Advanced Domestic Materials and Lithium Ion Cells Supply Capability

EnerSys

2021 Space Power Workshop

April 19th 2021, The Energy Storage I session

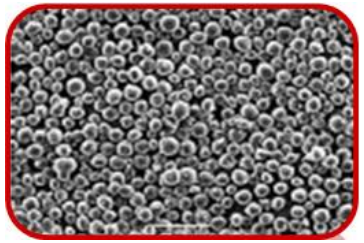
Presentation Topics

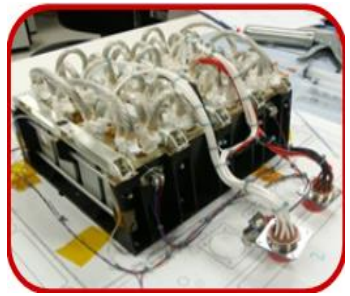
1. History
2. Cathode Active Materials Production Overview
3. Anode Active Materials Production Overview
4. Cell Production Overview
5. Summary

Our Objectives

Vertical Integration: from materials to packs to secure domestic supply

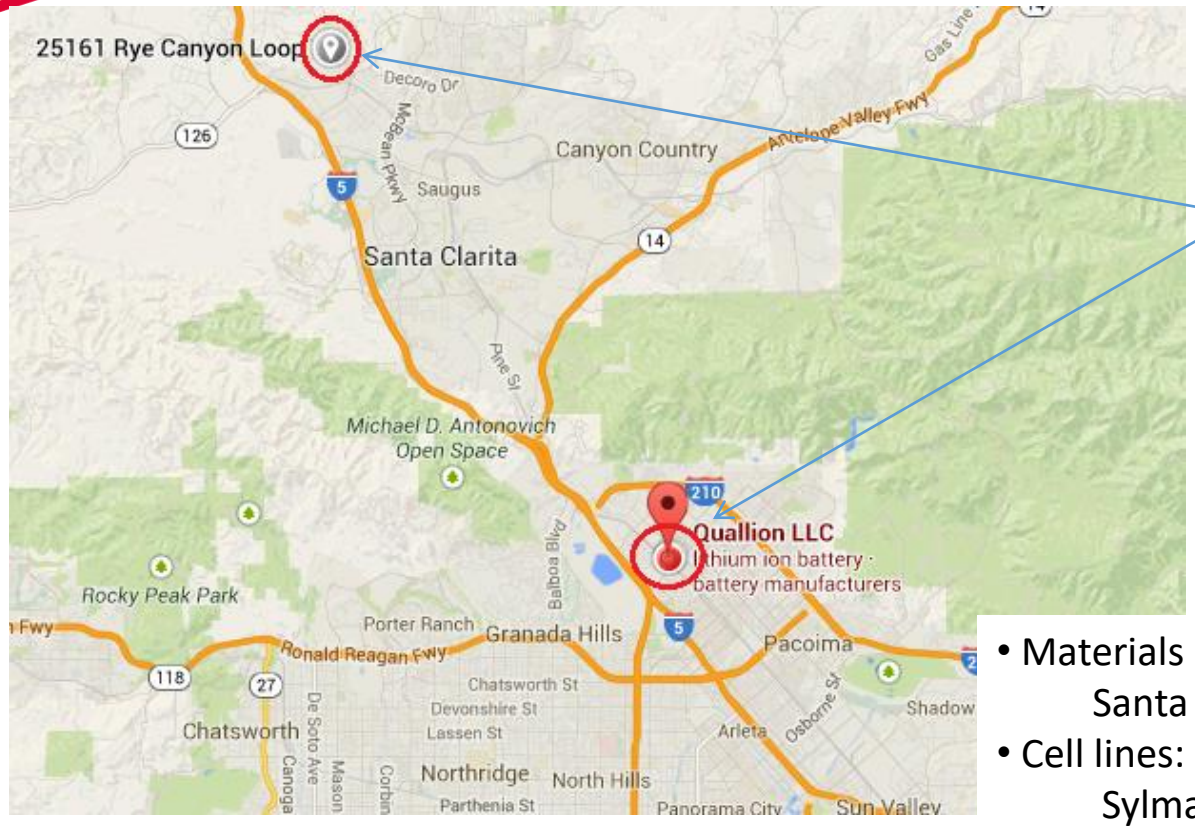
Materials	Cells	Electronics	Battery Pack
Critical anode and cathode raw materials – production and analysis Sylmar, CA Santa Clarita, CA	High-performance custom cells in wound, stacked-plate, prismatic, pouch, and 18650 formats from 1 to +100,000/year Sylmar, CA Horsham, PA	Custom engineered electronics for battery management and system interface Sylmar, CA	Complete cell packs engineered, manufactured and tested for any high-performance applications Sylmar, CA Longmont, CO





Production lines

Developed under Title III program



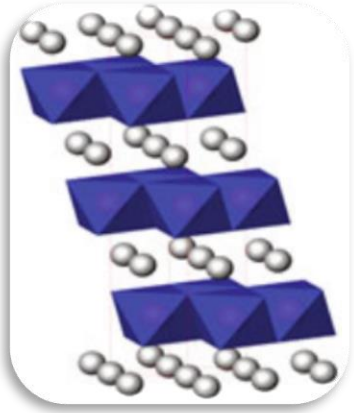
- Materials Plant:
  Santa Clarita, CA (new 14,000 ft^2 facility)
- Cell lines:
  Sylmar, CA

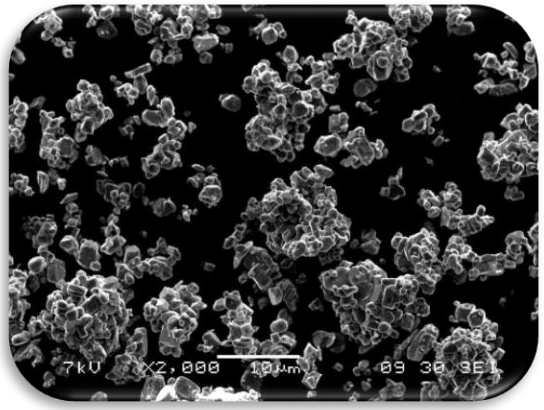
2006	2010	2012	2013	2014
Contract Award	**R&D**	**Construction**	**Startup**	**Production**
September 5, 2006	Completed Table Top Testing and Process Design	Completed Construction and Equipment Installation	Completed Process Qualification	Production and Continuous Improvement

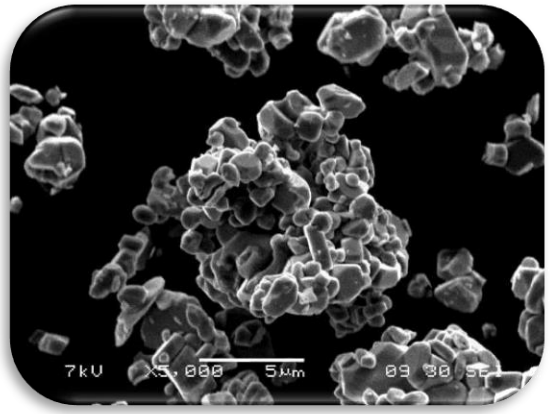
Cathode Materials Production Overview

Lithium Cobalt Oxide, LCO ($LiCoO_2$) Cathode

- The cathode material; previously most commonly used in lithium ion batteries for consumer devices (cell phones, laptops, and digital cameras)
- LCO was the 1st of the layered transition metal oxides to be commercialized. LCO has a layered structure in which Co and Li, located in octahedral sites, occupy alternating layers in a cubic close-packed oxygen array with overall hexagonal symmetry.







- **Advantages:**

  - High specific energy, proven chemistry

- **Disadvantages:**

  - Requirement of high charge voltage to enable the theoretical capacity of 272mAh/g
  - Relatively short cycle life span due to dissolution of cobalt when delithiated
  - Safety concern at highly delithiated state

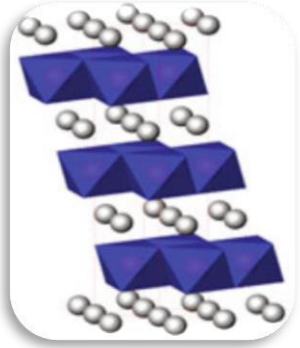
Intercalation Reaction

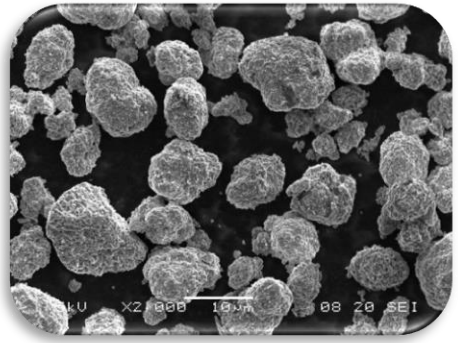
Charging (cathode): $LiCoO_2 \rightarrow e^- + xLi^+ + Li_{1-x}CoO_2$

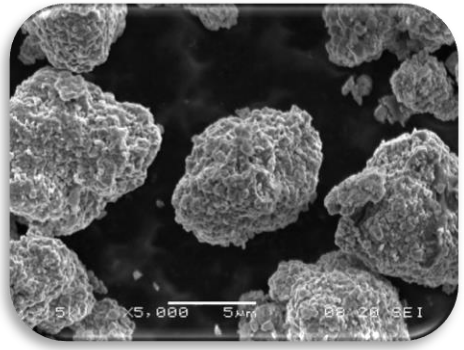
Charging (anode): $C_6 + x\,Li^+ + e^- \rightarrow Li_x\,C_6$

Lithium Nickel Cobalt Aluminum Oxide, NCA ($LiNi_{0.80}Co_{0.15}Al_{0.05}O_2$) Cathode

- Layered transition metal oxide, similar to LCO
- Addition of Ni increases specific energy, addition of Al improves thermal stability. By partially substituting aluminum for cobalt, both the thermal stability of the delithiated material and the electrochemical properties are enhanced.
- Getting more popularity in various applications







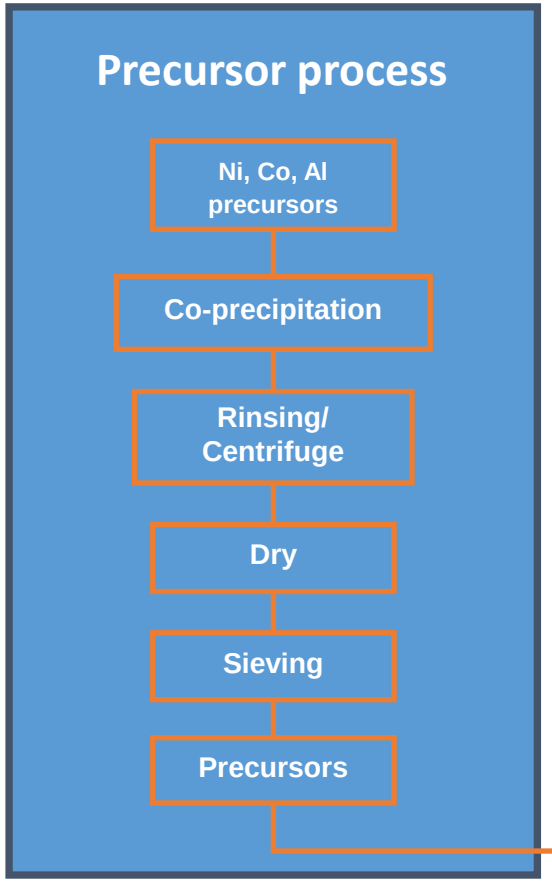
- **Advantages:**
  - Performance is well established, improved thermal stability, higher specific capacity, higher specific energy, and improved safety
- **Disadvantages:**
  - High cost, difficulty in manufacturing

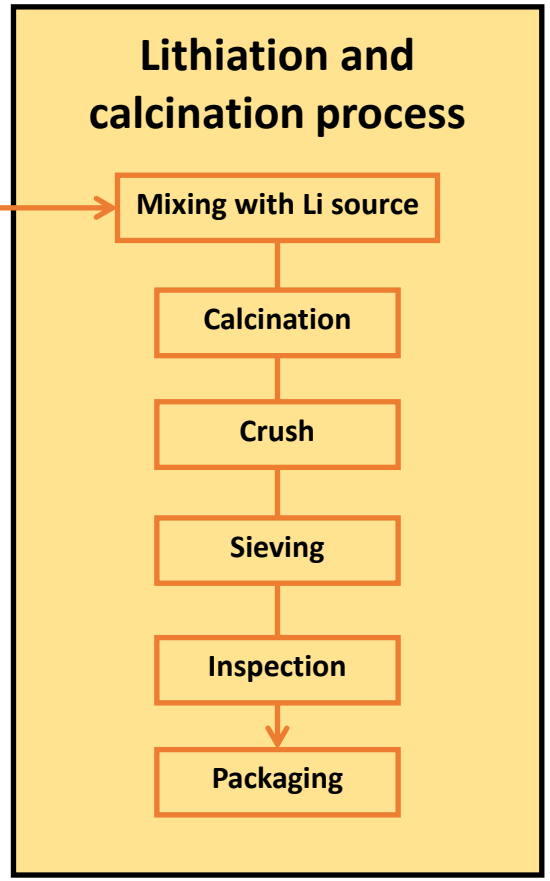
Intercalation Reaction

Charging (cathode): $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2 \rightarrow e^- + xLi^+ + Li_{1-x}Ni_{0.8}Co_{0.15}Al_{0.05}O_2$

Charging (anode): $C + x\ Li^+ + e^- \rightarrow Li_x\ C_6$

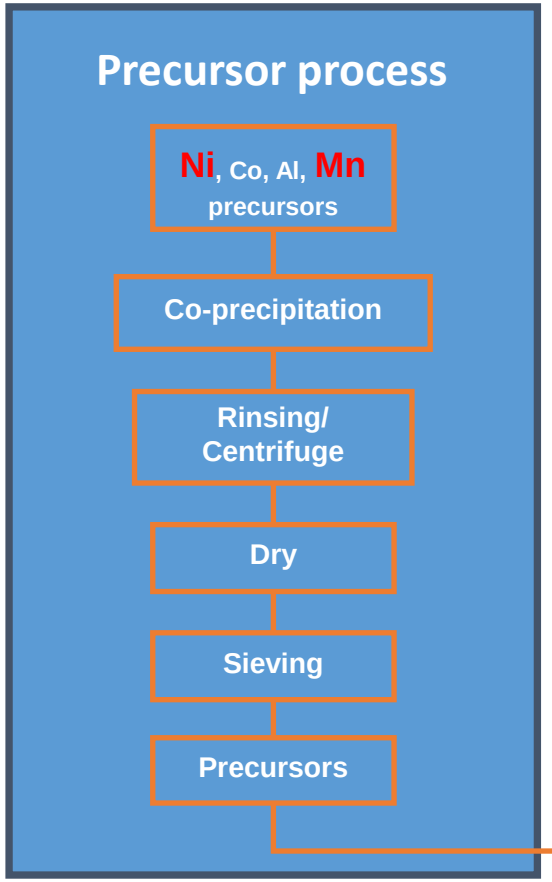
Cathode Materials Production Line

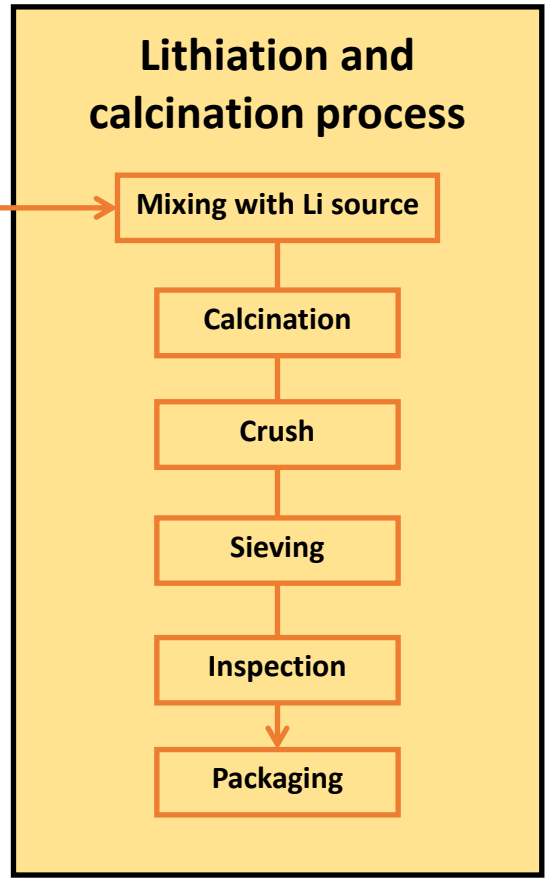




- 200kg / month production (capable of 500kg)

Cathode Materials Production Line





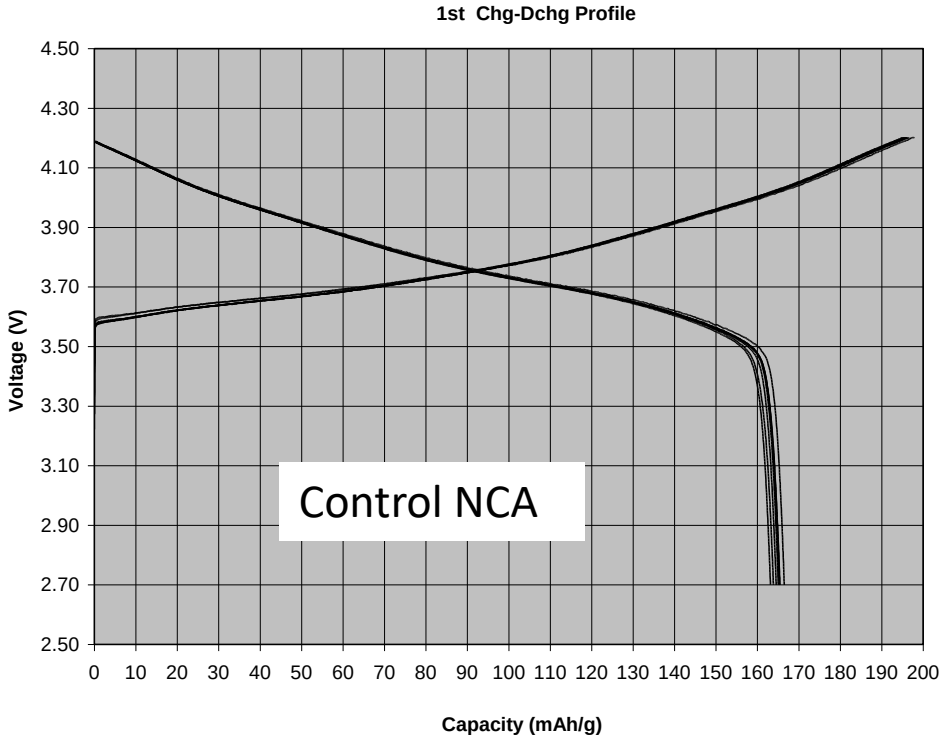
- NCA, LCO, NMC, and NMCA can be produced in the same line
- Ni content can be controlled to generate Ni rich NMC or NCA

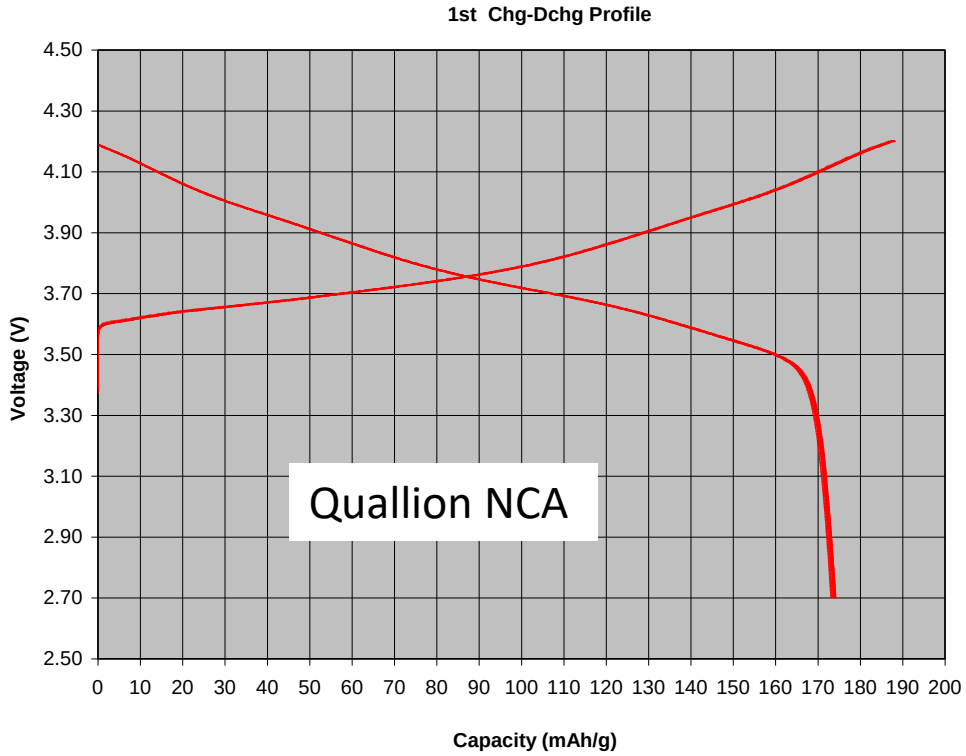
NCA Electrochemical Performance – Half Cells

	Cycle 1		
	Charge Cap (mAh/g)	Discharge Cap (mAh/g)	Irr Cap (mAh/g)
Control NCA	196.2 (7)	164.9 (1.0)	31.3 (5)
T13K001-01	187.9(3)	173.8 (0.3)	14.07 (13)

Charge: (C/20) A, 4.2V CCCV, C/100 cutoff

Discharge: (C/20) A to 2.7V

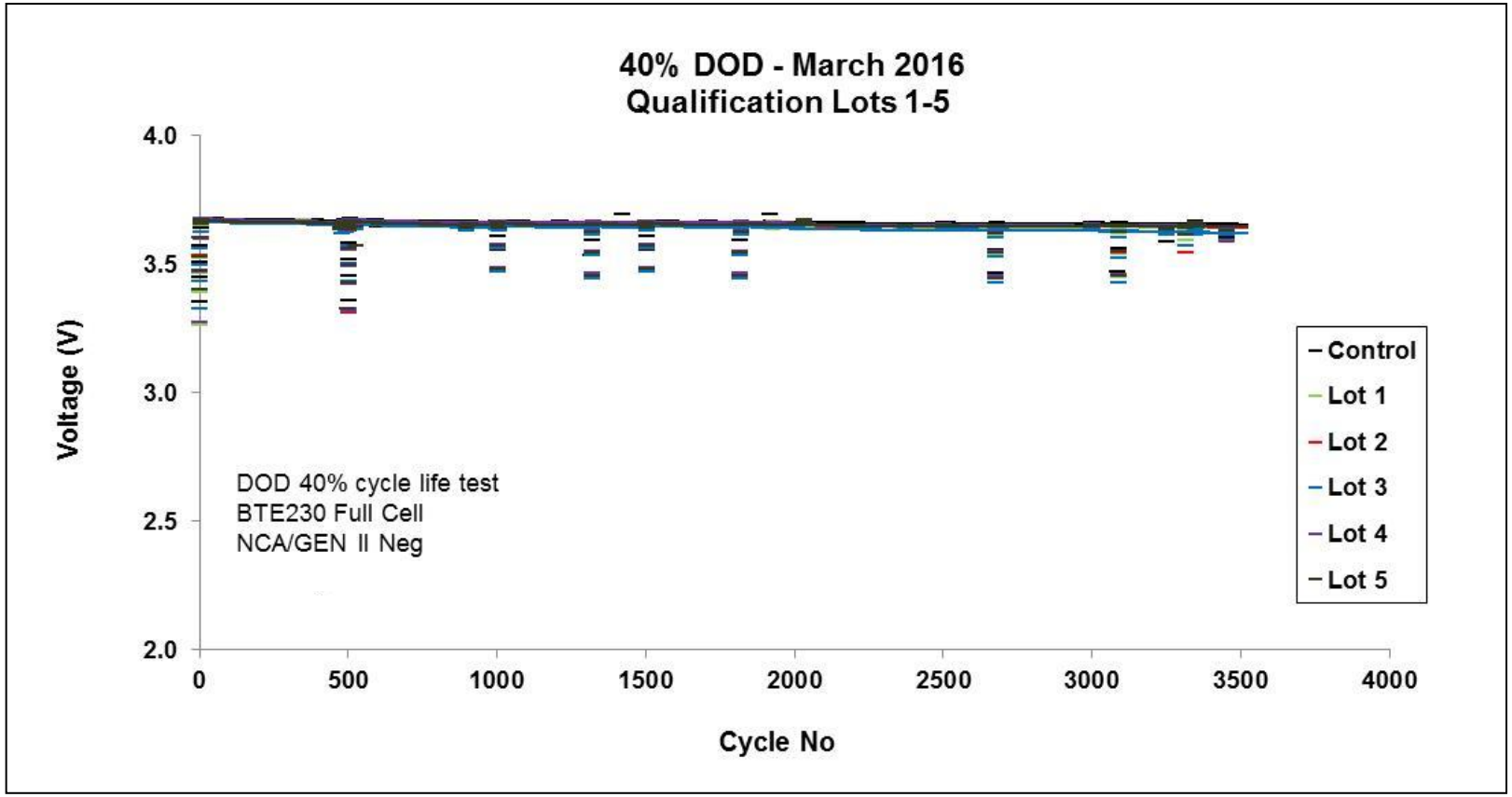




- Quallion NCA is equivalent or better than the control

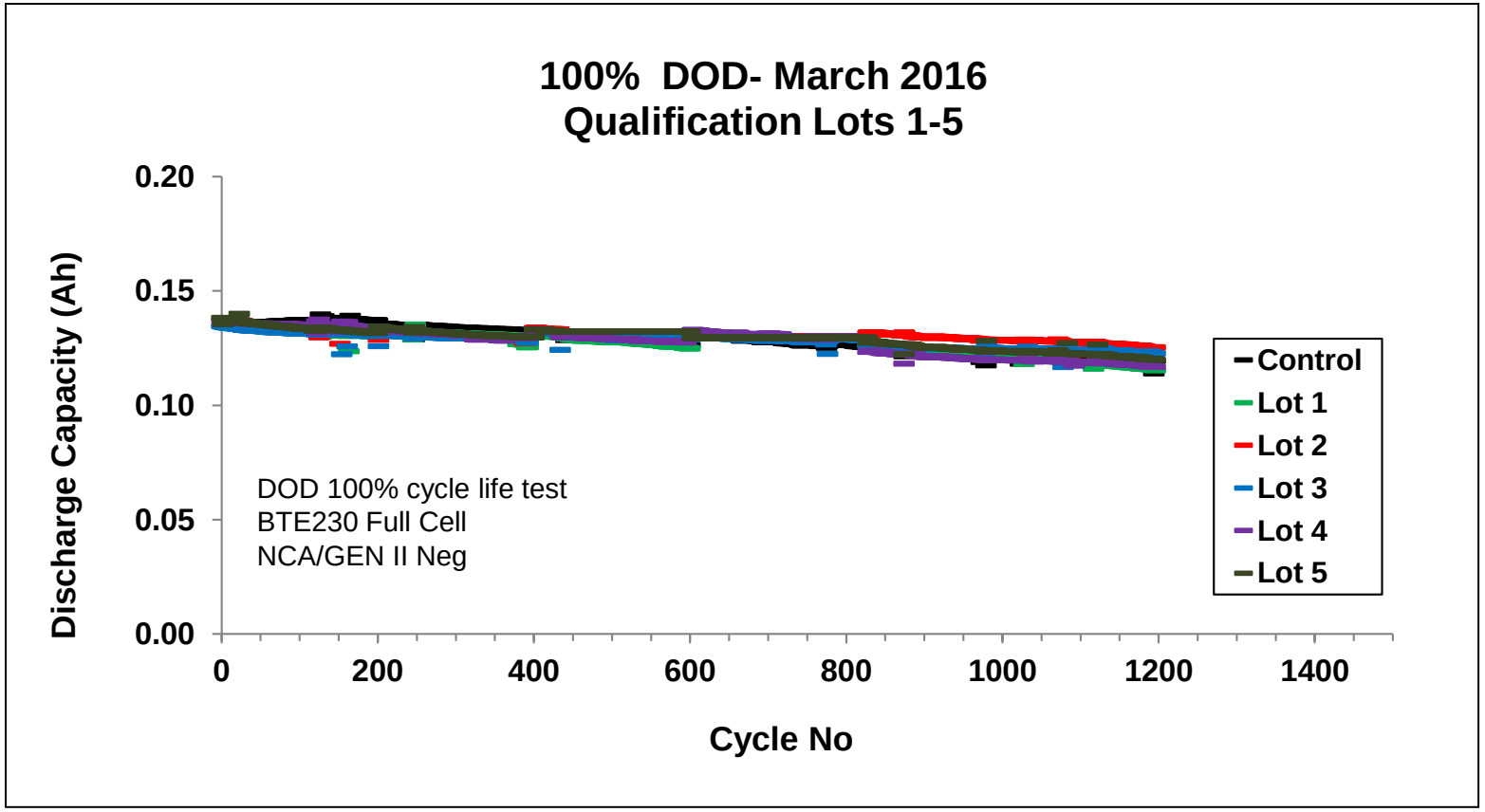
NCA Electrochemical – Long Term Cycling
(40% DOD at room temperature)

End of Discharge Voltage



- No change in EOD voltage at 40% DOD

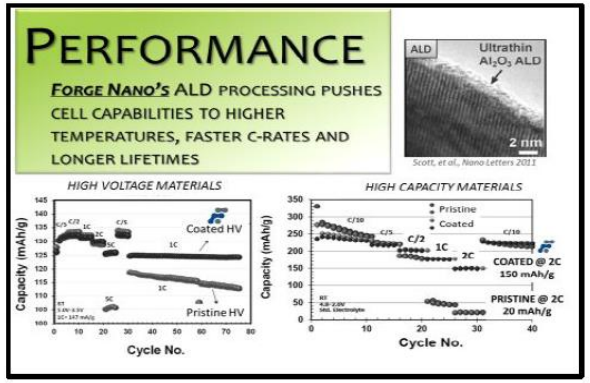
NCA Electrochemical – Long Term Cycling
(100% DOD at room temperature)

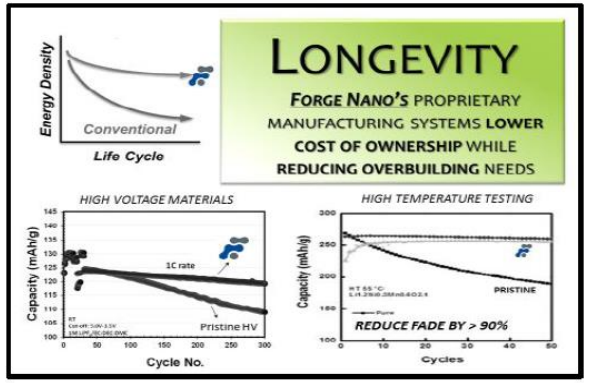


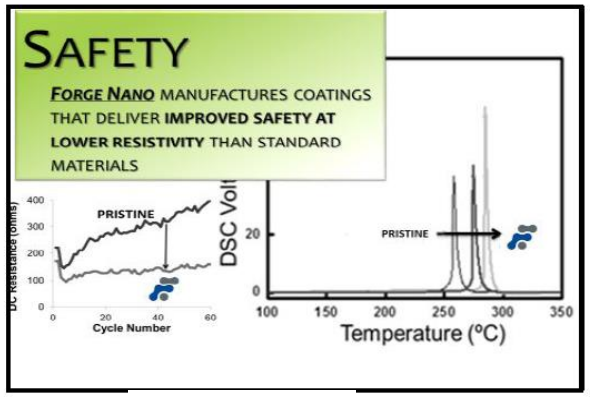
- More than 90% capacity retention after 1000 cycles at 100% DOD

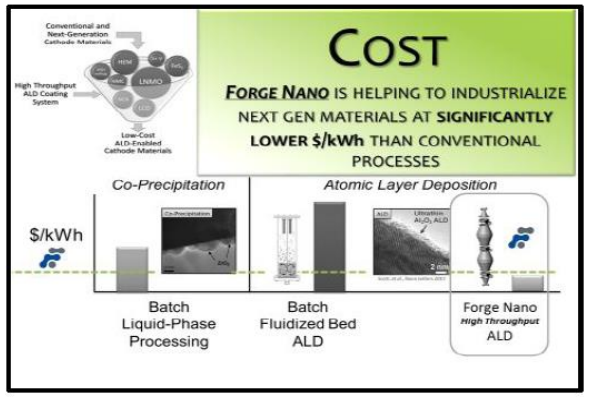
ALD Coating for High Voltage Operation

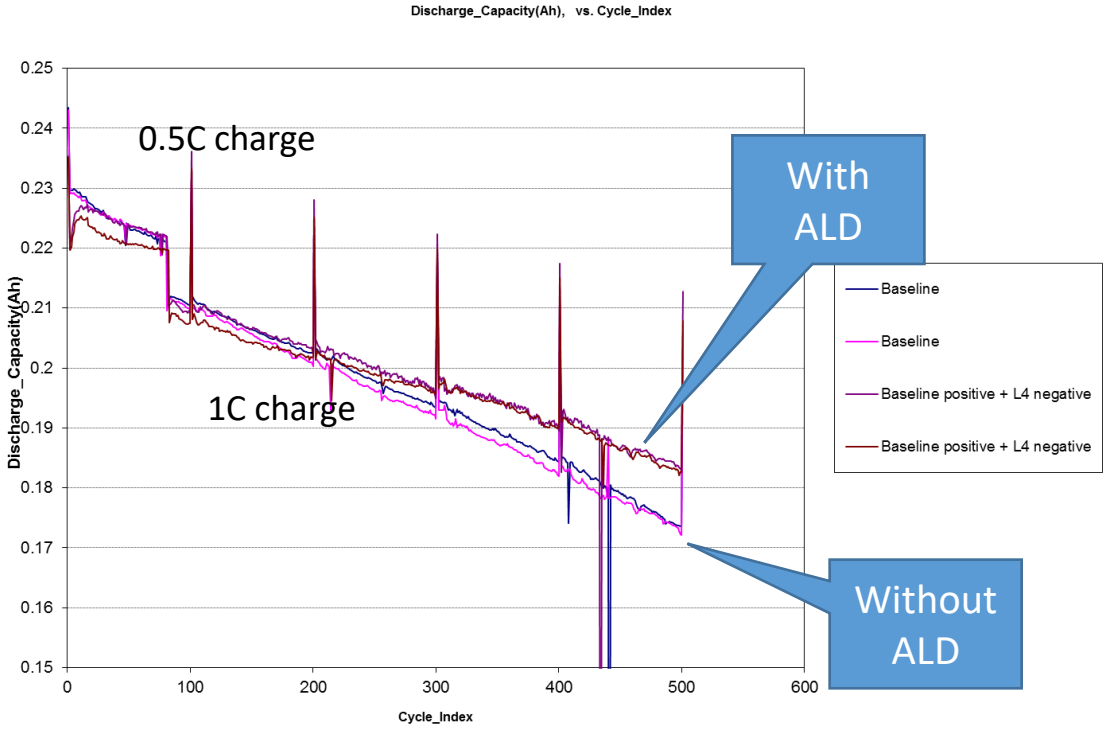
Forge Nano ALD Coating









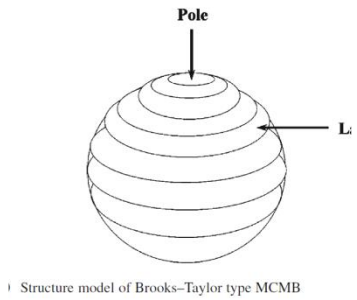


- Higher capacity (230mAh, 15% increase) at 4.5V charge voltage compared to 4.1V
- Better cycle with ALD (80% vs 74%)

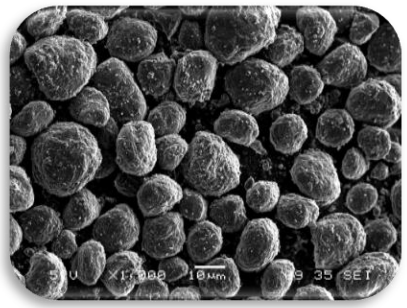
Anode Materials Production Overview

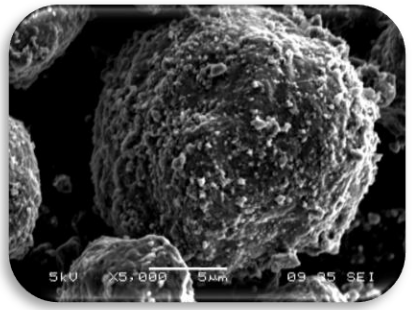
Mesocarbon Microbeads, MCMB Anode

- MCMB is a benchmark synthetic graphite anode material for Li-ion batteries.
- Spherical graphite beads with a stacked, sheeted structure, 15 – 30 µm average diameter



Structure model of Brooks–Taylor type MCMB



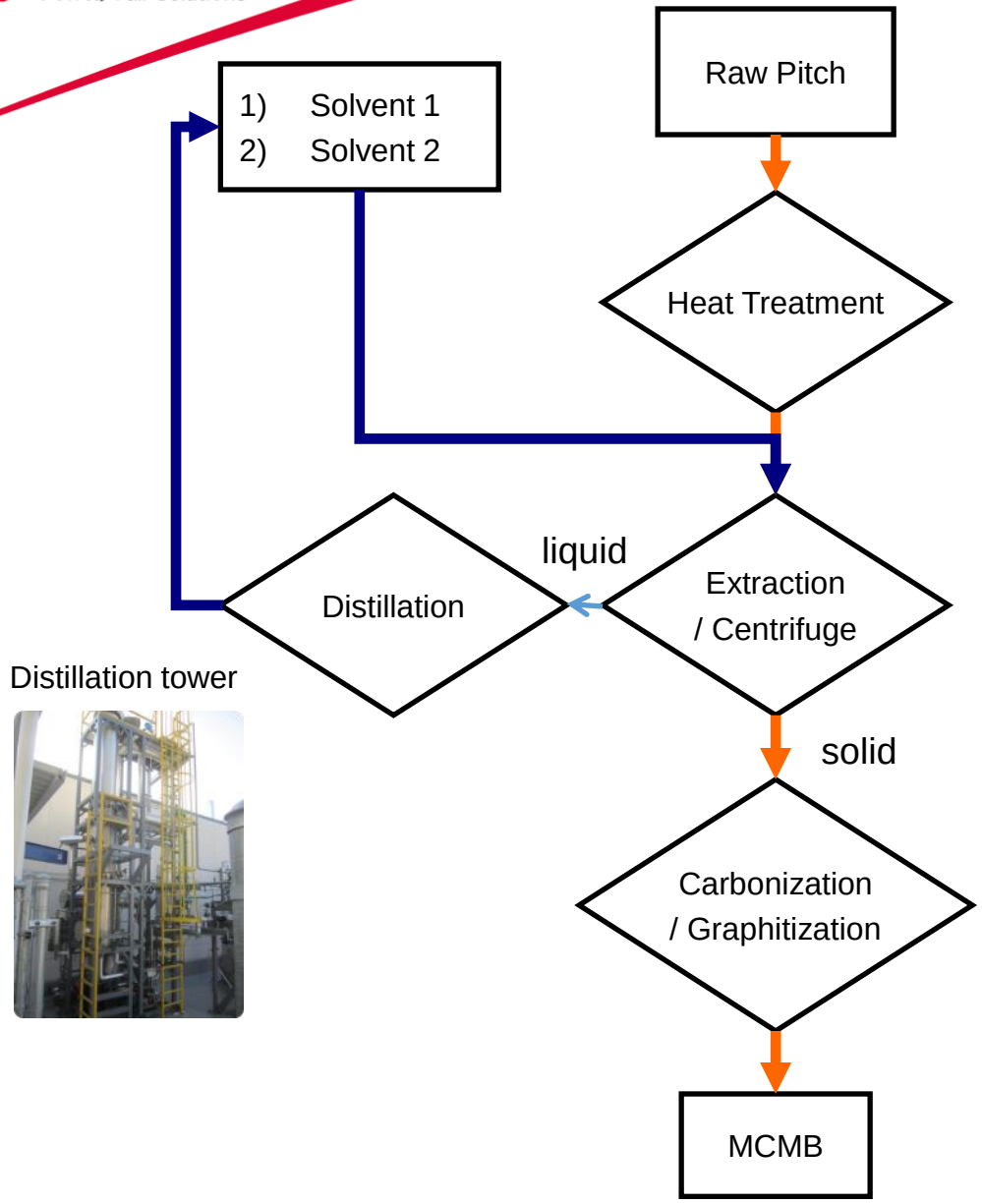


- **Advantages:**
  - Due to its spherical shape, MCMB has a high packing density that results in high energy density
  - The small surface area of MCMB decreases irreversible capacity corresponding to electrolyte decomposition
  - Most surfaces of spheres are edge plane surfaces, allowing for easy Li+ intercalation
- **Disadvantages:**
  - High manufacturing costs and low overall yields

Intercalation Reaction

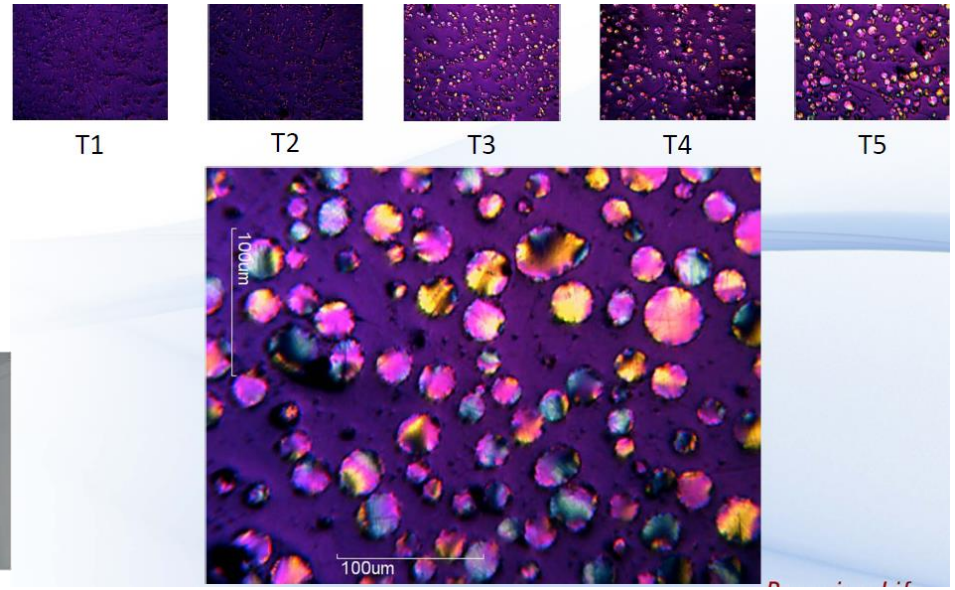
Charging (anode): $C_6 + x\ Li^+ + e^- \rightarrow Li_x\ C_6$

MCMB Process Flow



Reactor

Growth of mesophase

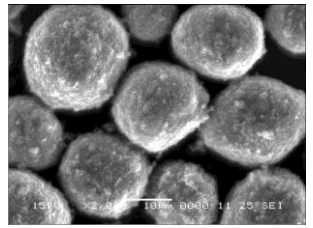


Centrifuge

Distillation tower

Furnace

Graphitized mesophase (MCMB)

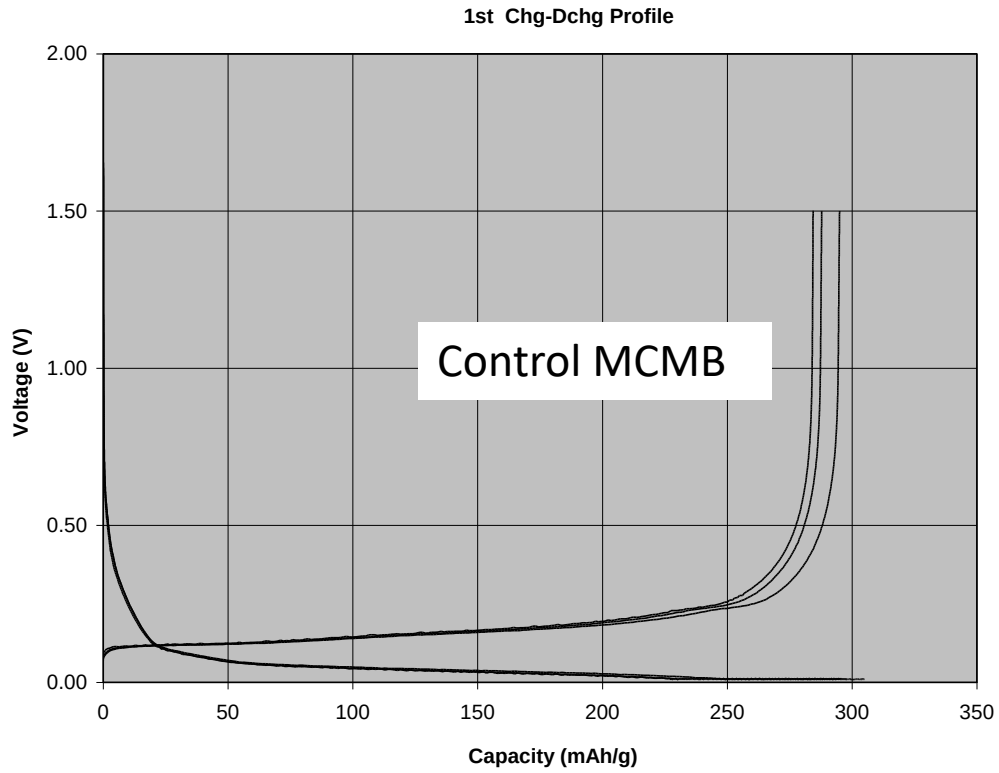


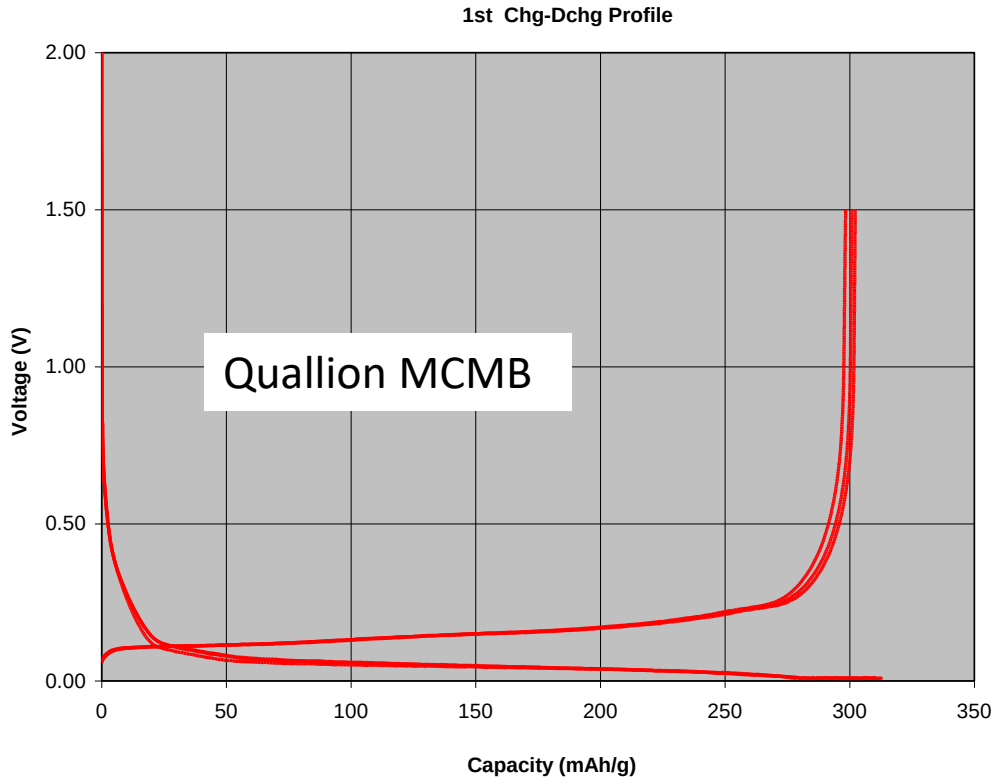
MCMB Electrochemical Performance – Half Cells

	Cycle 1		
	Charge Cap (mAh/g)	Discharge Cap (mAh/g)	Irr Cap (mAh/g)
Control	299 ± 4	289 ± 5	10.3 ± 0.5
T13F002-1	312 ± 3	300 ± 3	11.2 ± 0.8

Charge : C/20,0.01V,C/40 cutoff at R.T.

Discharge :C/20 to 1.5V at R.T.

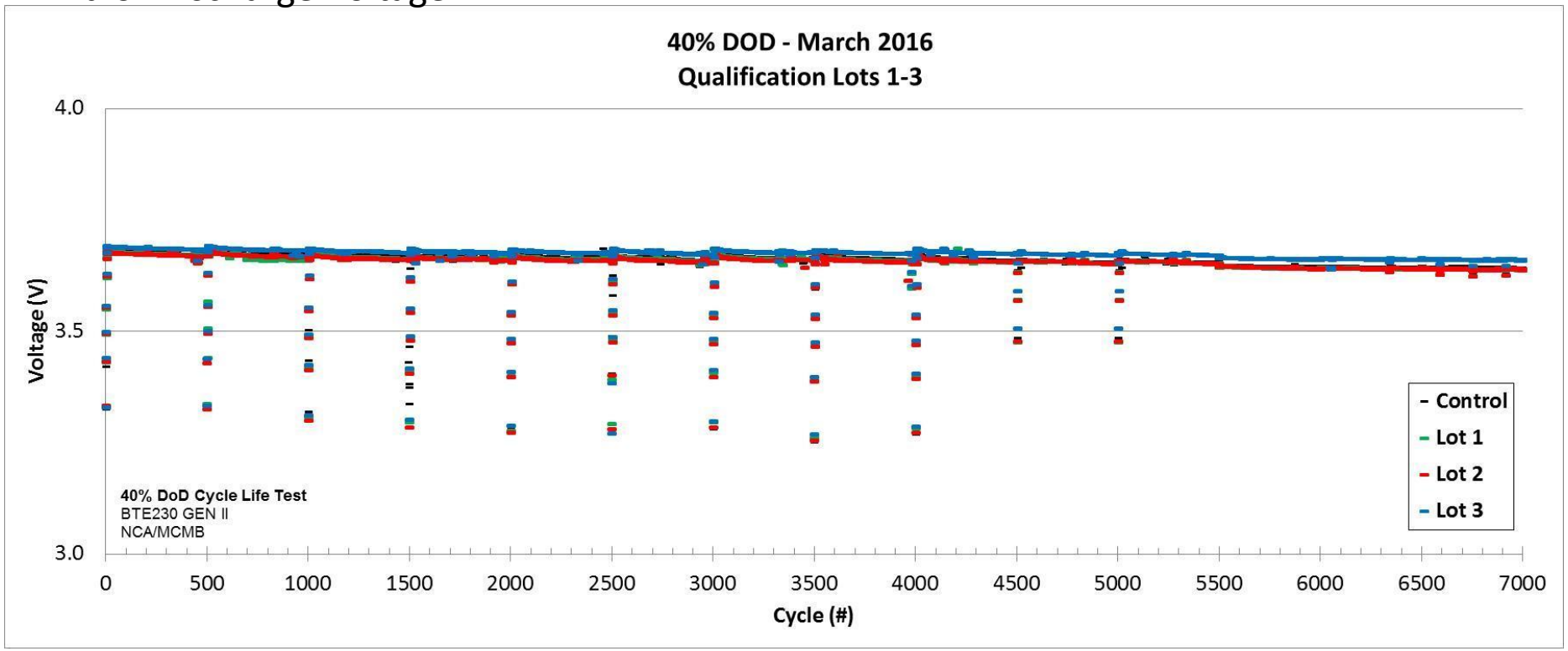




- Quallion MCMB is equivalent or better than the control

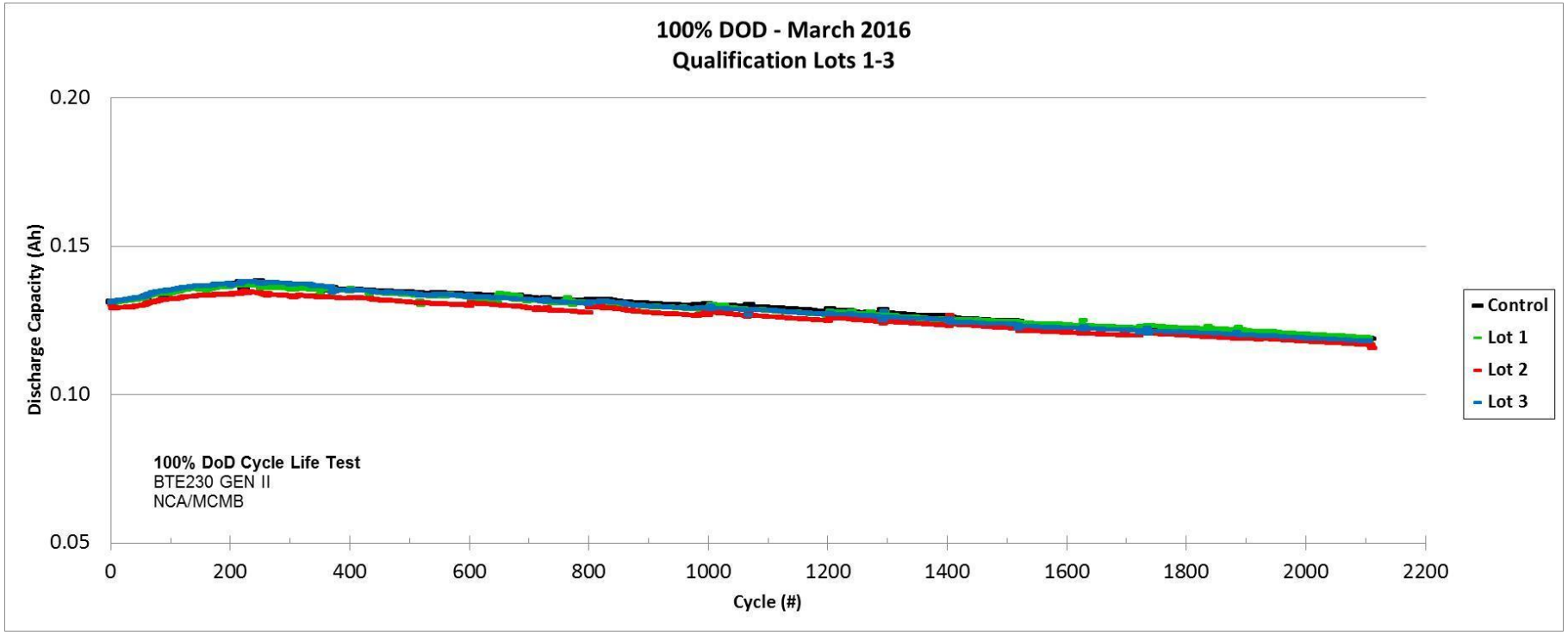
MCMB Electrochemical – Long Term Cycling
(40% DOD at room temperature)

End of Discharge Voltage



- No change in EOD voltage at 40% DOD after 7000 cycles

MCMB Electrochemical – Long Term Cycling
(100% DOD at room temperature)



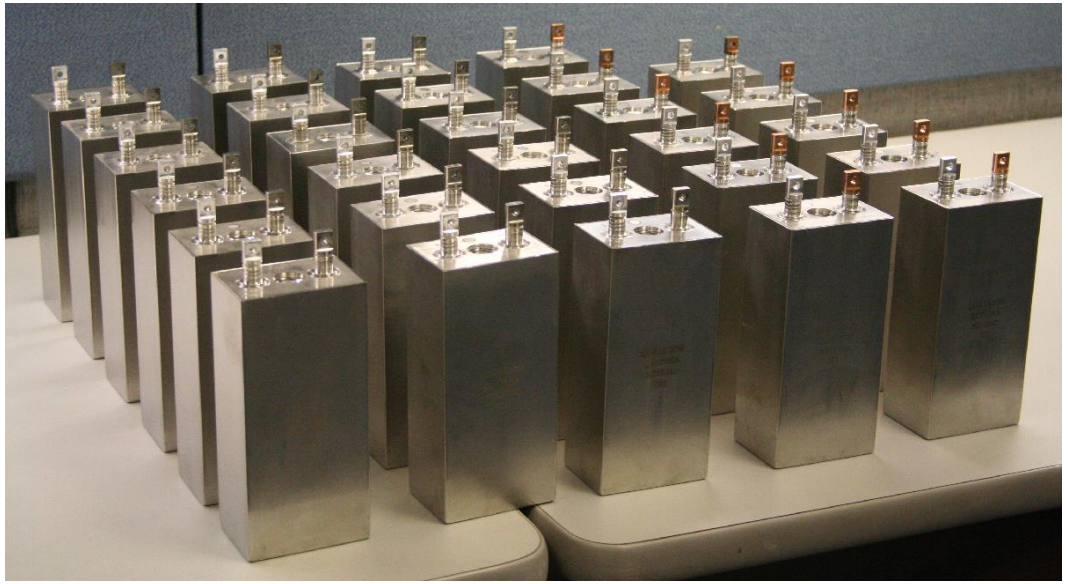
- More than 90% capacity retention after 2000 cycles at 100% DOD

Cell Production Overview

Prismatic and cylindrical

72 Ah Prismatic Cell

72 Ah Cell (QL075KD) Cells



- Gen I and Gen II Chemistry
- True-Prismatic
- Zero-Volt enabled
- Line Capacity of over 4,000 72 Ah Cell/year

Quallion Long Life 18650 Cell

- **Targeted**
  - Heritage chemistry from long life medical and aerospace cells
  - Full domestic control of active materials and manufacture
  - 40% DOD for 45,000 cycles with 70% retained capacity
  - Wide range temperature operation (-40 ~ 60°C)
  - Excellent zerovolt storage capability

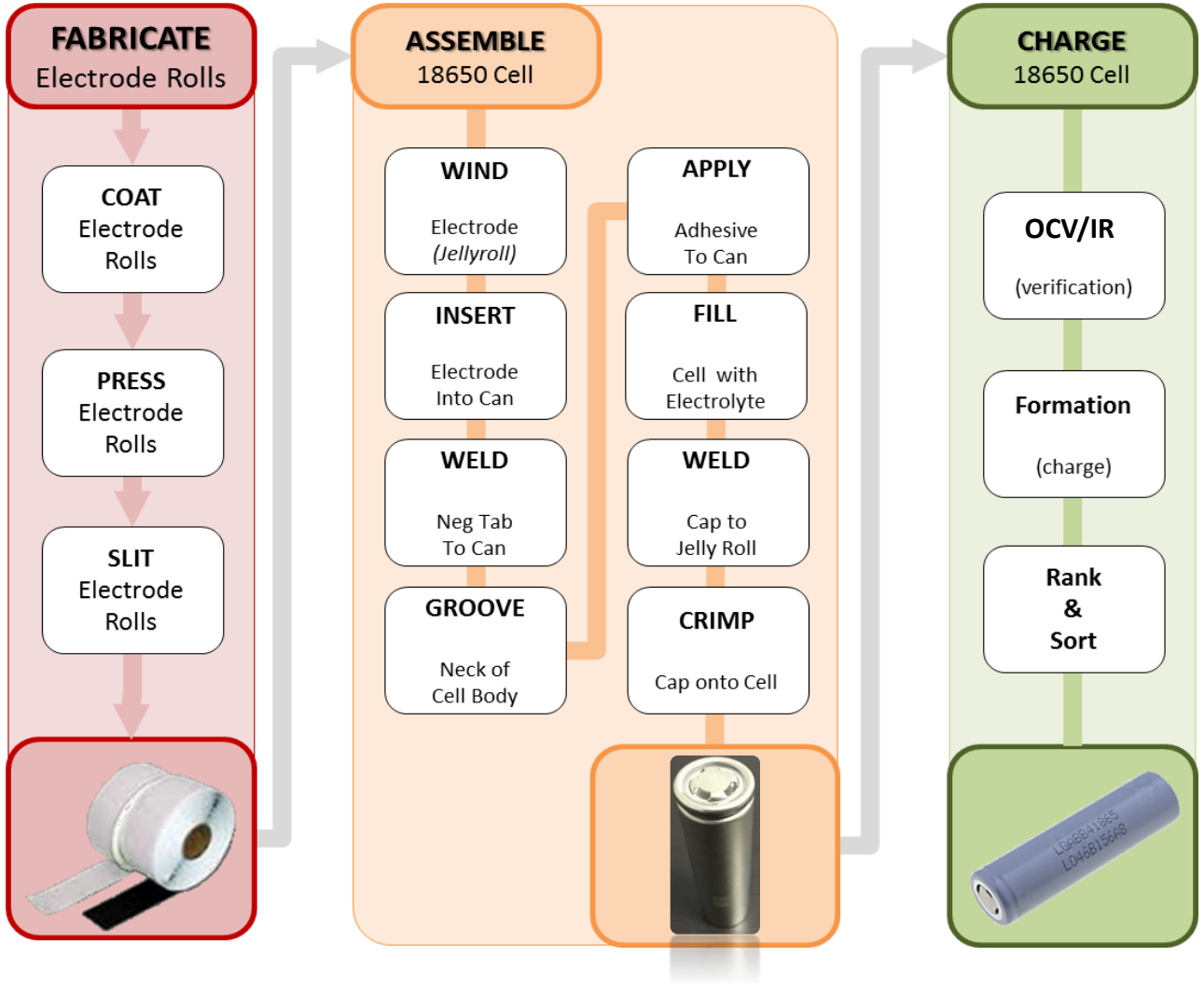
Cell Specifications	
Capacity / Energy Density	• 1.4 Ah / 118 Wh/kg (UN/UL/IEC certified) • 1.35 Ah / 115 Wh/kg (in test) • 2.3 Ah / 200 Wh/kg (in test) • 4.4 Ah / 350 Wh/kg (in development)

18650 Cell Manufacturing Overview

Roll to roll continuous coating

Auto winding station

- **Full automation: < 35 sec/cell**
- **Supply**
  - Electrode rolls
  - Separator rolls
  - Tab rolls
  - Tape rolls
- **Included process**
  - Tab welding
  - Electrode cutting
  - Winding
  - Taping



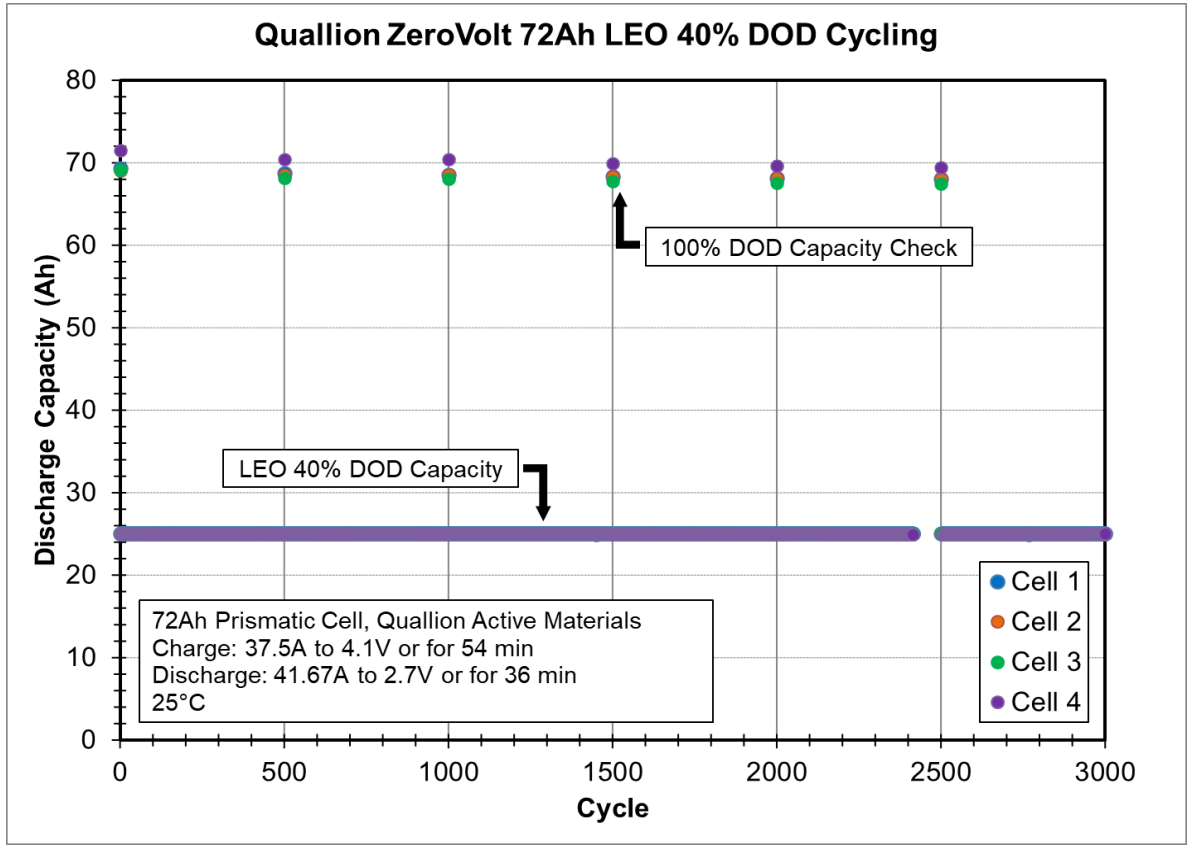
Negative weld station

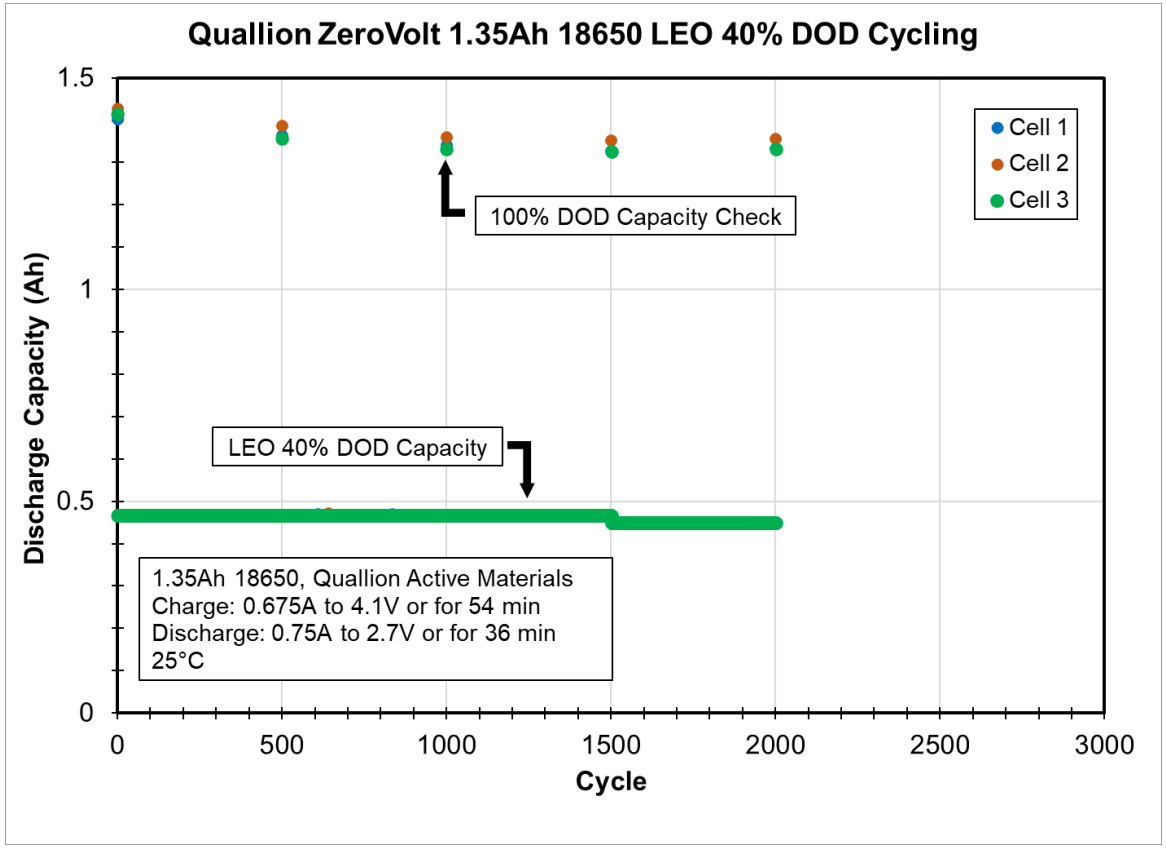
Grooving and sealant application station

Filling station

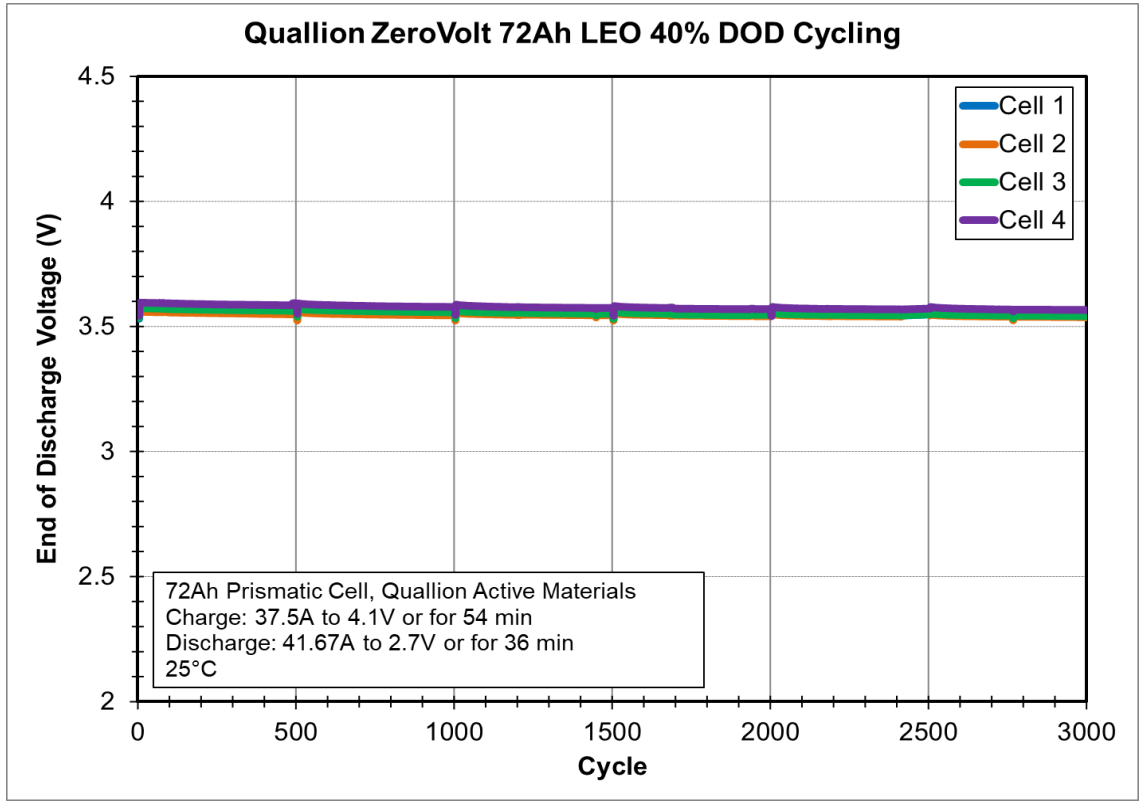
Positive weld and crimping station

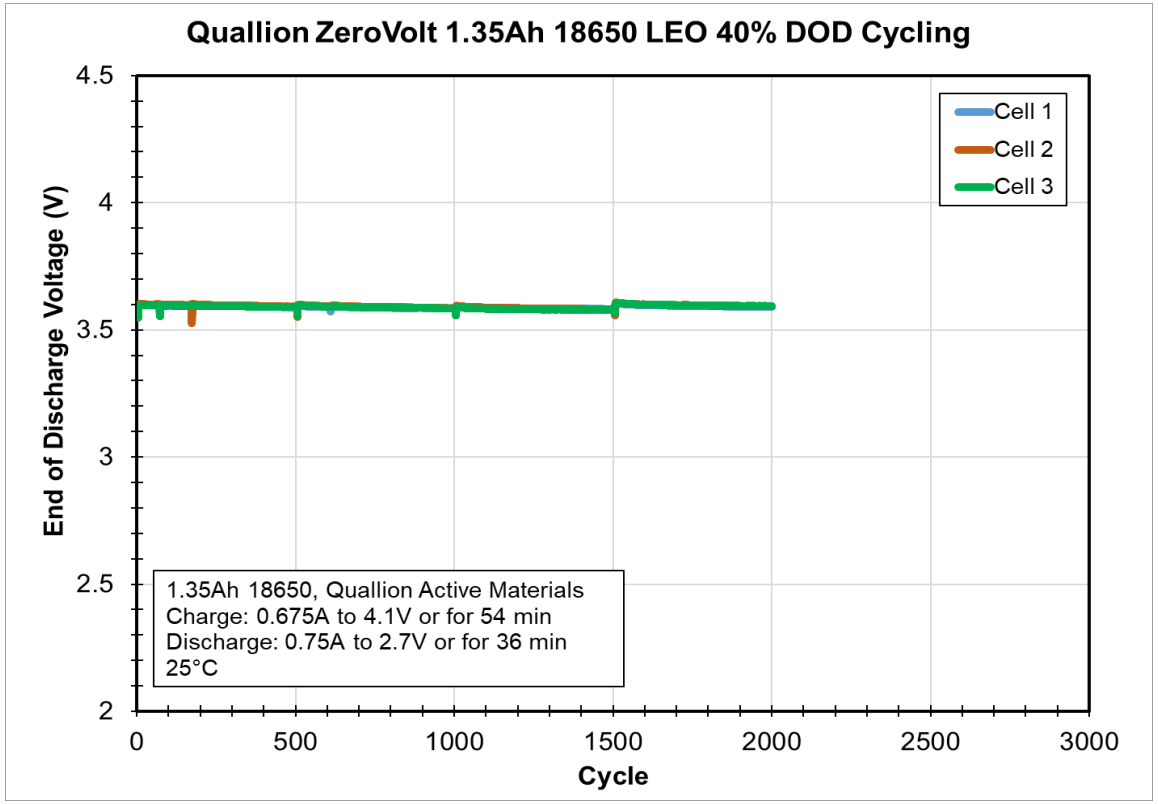
LEO 40% DOD Cycle Performance -72Ah Cell and 1.35Ah 18650 Cell-



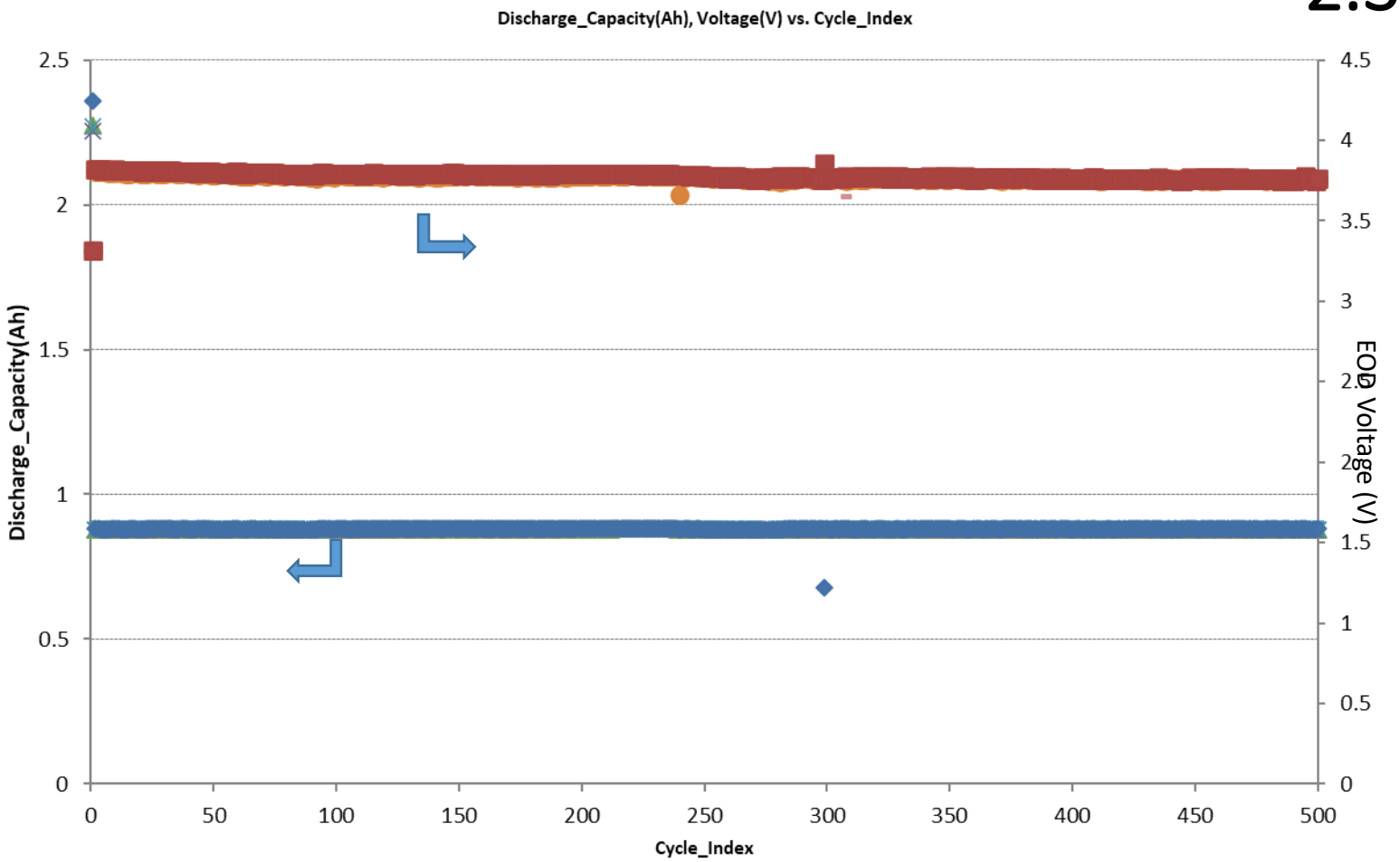


LEO 40% DOD Cycle Performance -72Ah Cell and 1.4Ah 18650 Cell-





C/2 40% DOD Cycle Performance -2.3Ah 18650 Cell-



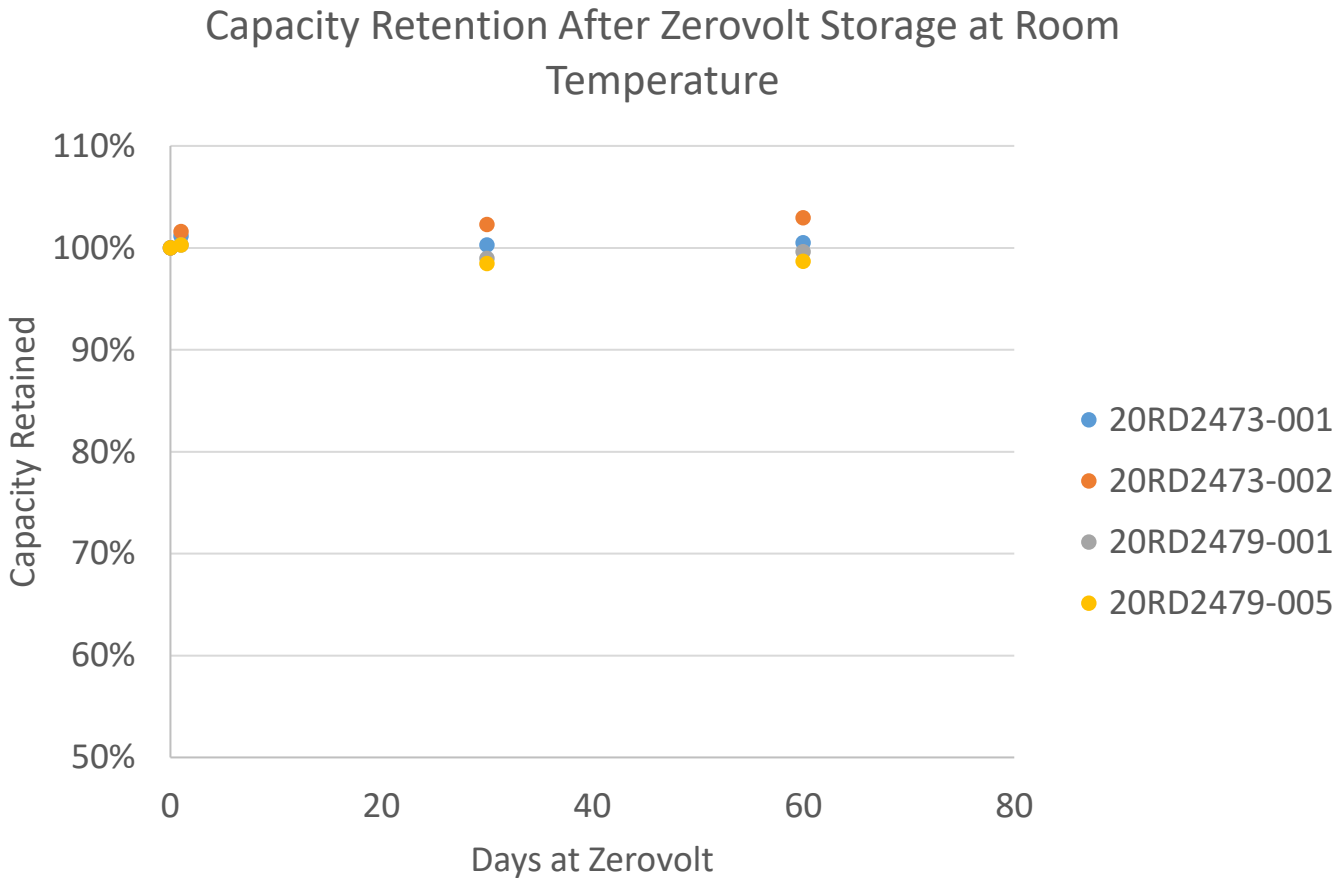
Test condition

All at 23°C

1. CC Charge at 1.15A (0.5C)
2. CV Charge at 4.2V to 0.023A
3. Rest for 10min
4. CC Discharge at -1.10A (0.5C) for 48min

- No change in EOD voltage at 40% DOD after 500 cycles

Zerovolt Storage Performance -2.3Ah 18650 Cell-



Capacity Check

1. CC Charge at 0.23A
2. CV Charge at 4.2V to 0.023A
3. Rest for 10min
4. CC Discharge at -0.115A to 2.7V

Zerovolt storage

1. CC Discharge to 0V at 0.23A
2. CV Discharge at 0V to 0.023A
3. Connect to 100ohm resistor

- No capacity changes after 60 days

Summary

- LCO/NCA precursor and LCO/NCA final lines demonstrated >200 kg/month (max 500 kg/month) Capacity.
- The cathode production line can accommodate higher Ni NCA, NMC and NMCA
- MCMB capacity of 200kg/month target was reached.
- Physical properties of LCO/NCA/MCMB meet the specifications.
- Electrochemical performances of LCO/NCA/MCMB match the control.
- Domestic 18650 line has been installed giving complete vertical integration from raw materials to cell manufacturing.
- Excellent cycle Life performances were demonstrated for 1.4Ah, 1.35Ah and 2.3Ah 18650 cells.

We are at the forefront to provide high quality domestic materials and cells at a commercial level

Next Focus

- Development of higher energy density cell with 350Wh/kg..
- Getting all the components from the US..
- Scale..

Thank you for your attention!