

Advanced ALD Coated Lithium-Ion Batteries

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Introduction

- Forge Nano is the industry leader in Atomic Layer Deposition (ALD)
- ALD coating is the process of material coating at the molecular level applying an uniform and consistent coating.
- Forge Nano is the only company capable of performing ALD coatings to scale
  - Forge Nano ALD is capable of coating numerous materials on various materials and products.
  - I am focused on ALD coating on battery anode and cathode powders to improve the performance of the lithium-ion battery cells
- In this presentation I will:
  - Address the performance benefits of ALD coatings on battery materials
  - Provide an introduction on a new Forge Nano developed ALD 0V performing cell.

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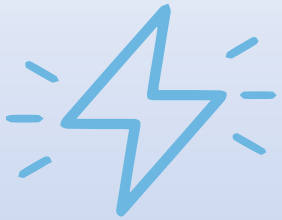
The Nanocoating Makes Batteries Better

High Energy Density



~20%
increase in range for same battery size and chemistry

Increased capacity and voltage

Increased Lifetime



2-10x
increase in cycle life(1)

Lower degradation rate of time

Safer



50%
decrease in heat generation(2)

Decrease rating to
EUCAR 3(1)

More temperature tolerant and lower fire risk

Faster Charge



10 minute
fast-charge without sacrificing battery life

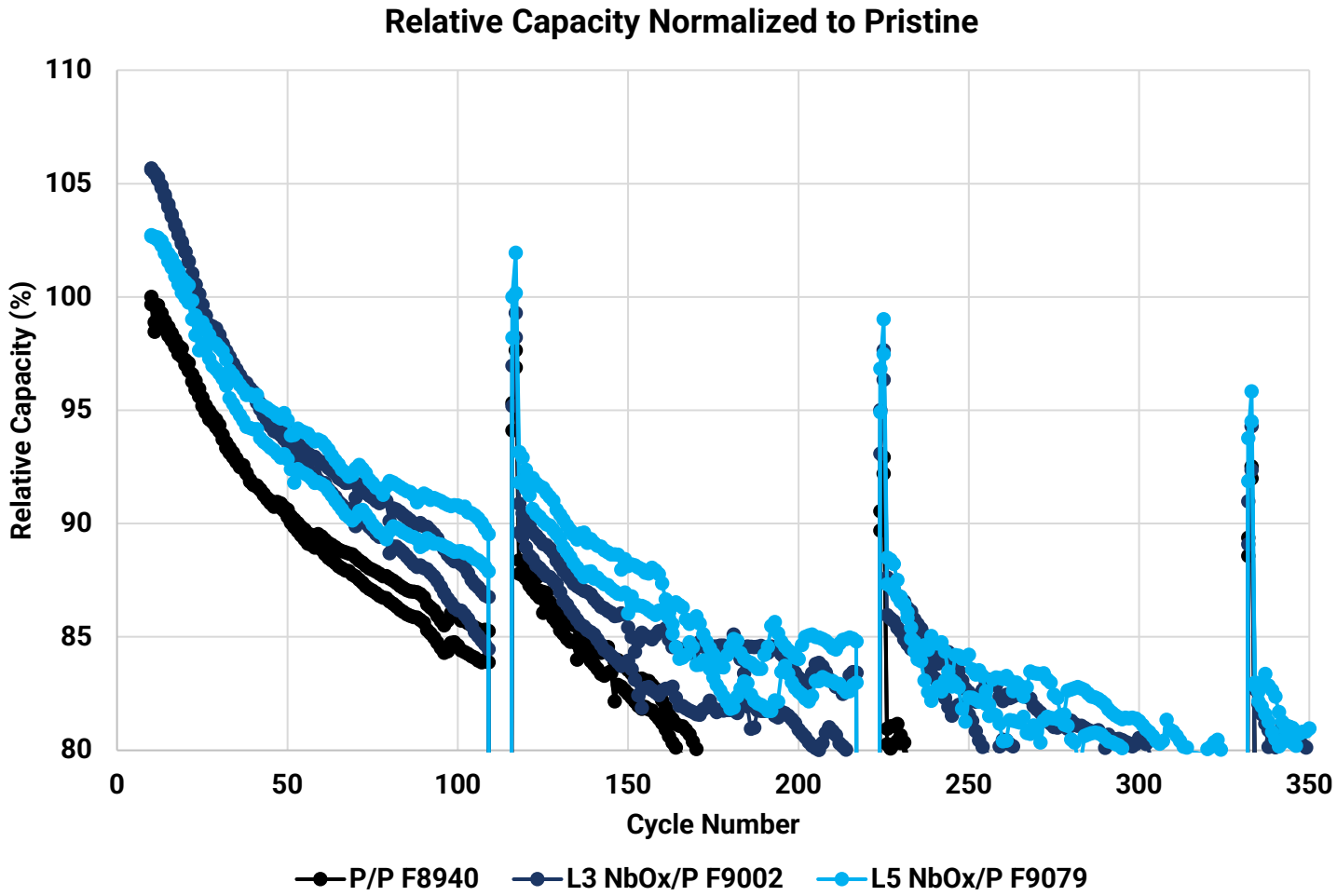
Allows for higher charge voltage

(1) Independently validated by major auto manufacturer.
(2) Quantified by % reduction in exothermic energy from arc test.
(3) Projected for full-scale production based on detailed cost modeling.

ALD Benefits on NMC811 Cathode Materials

Niobium Oxide increases BOL capacity by 5% and cycle life by 77%

Testing Conditions
Counter Electrode: Natural Graphite **Loading**: 10 mg/cm2 **Temperature**: 30°C ***Voltage: 3.0-4.2V*** **Cycling Condition**: CC-CV until C/20 **Formation**: x3 0.1C/0.1C **Pulse DCIR:** at 60% SOC every 100 cycles **SOH**: x2 0.1C every 100 cycles ***Cycling: 0.5C/1C***



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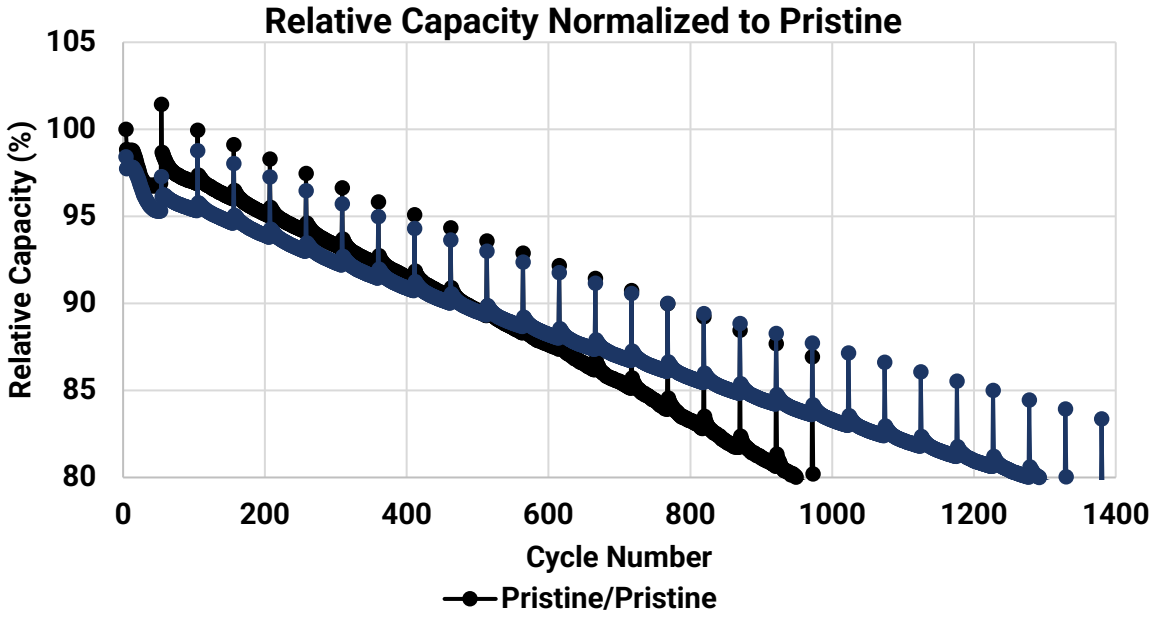
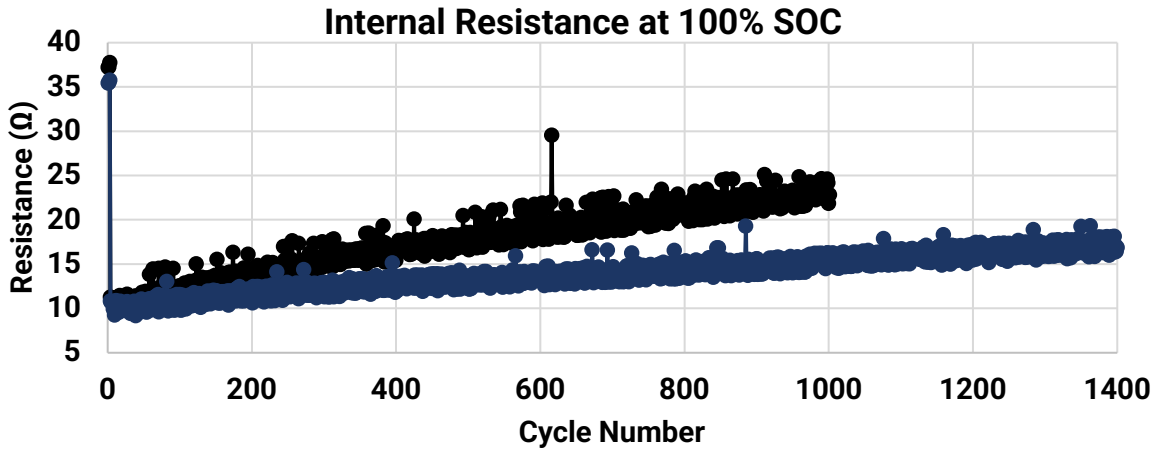
ALD Benefits on NMC811 Cathode Materials

ALD increased lifetime by 37% and reduced resistance growth by 36%

Testing Conditions
Counter Electrode: Natural Graphite
Loading: 20 mg/cm2
Temperature: 30°C
Voltage: 3.0-4.2V
Cycling Condition: CC-CV until I<C/20
Formation: x3 0.1C/0.1C
SOH: x1 0.33C every 50 cycles
Cycling: 0.5C/0.5C

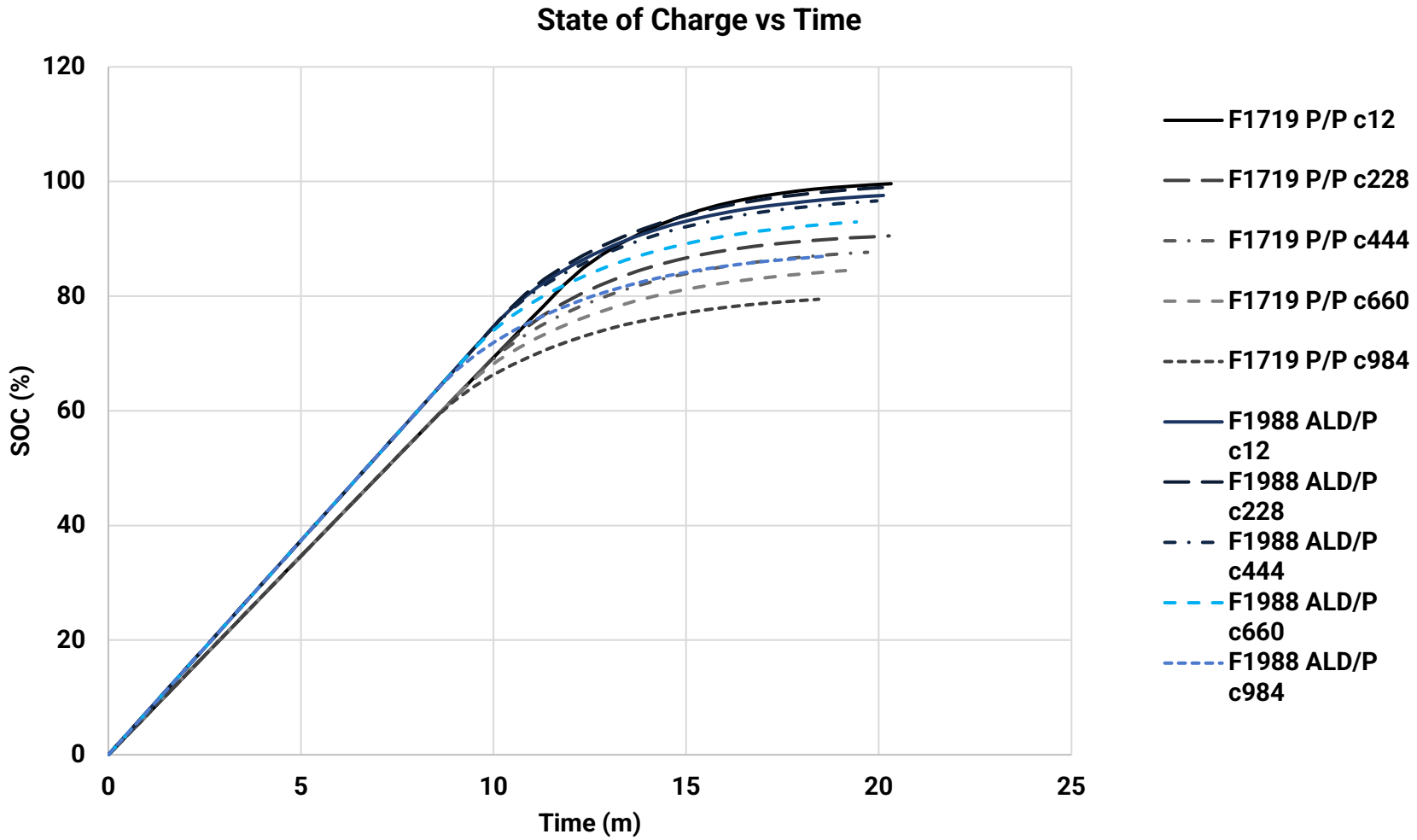




ALD Benefits on NMC811 Cathode Materials

ALD reaches 80% SOC in 11 minutes

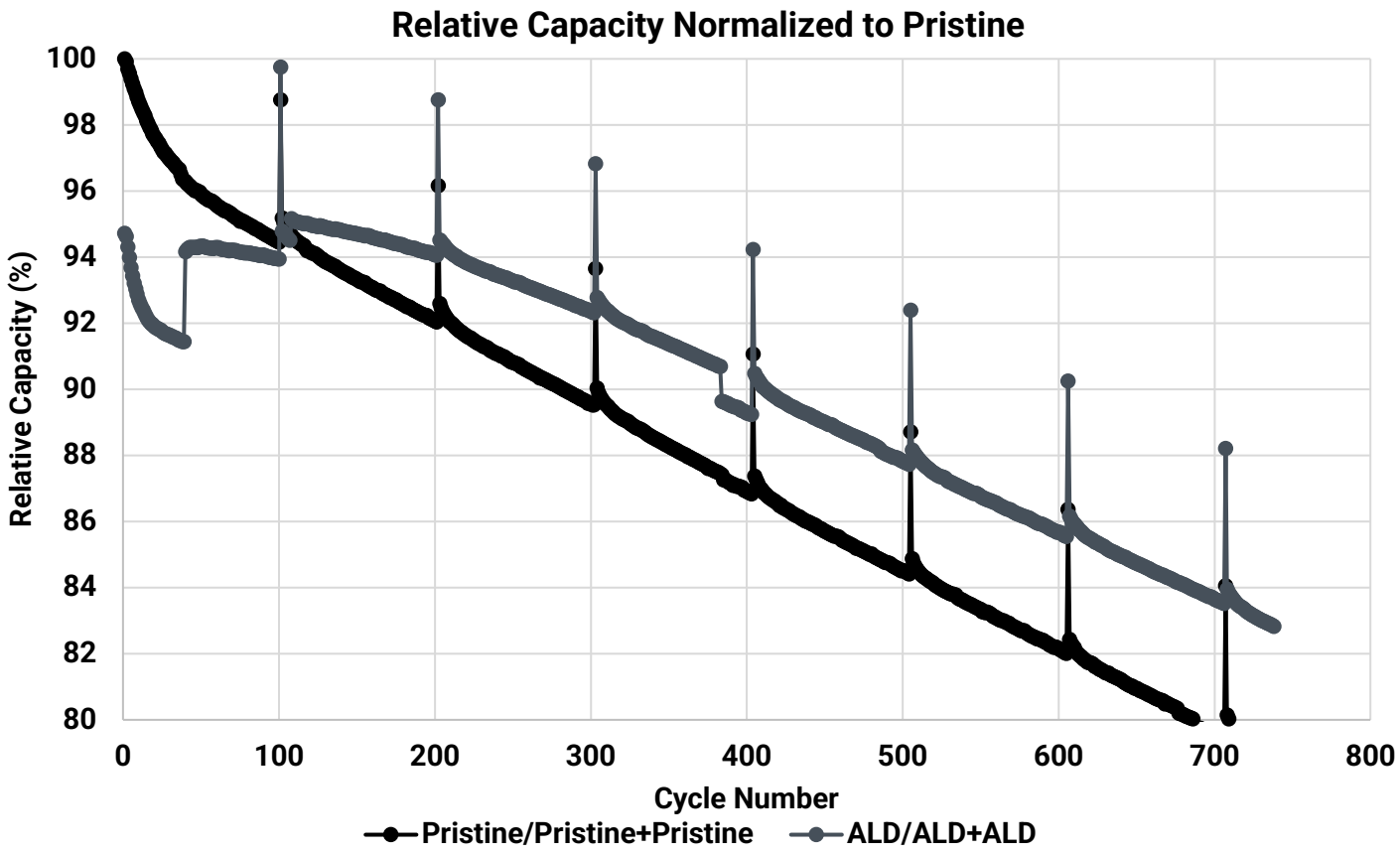
Testing Conditions
Counter Electrode: Natural Graphite **Loading**: 10 mg/cm2 **Temperature**: Ambient ***Voltage: 3.0-4.2V*** **Cycling Condition**: CC-CV until C/20 **Formation**: x3 0.1C/0.1C **Pulse DCIR:** at 60% SOC every 100 cycles **SOH**: x2 0.1C every 100 cycles ***Durability: 4C/1C***



ALD Benefits on NMC811 Cathode Materials and Graphite/Silicon Anode Materials

ALD on Anode and Cathode increased capacity retention (energy density) and cycle life

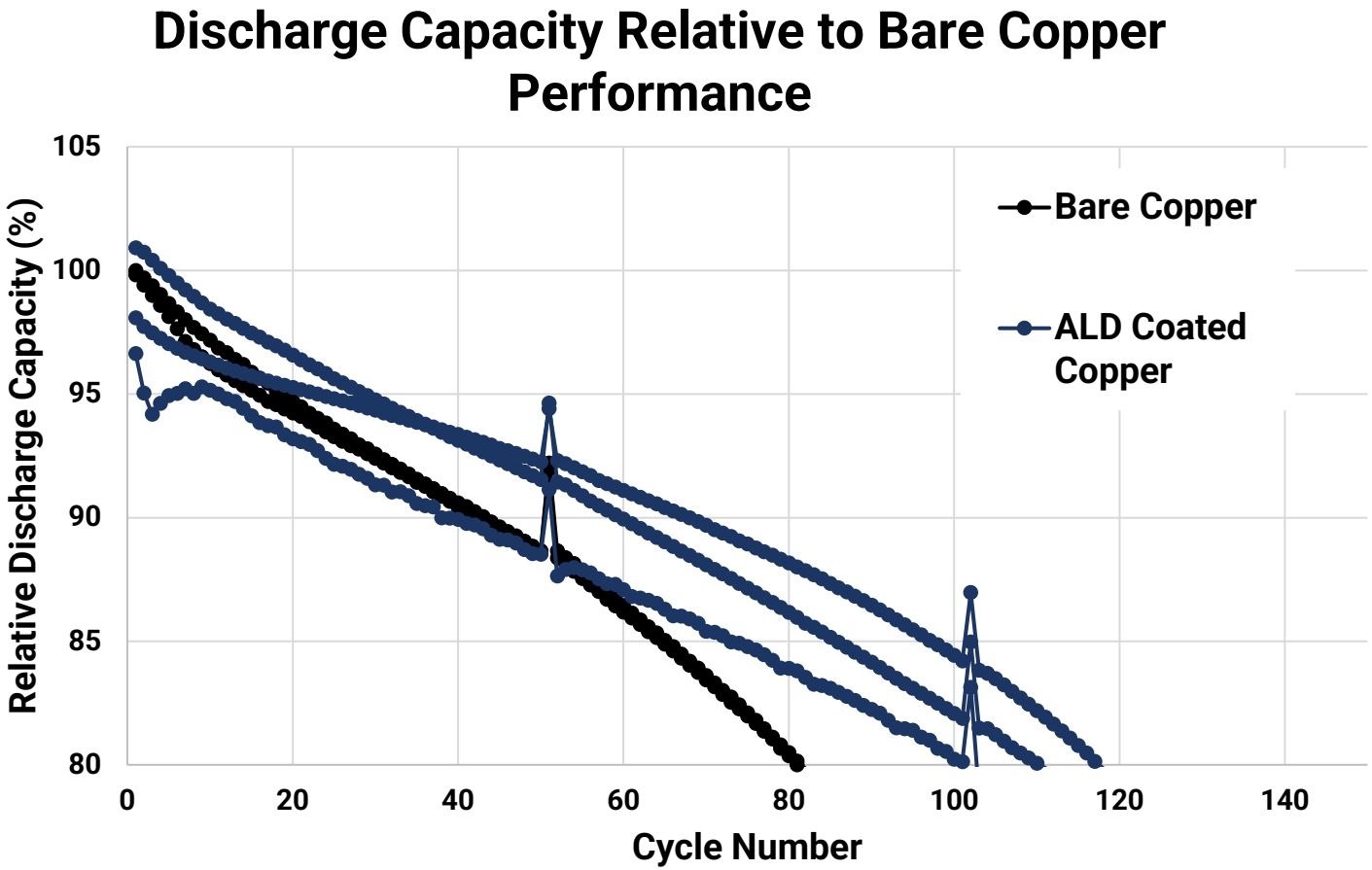
Testing Conditions
Counter Electrode: Silicon + Natural Graphite **Loading**: 10 mg/cm2 **Temperature**: 30°C ***Voltage: 2.5-4.2V*** **Cycling Condition**: CC-CV until C/20 **Formation**: x3 0.1C/0.1C **EIS**: at 40% SOC every 50 cycles **SOH**: x1 0.33C every 50 cycles ***Cycling: 0.5C/1C***



Benefits of ALD Coatings for New 0V Cell Technology

- ***TiN coated Cu extends cycle life compared to bare Cu when cycling between 0-4.4V***

Testing Conditions
Material: NMC 811 vs Natural Graphite **Temperature**: 30°C **Cycling Condition**: CC-CV until C/20 **Formation**: 3.0-4.4V x3 0.1C/0.1C **SOH**: x1 0.33C every 50cycles ***Cycling: 0-4.4V 0.5C/1C***



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Thank you for your interest

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