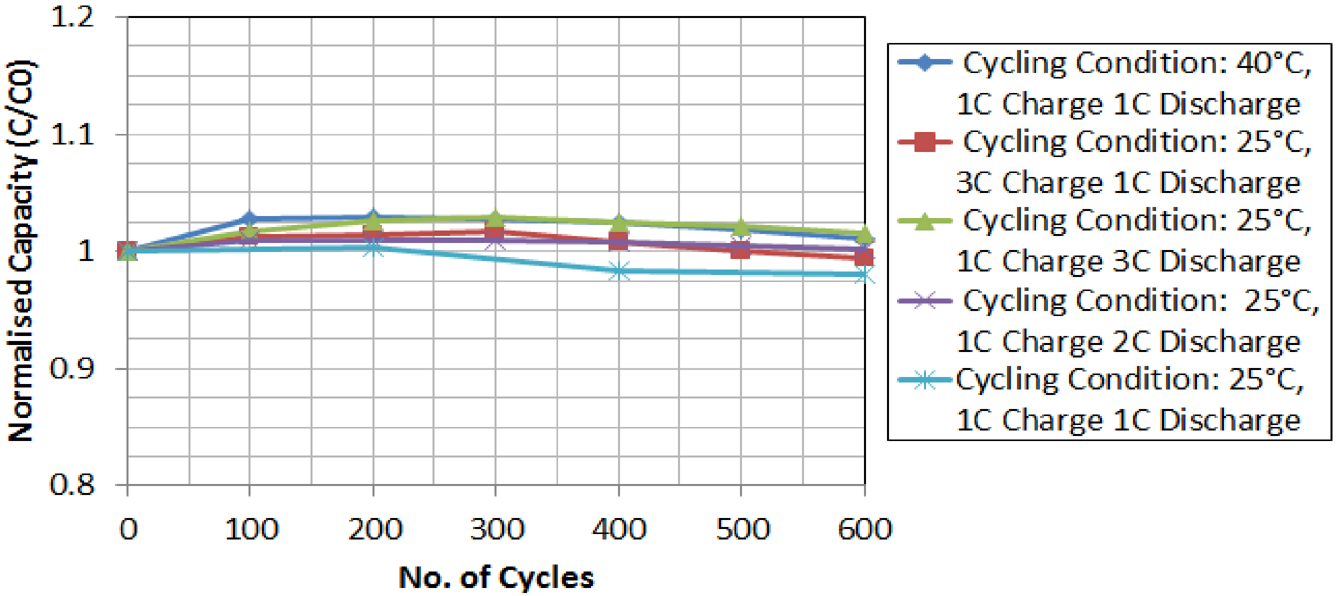


Results & Discussion: Cell Discharge Capacity

Discharge capacity (1 C Rate) measured at 25°C

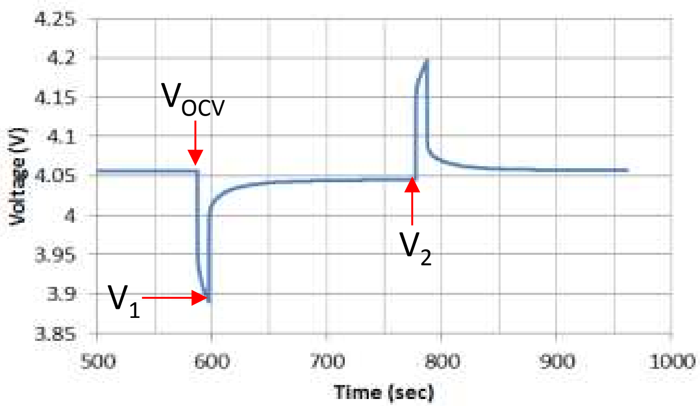
Cut off voltage: 4.2 V – 2.7 V Cut

off current: 3A



Results & Discussion: Loss of Power Capability

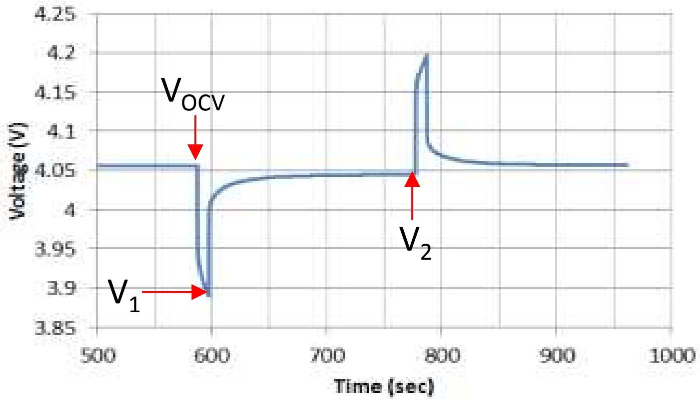
Pulse Power measured at 25°C



$$P_{DCH} = \frac{2}{9}\frac{V_{OCV}^2}{R_{DCH,\ 10s}}$$

Results & Discussion: Loss of Power Capability

Pulse Power measured at 25°C



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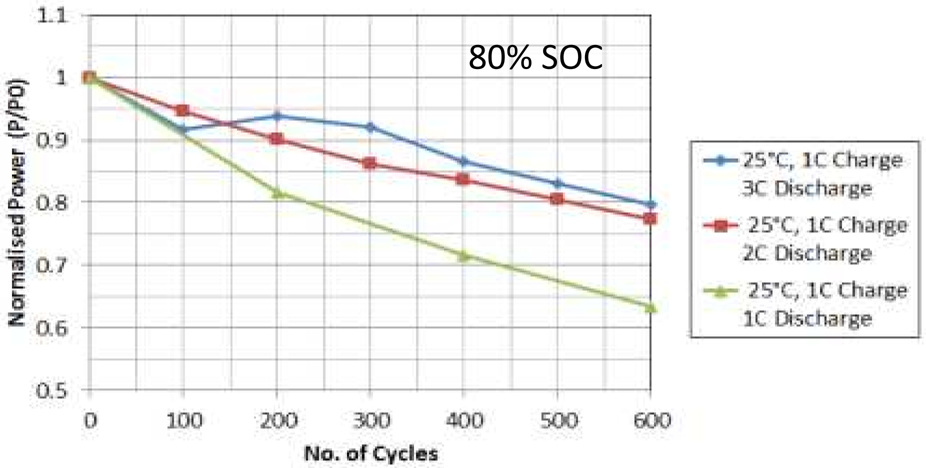
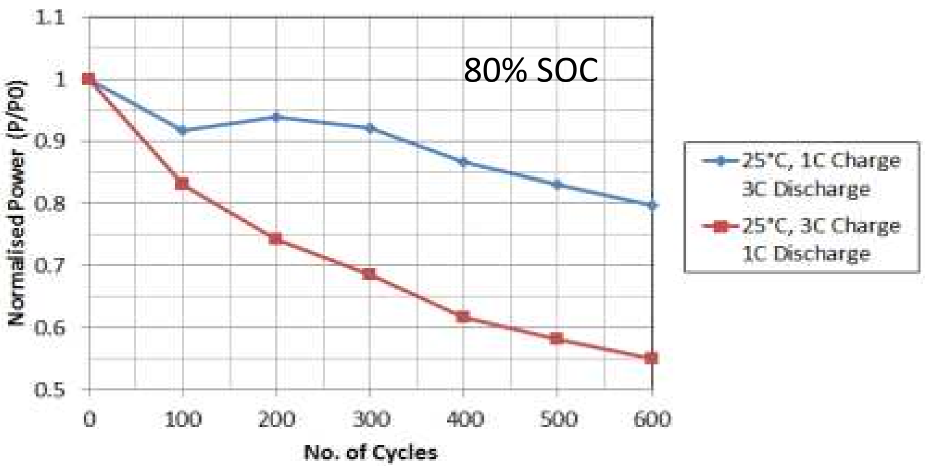




Results & Discussion: Loss of Power Capability

Low discharge rate showed more power fade

Increased cycling time

Higher average voltage

R_{DCH} ↑

EVS 27

Results & Discussion: Loss of Power Capability

Low discharge rate showed more power fade

Increased cycling time

Higher average voltage

R_{DCH} ↑

3C Charge

Higher average voltage

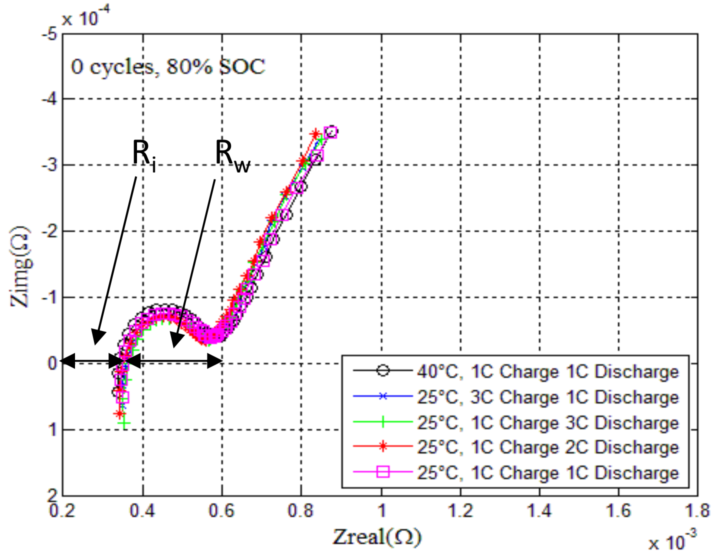
More charging time

3C Discharge

Lower average voltage

Less discharging time

Results & Discussion: EIS Measurements



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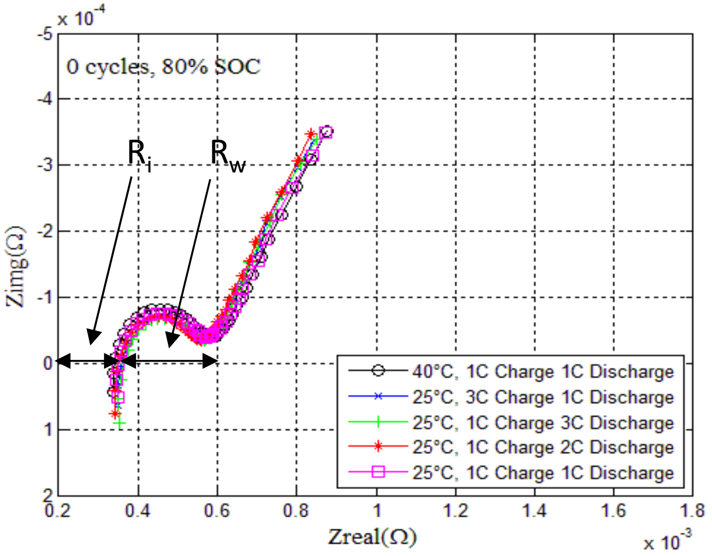

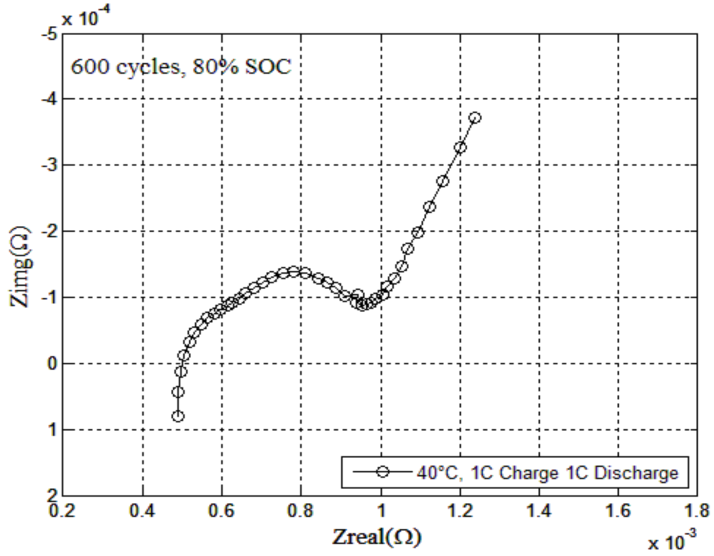

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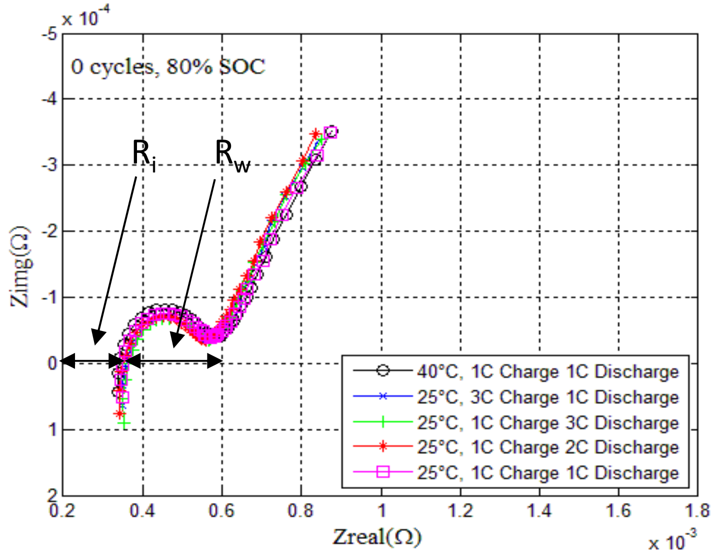

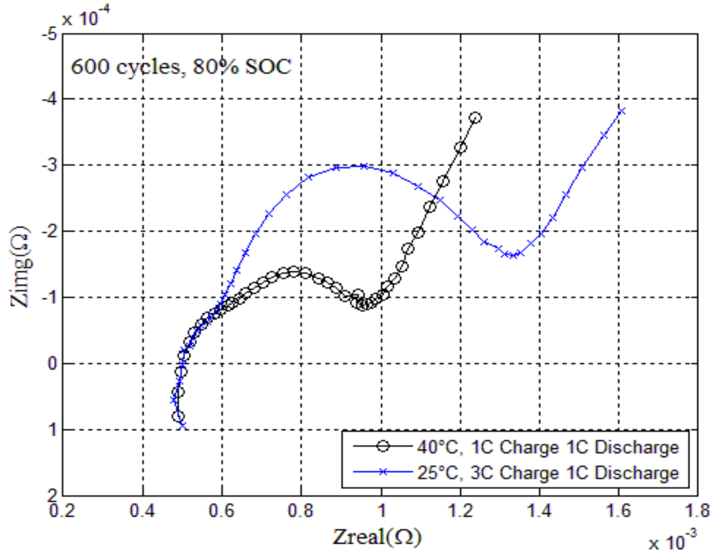

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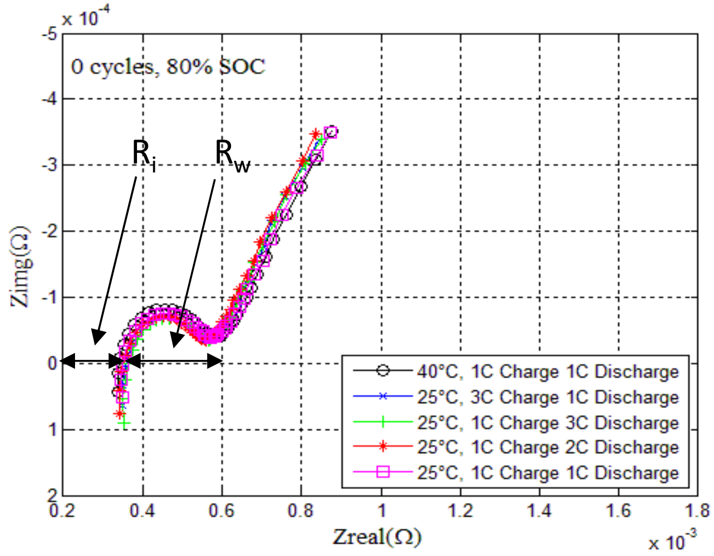

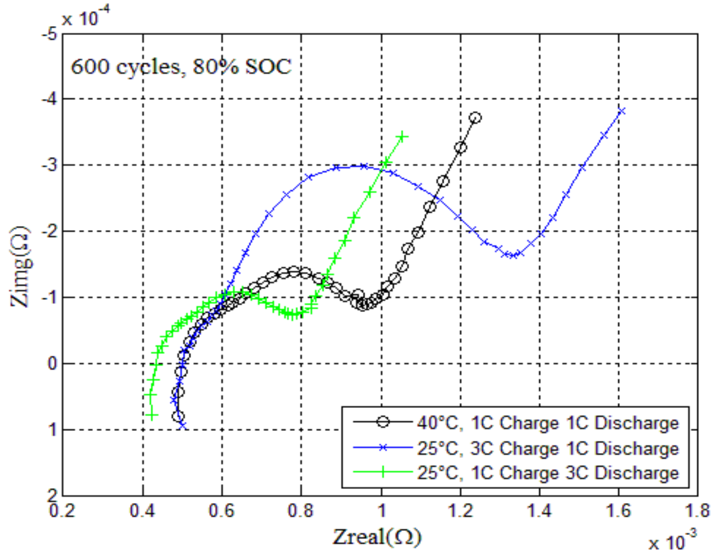

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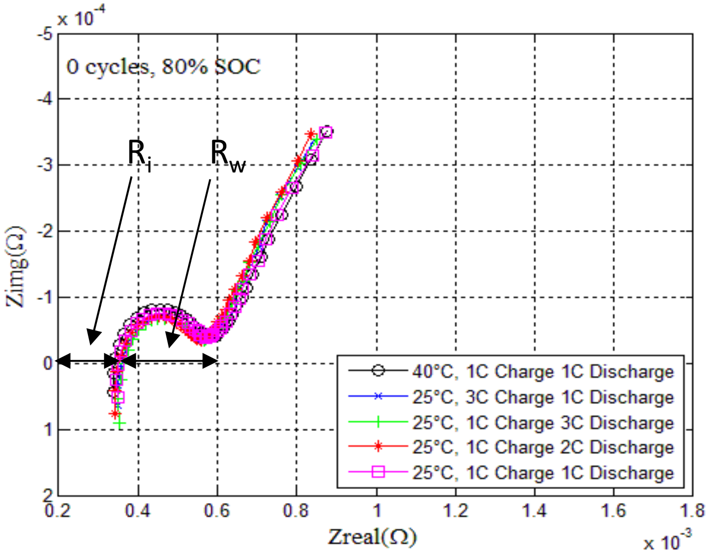

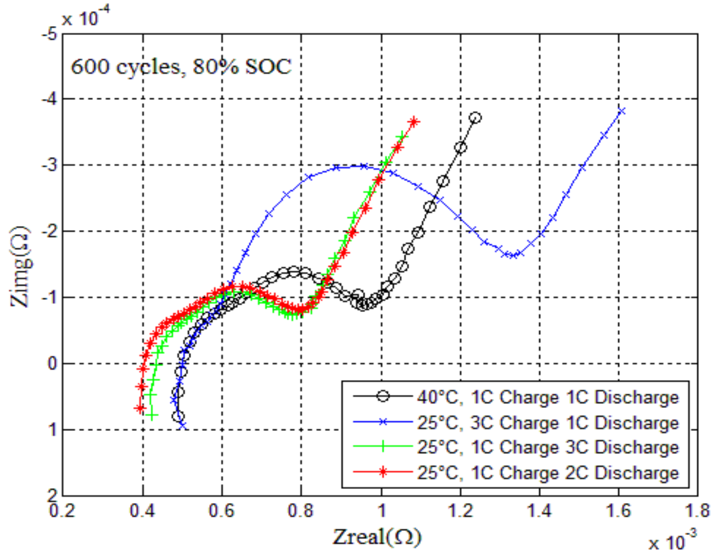

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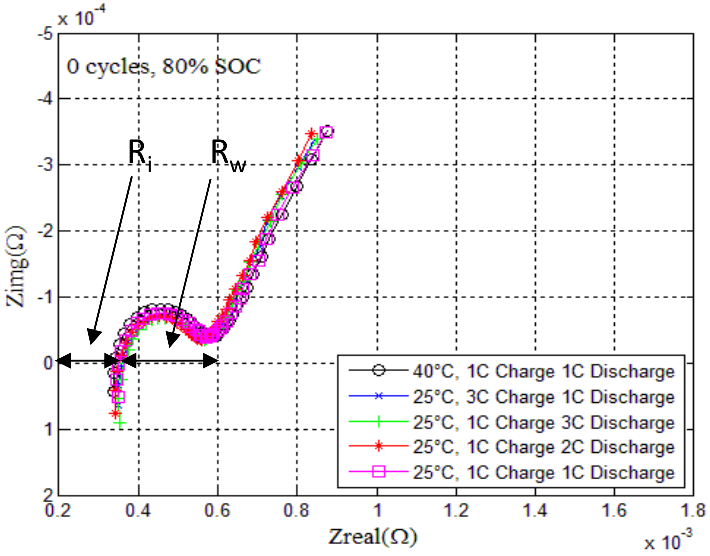

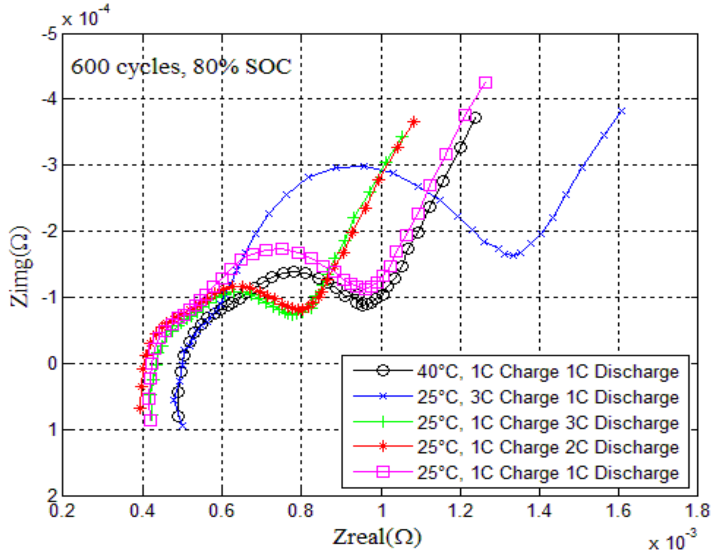

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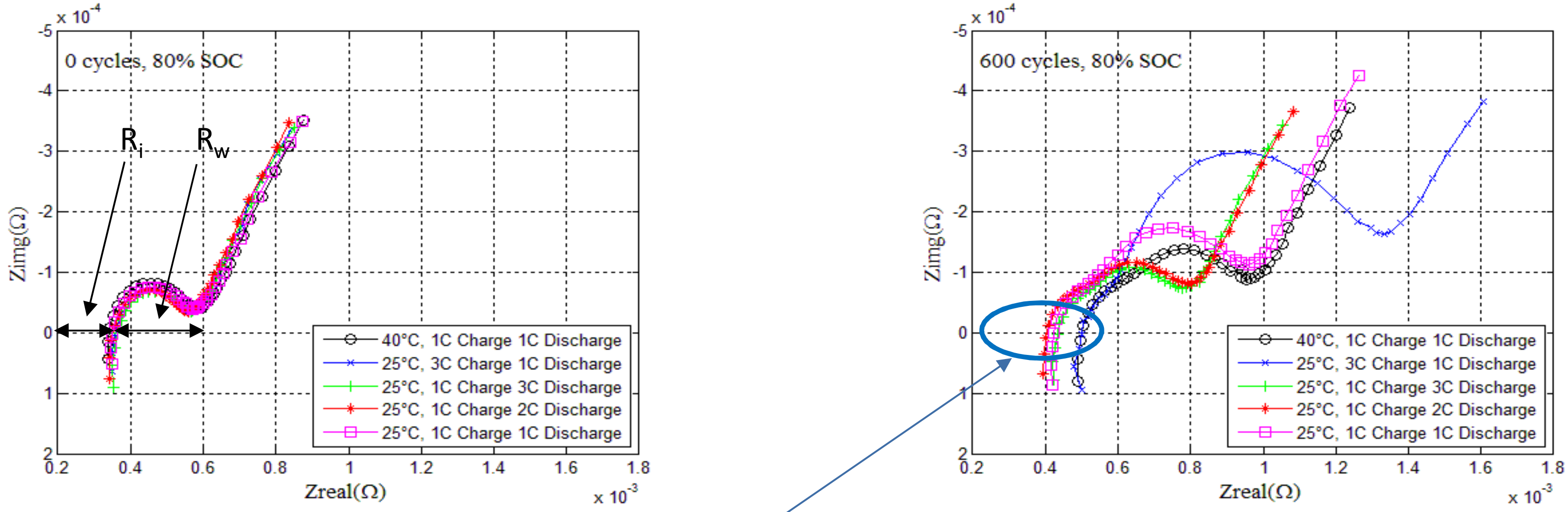
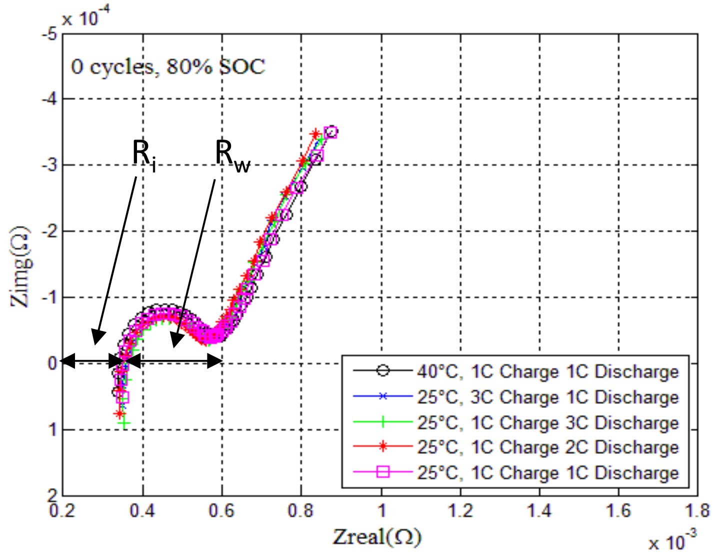
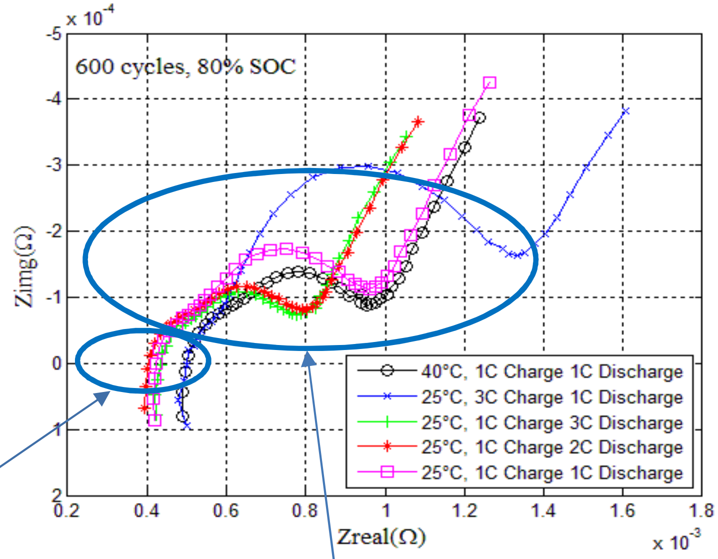


Right shift in x-intercept of impedance spectra

Results & Discussion: EIS Measurements

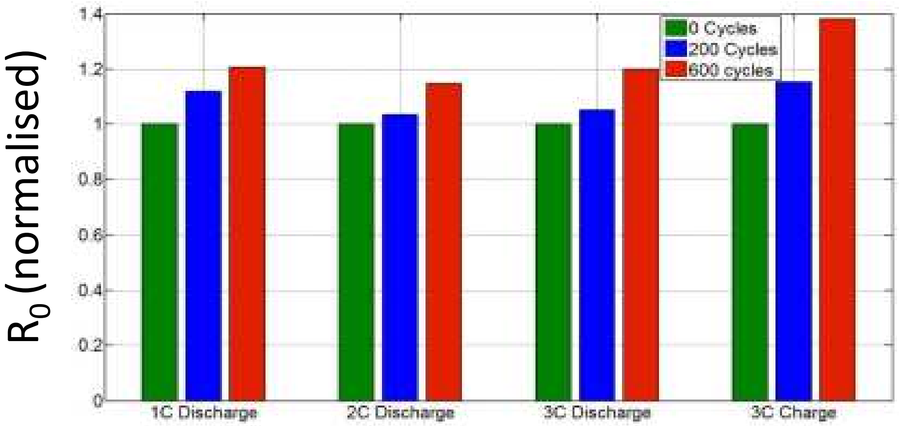


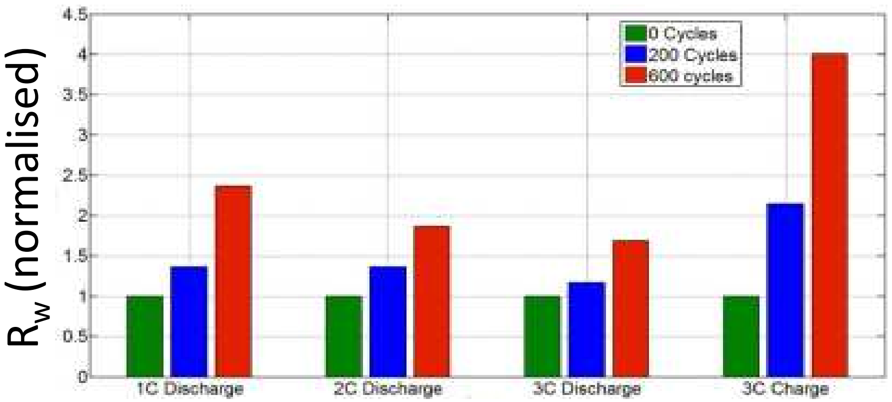


Right shift in x-intercept of impedance spectra

Rise in mid-frequency impedance

Results & Discussion: EIS Measurements



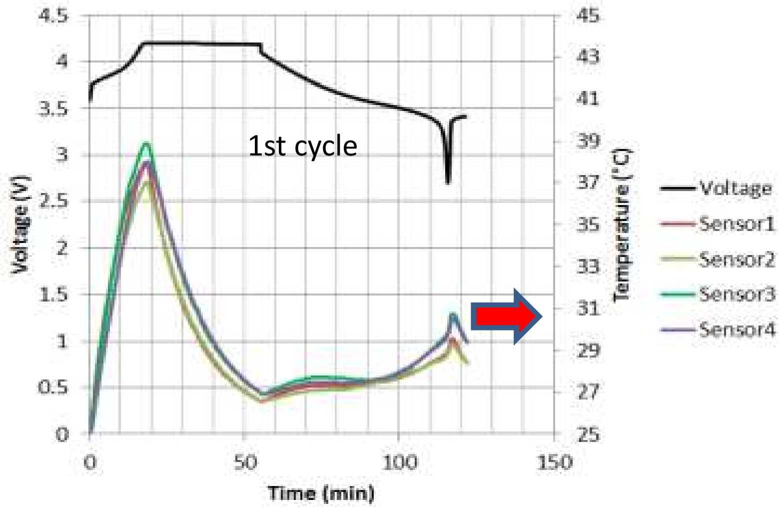


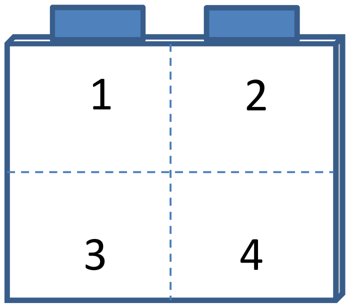
Cycles ↑ ⟶ R_i ↑ R_w ↑

- Significant increase in the mid frequency impedance mainly caused by growth of SEI layer

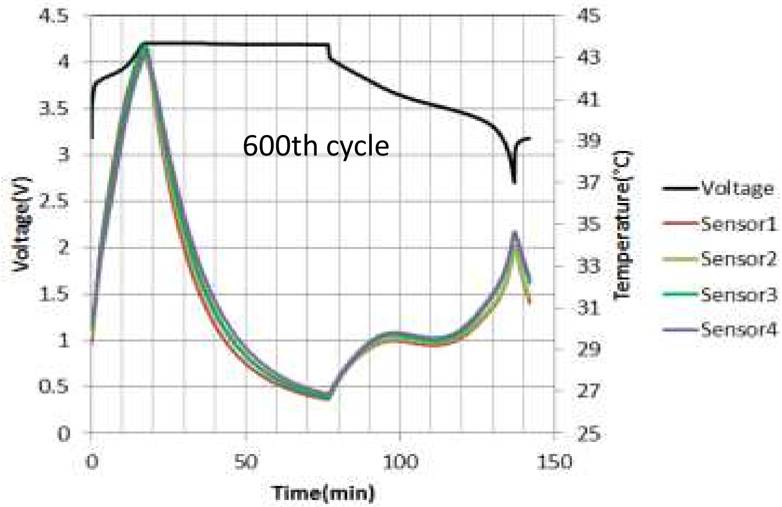
Results & Discussion: Temperature Measurements

Temperature profile of 3C charge cycling





*not to the scale



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Results & Discussion: Temperature Measurements

	Sensor 1		Sensor 2		Sensor 3		Sensor 4	
Cycle No.	1	600	1	600	1	600	1	600
Avg. Temp (°C)	29.250	31.078	29.033	31.221	29.80	31.449	29.583	31.592
Min Temp (°C)	25.149	26.61	24.914	26.792	25.176	26.699	24.941	26.881
Max Temp (°C)	37.996	43.476	37.035	43.011	38.87	43.537	37.986	43.083

- Cell temperature increased with cycle number due to impedance rise
- Increased cooling power demand due to more heat generation
- Greater temperature inhomogeneity in fresh cells compared to aged cells

Results & Discussion: SOH & RUL

- Decreasing Capacity
- Increasing Impedance

$$C_{EOL} = 0.8 * C_{BOL}$$

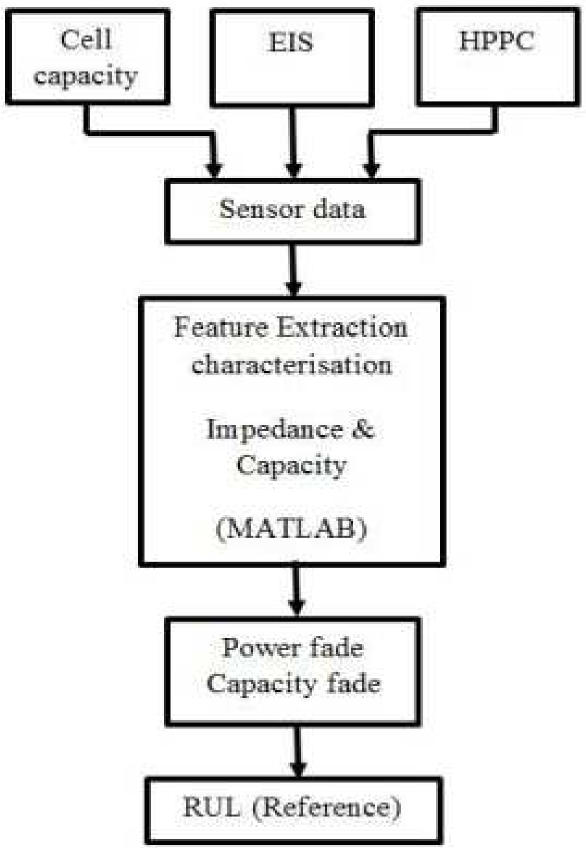
$$R_{EOL} = 2 * R_{BOL}$$

$$SOH_C\ (i) = \left(1 - \frac{C_{BOL} - C(i)}{C_{BOL}} * \frac{1}{0.2}\right)$$

$$SOH_R\ (i) = \left(1 - \frac{R(i) - R_{BOL}}{R_{BOL}} * \frac{1}{2}\right)$$

$$0 \leq SOH \leq 1$$

$$RUL\ (i) = f(cf(i), pf(i))$$



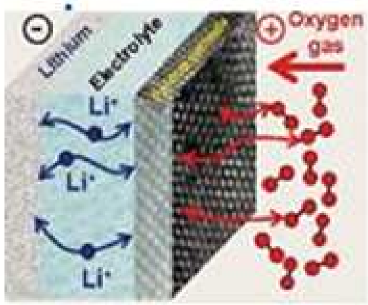
Conclusion & Future Work

- Cell capacities remained constant till 600 cycles
- Pulse power capability reduced with increase in cycle number
- R_W and R_i were the main contributors to ageing
- Average cell temperature increased as the cell aged, due to impedance rise
- Further studies required : Postmortem analysis, similar tests on short format cells

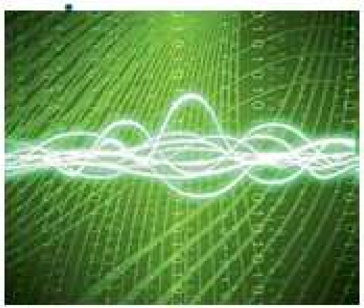
Thank you

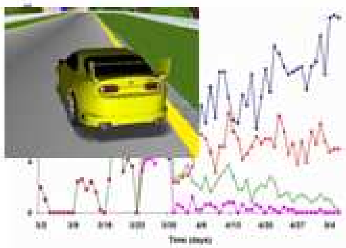
CREATE

Cluster A
Electrical Energy Storage



Cluster B
Simulation, Computa-tion ,Communication





Cluster C
Electric Vehicles

Cluster D
Infrastructure, Transportation

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