

Advanced 4Ah 18650 Li-ion Cell with Zero-Volt Tolerance for Space Applications

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Outline

- Introduction
- Problems and factors in zero-volt situation
- Results
 - Zero-volt exposure at 20 ohms for multiple 7 days
 - Zero-volt on the shelf for >9 months
 - Negative volt exposure (up to -0.5V)
- Conclusion

American Lithium Energy is scaling commercial production of advanced silicon anode cells in the USA

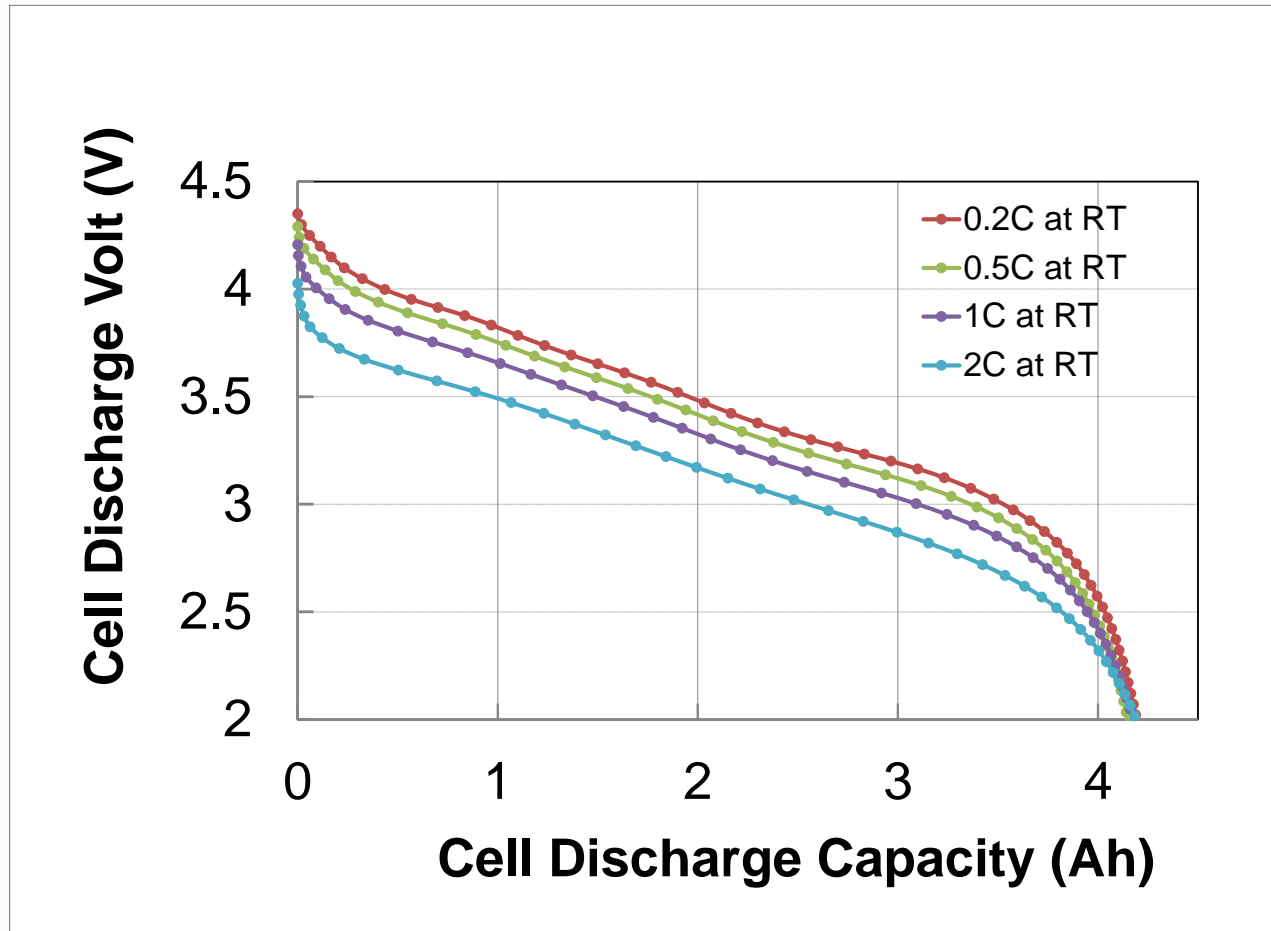
to meet the rapidly growing demand from Defense, Aerospace, and Commercial customers for onshore batteries



ALE 4Ah Nano Si 18650 Cells

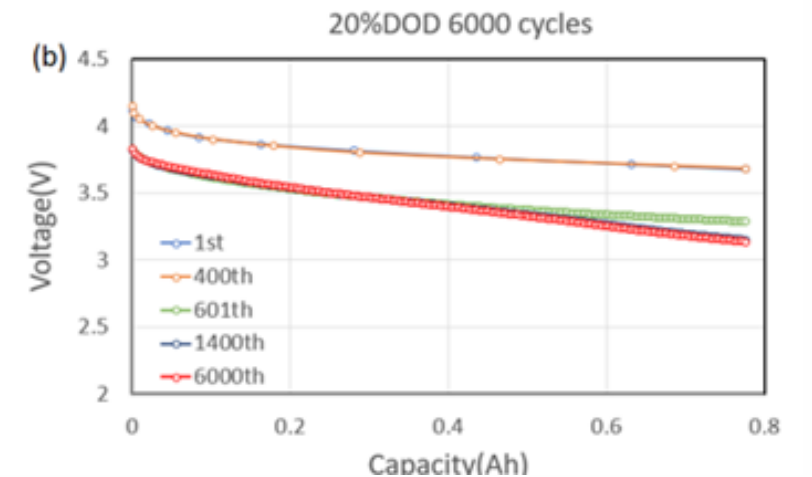
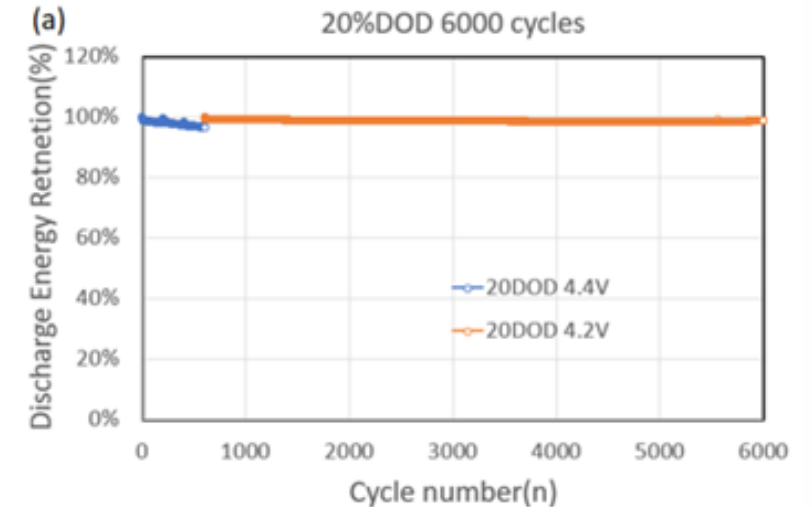
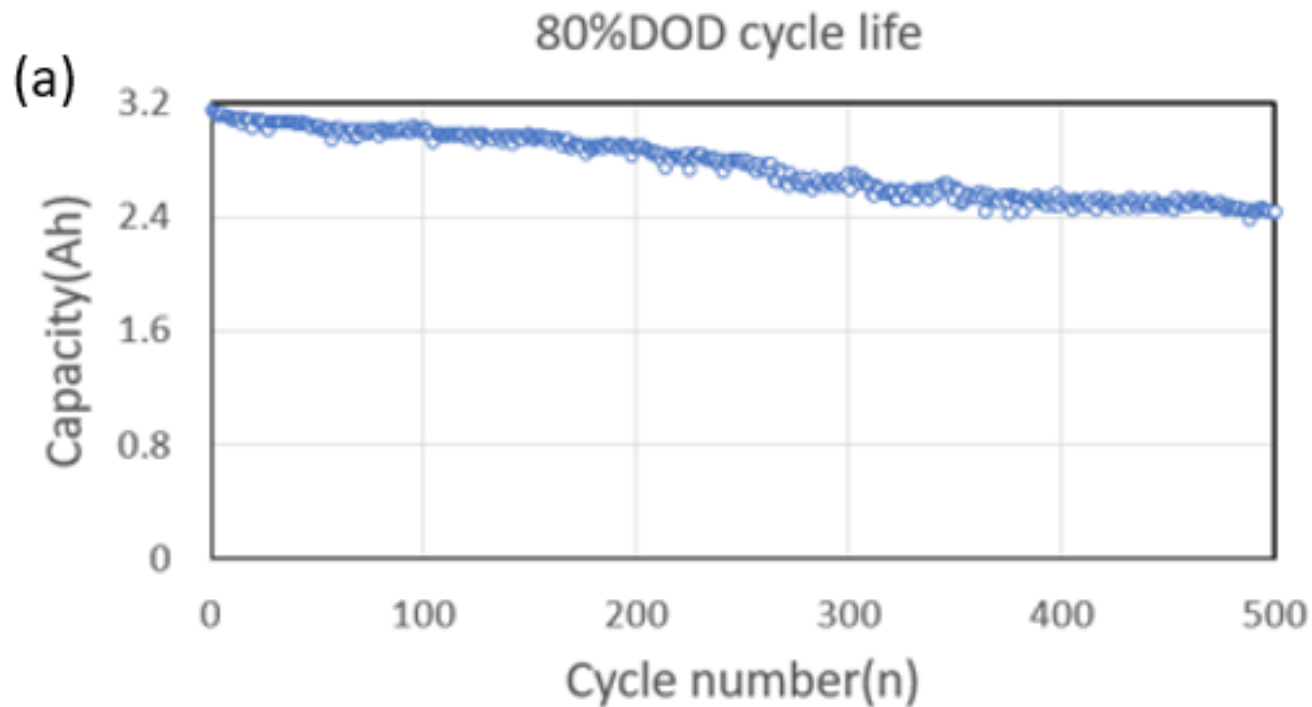
- High specific energy: up to 350 Wh/kg
- High power: Up to 700 W/Kg
- Excellent low temperature performance
 - -40C at C/5 and -57C at C/16
- Good cycle life
 - <2% energy loss after >6000 cycles at 20%DOD
 - Meet major UN 38.3 requirements
 - Pass impact, crush, overcharge and external short tests
- Good thermal stability
 - Pass 130°C (60 min.) hot box test

Cell Capacities at Different C Rates & at RT



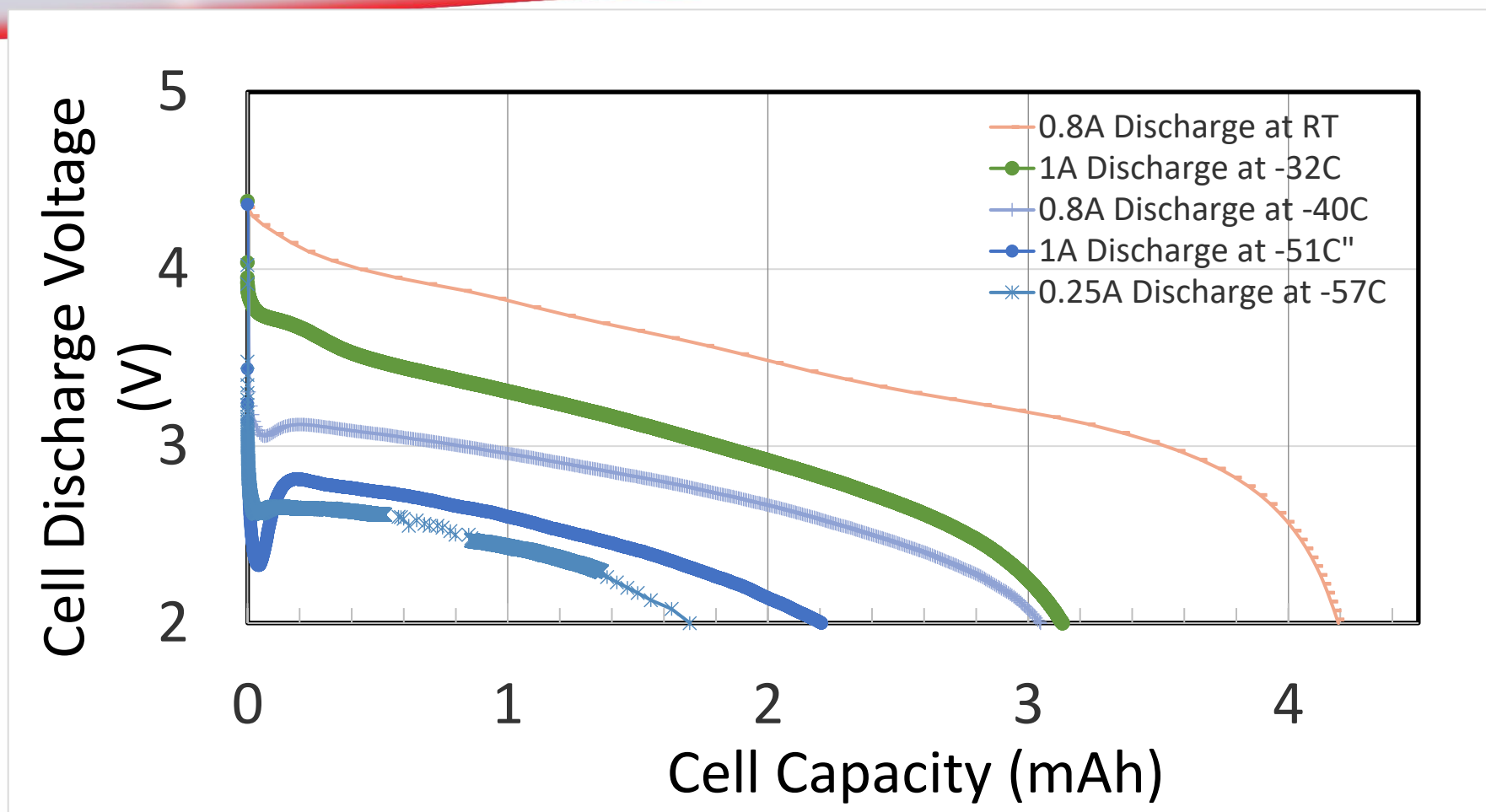
- The cell capacity at 2C rate is almost the same as that at C/5 rate
- The cell rate capability is good

Cycle Life: 20% and 80% DOD at RT



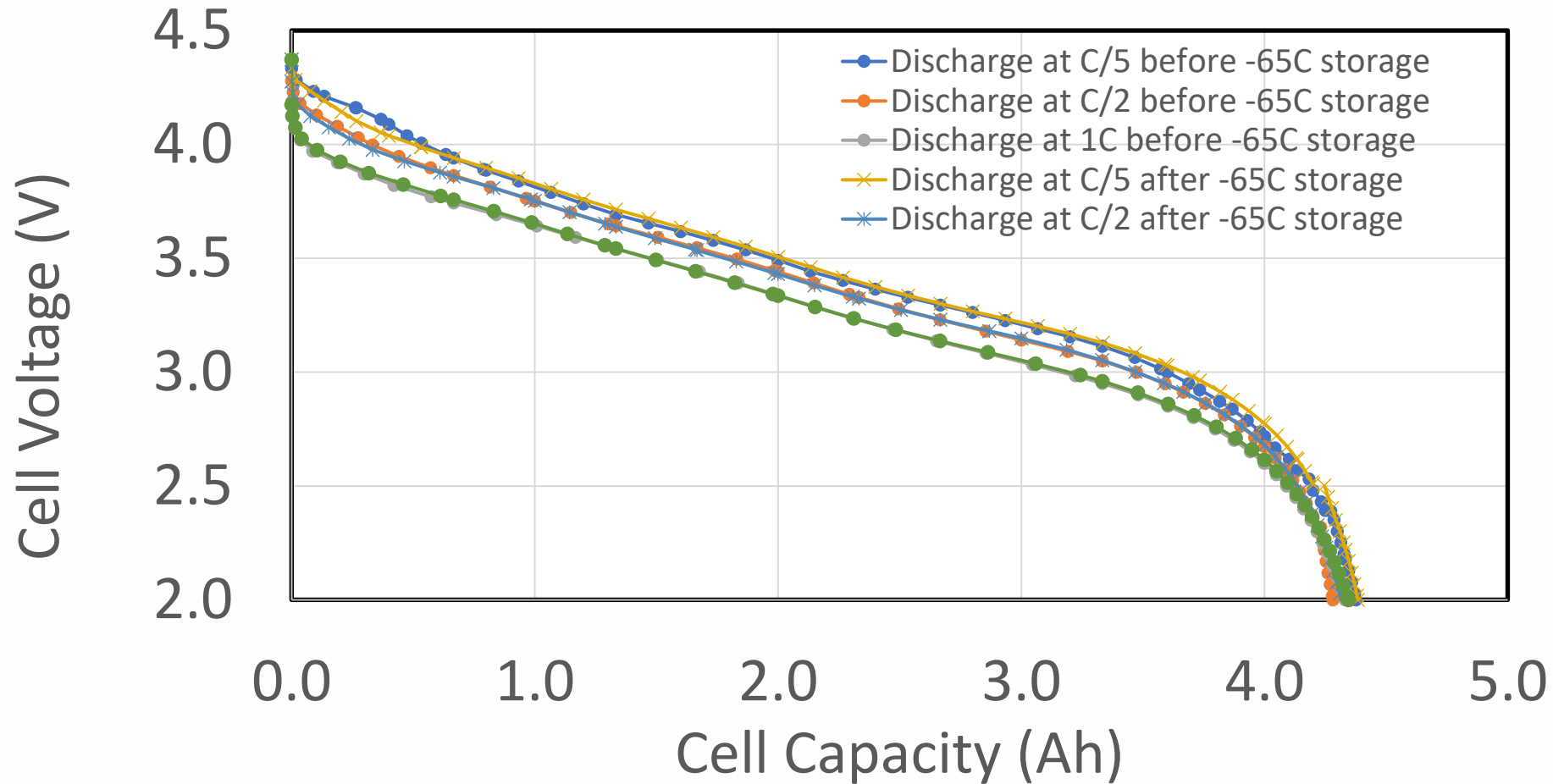
- The cycle life are very good at 20%DOD and 80%DOD
- The cell energy retention is about 98.6% after >6000 cycles at 20% DOD (18 months data)

Cell Discharge Capacities at Low Temperatures



- The cell can deliver >3Ah at -40°C and C/5 rate, and about 1.8Ah capacity at -57°C and at C/16 rate, respectively

Cell Capacities Before and After Storage Test at -65°C

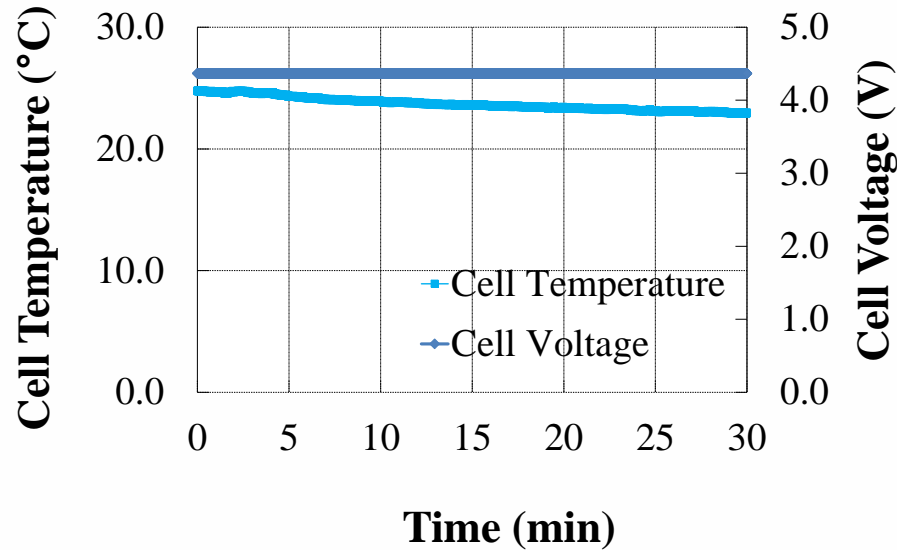


- The cell was cooled down to -65°C and hold there for 3 hrs before it warmed up naturally
- There is no capacity loss after the low temperature treatment

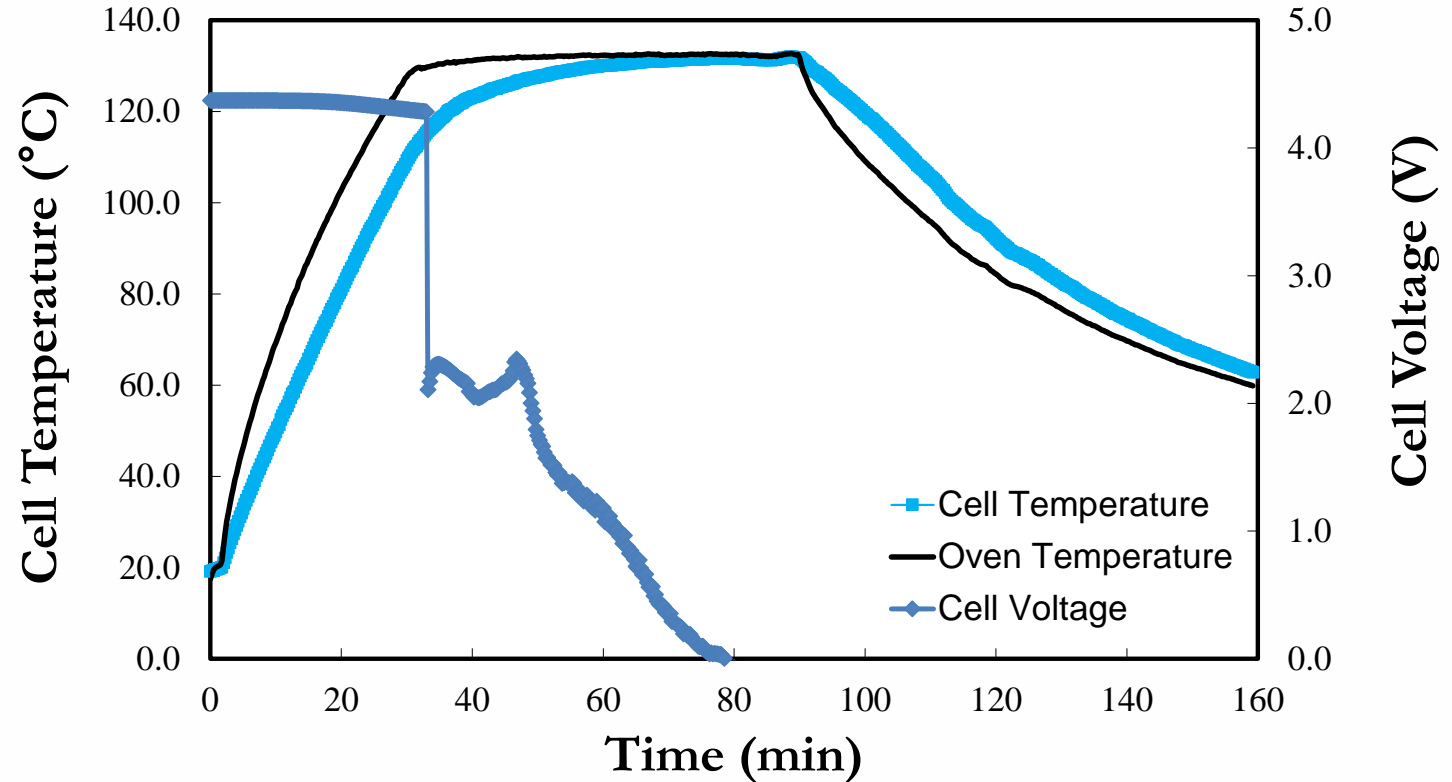
ALE 4Ah Nano 18650 Cells

Abuse Tolerance: Meet Major UN 38.03 Requirements

Crush Test

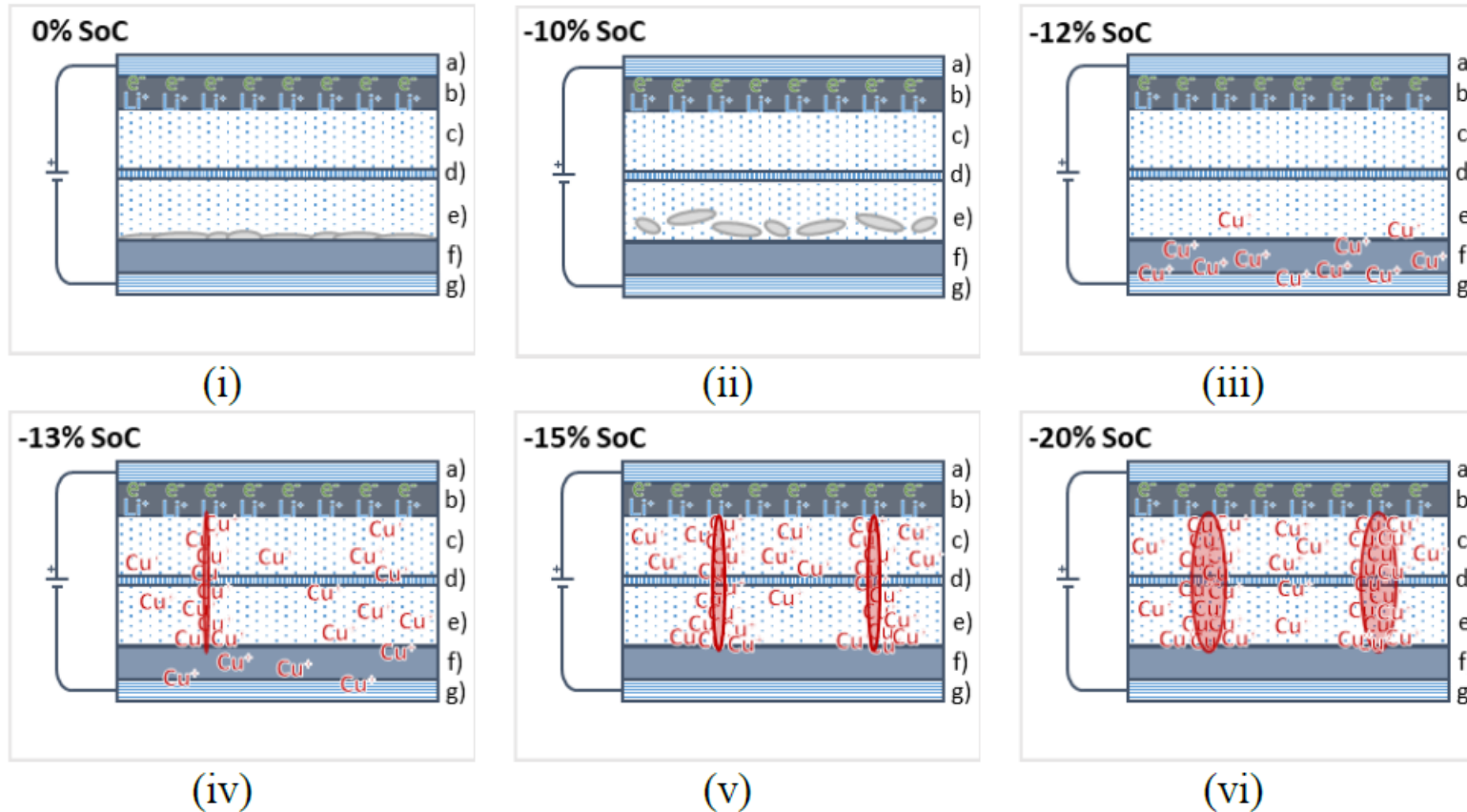


130 °C for 60 min



- No fire or explosion in impact, crush, external short and 130°C hot box tests

Zero Volt Failure Schematics



- Over discharge by 10% starts the decomposition of SEI layer
- Over discharge by 12% starts the Cu dissolution, and 13% by internal short

Zero Volt Stability Studies for 7 Days Repeatedly

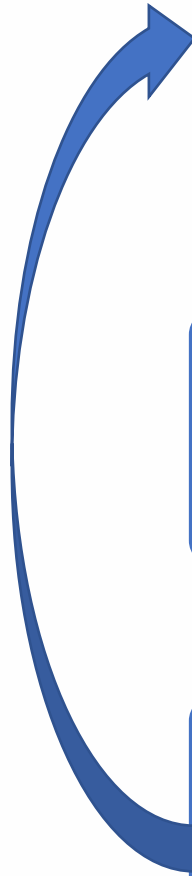
Capacity, DCR Measurement,
and Cycle Life Test



Zero Volt Exposure for 7 Days

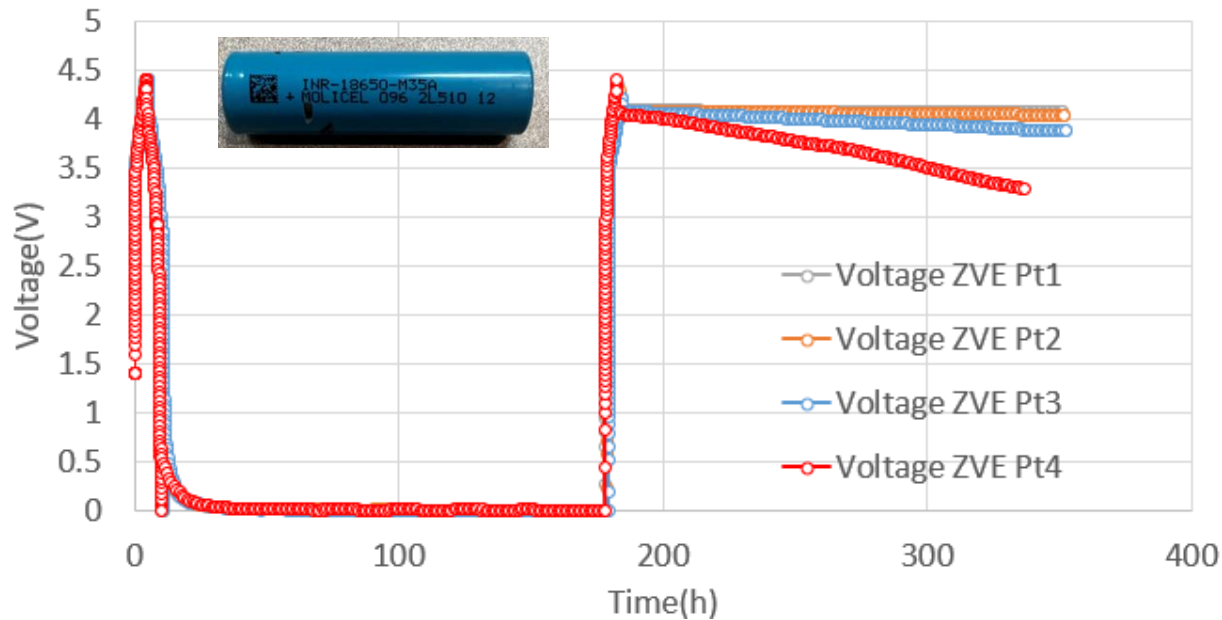


Capacity, DCR Measurement,
and Cycle Life Test

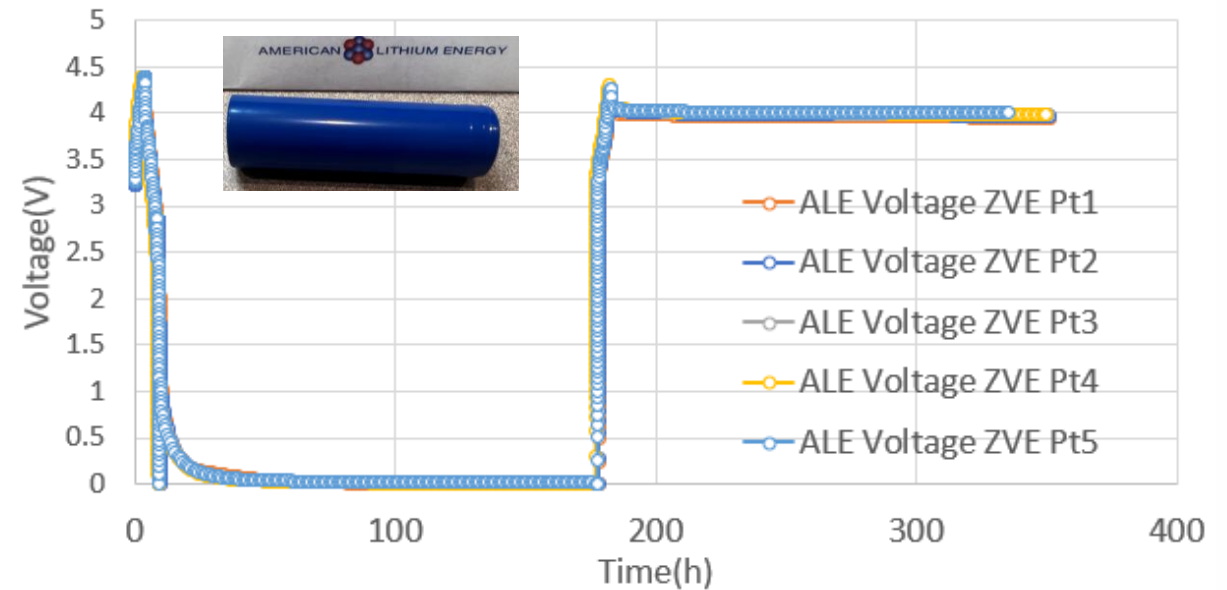


Zero Volt Studies: 3.5Ah Commercial Moli 18650 cell and ALE 4Ah 18650 cell

Commerical Graphite 3.5Ah Cell ZVE 20ohm 7days and Rest 7days



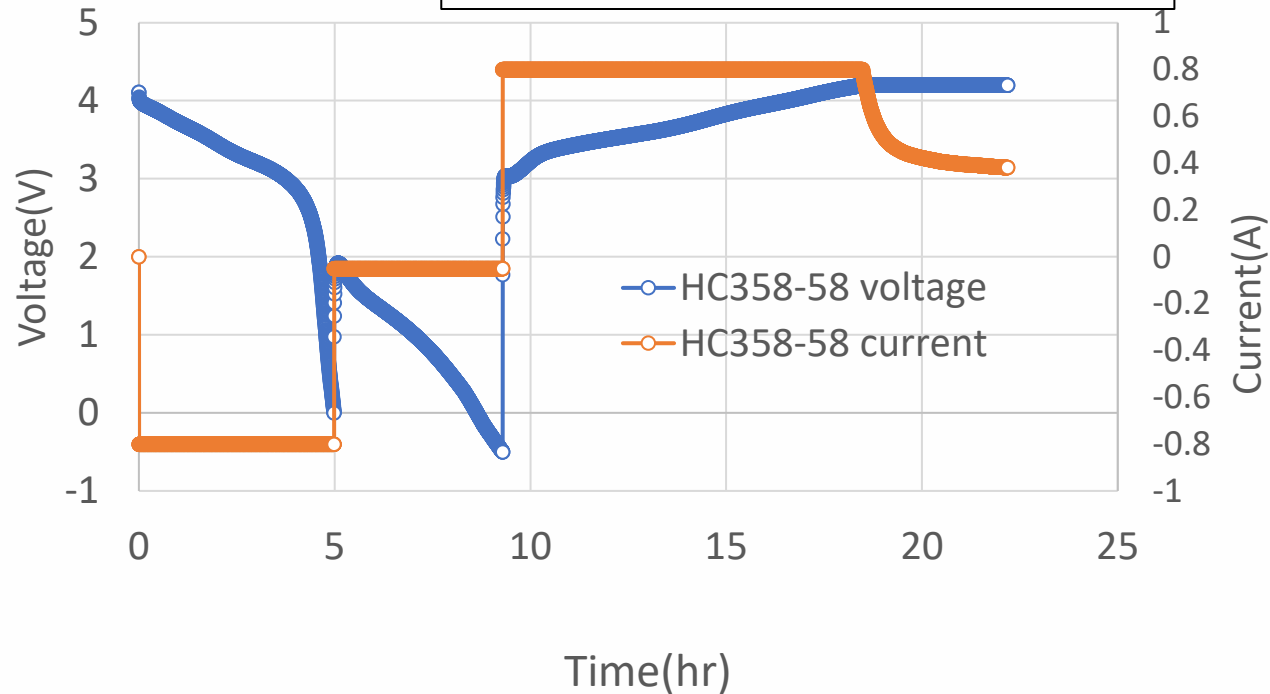
ALE 4Ah Nano Si Cell ZVE 20ohm 7days and Rest 7days



- Very high self-discharging or internal short during rest for commercial 3.5Ah 18650 cell after 4 times of ZVE at 20ohm constant resistance discharging for 7 days
- Negligible self-discharging or no internal short during rest from ALE 4Ah 18650 cell after 5 times of ZVE at 20ohm constant resistance discharging for 7 days
- Zero Voltage Stability is good for ALE 4Ah 18650 Cell

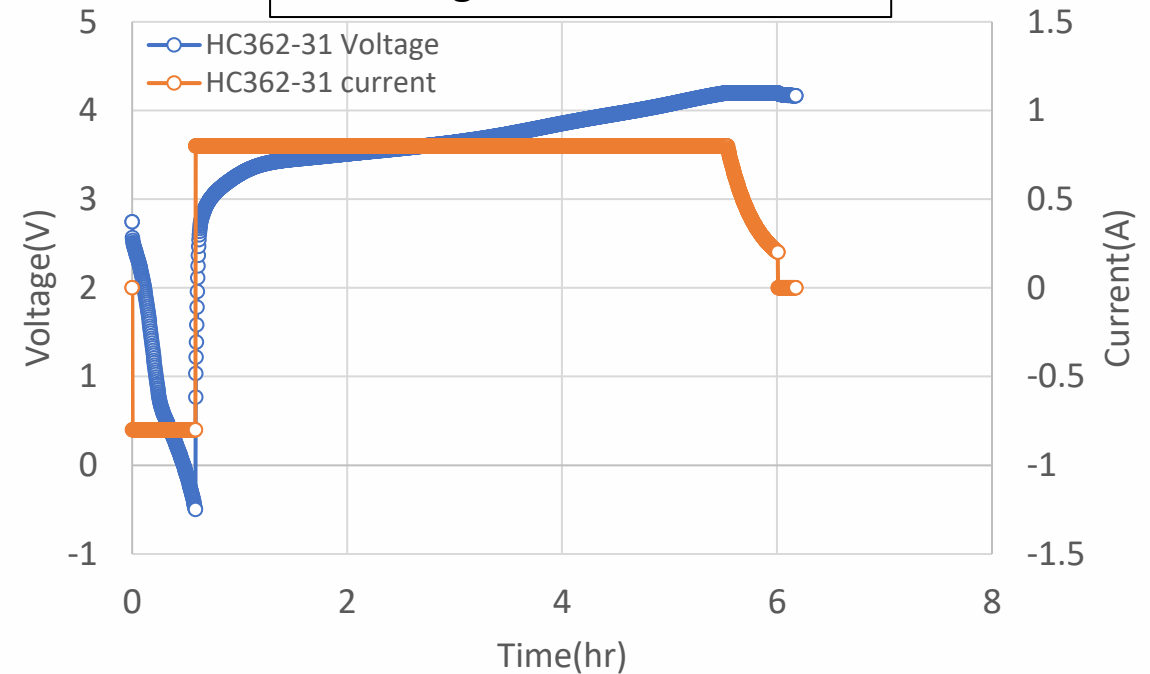
Negative Volt Exposure

- Procedure:
- Discharge to 0V at 0.8A
- Discharge 0.2Ah at 0.05A for 4h
- Charge to 4.2V at 0.8A



- Procedure:

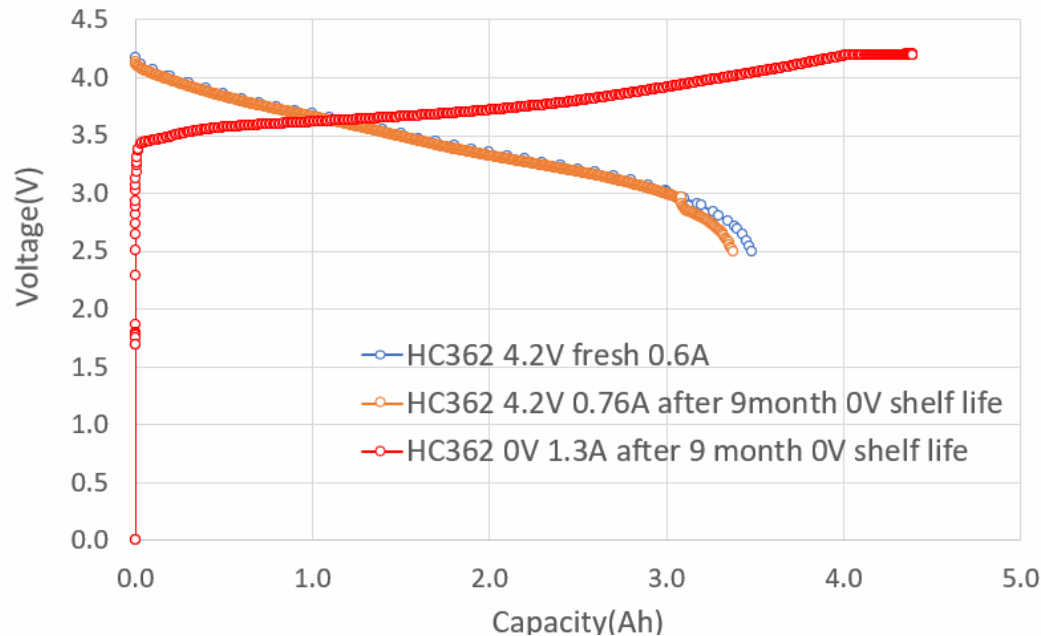
1. Discharge to -0.5V at 0.8A
2. Charge to 4.2V at 0.8A



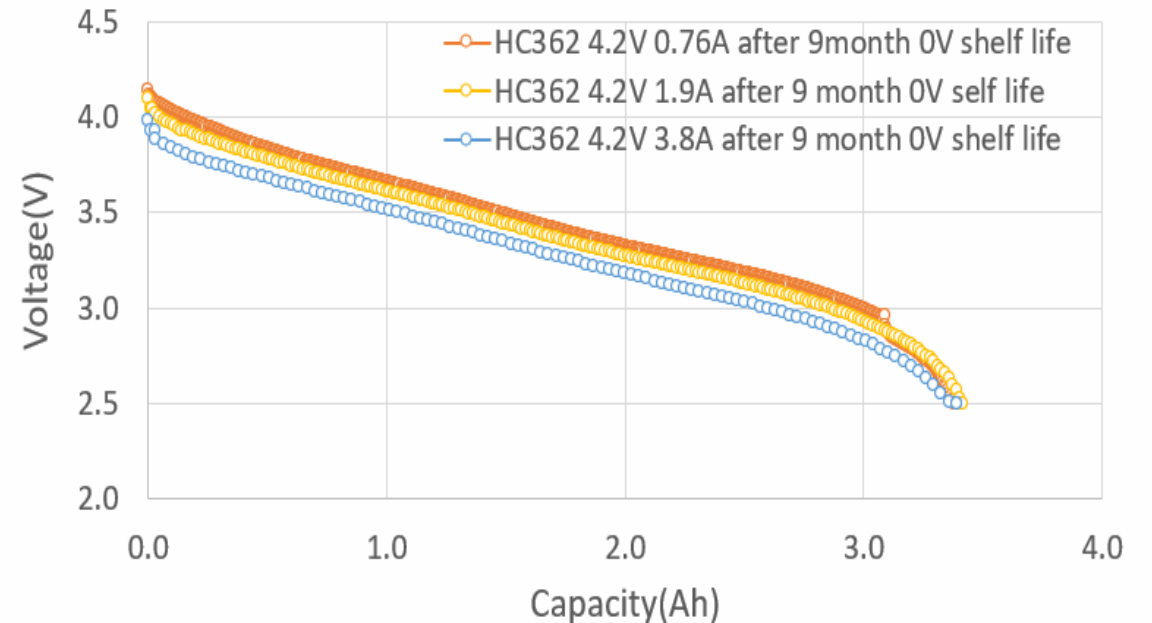
- Both ZV cells have been discharged to -0.5V and recharged to 4.2V
- *No capacity decay*

Zero Volt on the Shelf for Nine Months

Capacity fresh cell vs after 9month 0V shelf life



Rate Capability after 9 month 0V shelf life



- No capacity loss: Fresh cell with ZV design: the fresh capacity is 3.48Ah (4.2-2.5V), and 3.37Ah (4.2-2.5V) after charge from storage for 9 month at 0V, The 0.1Ah capacity loss is negligible, owing to higher discharge current.
- No power loss: The rate capability is quite good, the capacity is 3.37Ah (0.76A), and 3.41Ah (1.9A), and 3.39Ah (3.8A) after storage for 9 month at 0V.

Conclusion

- ALE 4Ah 18650 cell with zero volt technology is very stable at zero volt
 - No capacity or power loss after 5 times for seven days at zero volt
 - No energy and power loss at zero volt after nine months
- ALE 4Ah 18650 cell can deliver >3Ah capacity at -40°C and C/5, and 1.8Ah at -57°C and C/16
- ALE 4Ah 18650 cell is stable after the storage down to -65°C per our limited test, which is very beneficial to NASA application since the battery in space can be easily exposed to extremely cold temperature or environment