



400+ Wh/kg Safe Lithium-Ion Cells with
Silicon Nanowire Anode Technology

Ionel Stefan
CTO, Amprius Technologies, Inc.
1180 Page Ave., Fremont, CA

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AMPRIUS TECHNOLOGIES, INC.

- Established Leader in Silicon Anode Technology
- High performance Li-Ion Cell for premium applications

ENABLING TECHNOLOGY

Pioneers and established leaders in silicon anode materials and high energy density lithium ion batteries

- 2008 Company founded at Stanford
- 2009 First Funding
- 2018 First Commercial Product

BEST PERFORMANCE

Highest energy density lithium-ion cells

1200
Wh/liter

450
Wh/kg

100%
Silicon nanowire
anode

50+
Independent patent filings
on nanowire technology
and lithium-ion cells

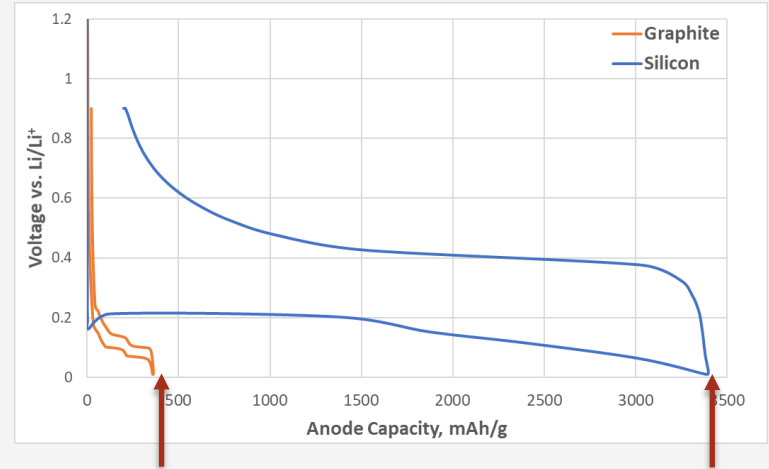
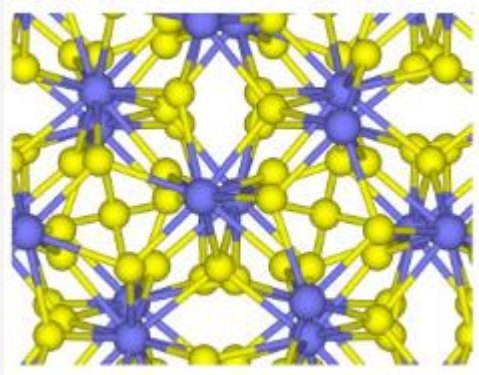
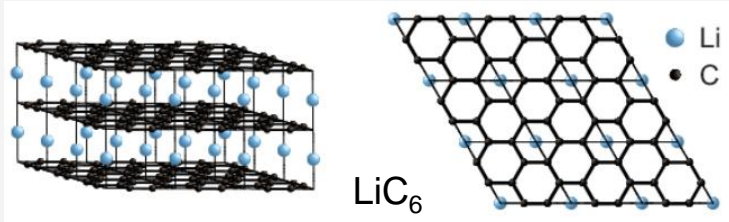
COMPREHENSIVE PLATFORM

Technology platform includes entire ecosystem for optimal performance:

- Scalable silicon nanowire anode manufacturing
- Advanced Electrochemistry
- Highest energy cell designs

SILICON ANODE - HIGHEST LITHIUM STORAGE CAPACITY

Intercalation vs. alloying



372
(theoretical Graphite)

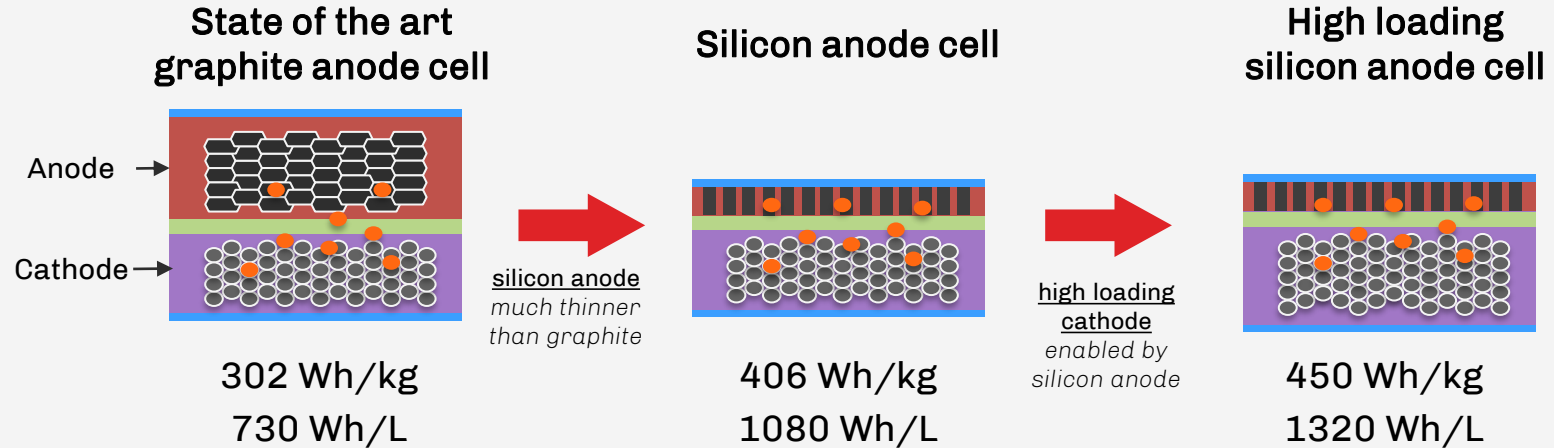
3400 (Si Nanowire)
3569 (theoretical Si)

- AMPRIUS SILICON CLOSE TO THEORETICAL CAPACITY
- 94% FIRST CYCLE EFFICIENCY

SILICON ADVANTAGE VS. GRAPHITE

80%+ advantage in energy density (Wh/L)

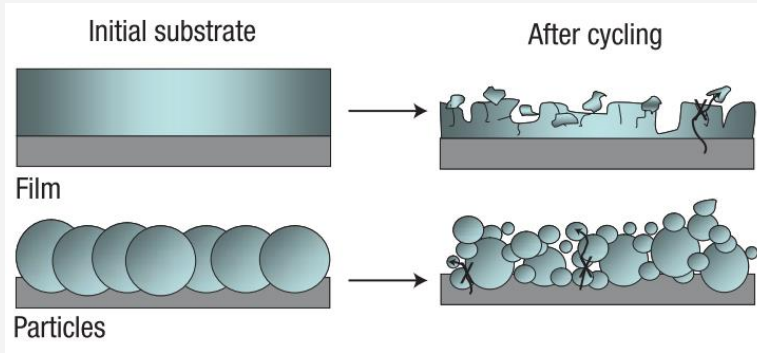
50%+ advantage in specific energy (Wh/kg)



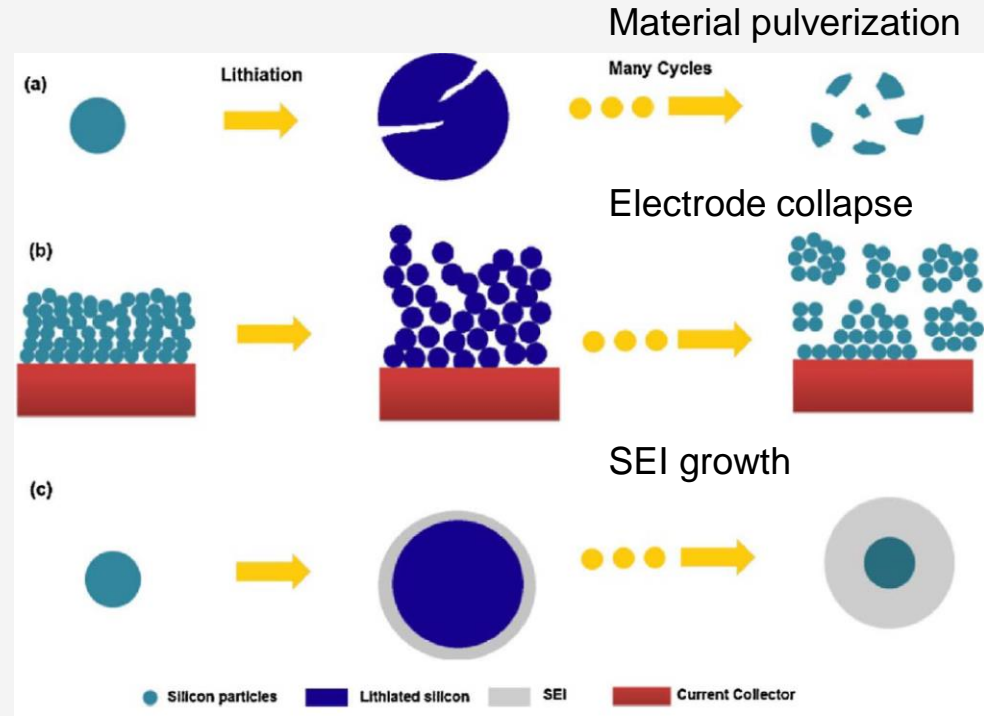
- The silicon nanowire anode is a direct replacement for the graphite anode
- High loading advanced cathode designs only possible with silicon anode

SILICON MATERIALS - THE SWELLING PROBLEM

Anode	Capacity	Swelling
LiC_6	372 mAh/g	10%
$\text{Li}_{15}\text{Si}_4$	3569 mAh/g	270%



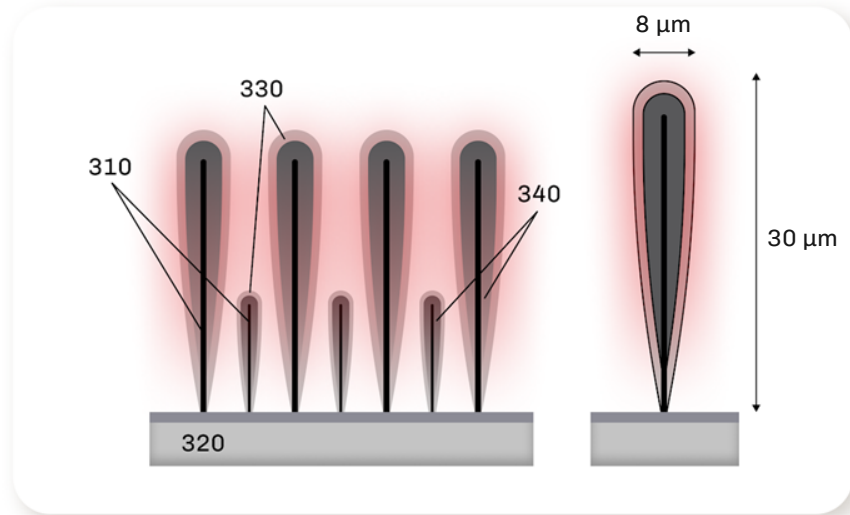
C.K. Chan, H. Peng, G. Liu, K. McIlwrath, X.F. Zhang, R.A. Huggins, Y. Cui, Nat. Nanotechnol. 3 (2008) 31–35.



K.M. Abraham, J. Phys. Chem. Lett. (2015) 830–844.

THE AMPRIUS SILICON NANOWIRE ANODE SOLUTION

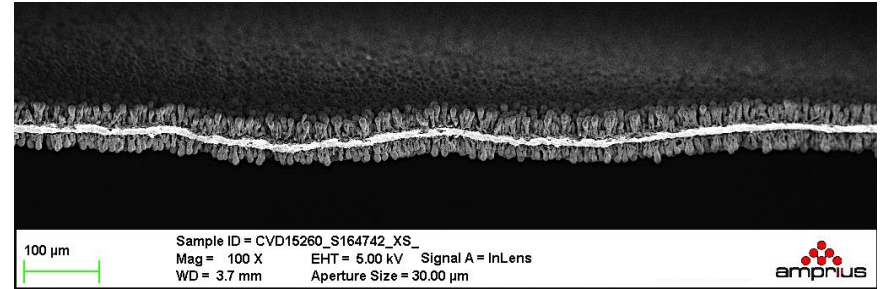
A New Structure for 100% Silicon Based on Nanowires



310 - Conductive nanowire grown from substrate

340 - Bulk coating of low density, porous amorphous silicon

330 - Thin layer of high-density amorphous silicon



KEY BENEFITS

- Micro & Macro porosity- solves swell problem
- Nanowire rooted mechanically and electrically continuous with substrate
- Stable Solid Electrolyte Interphase (SEI)

MANUFACTURING: ROLL-TO-ROLL FOR SILICON NANOWIRE ANODE PRODUCTION

Pilot Scale Manufacturing – demonstrated scalability with Pilot Tool

Bare Foil In and Finished Anode Out



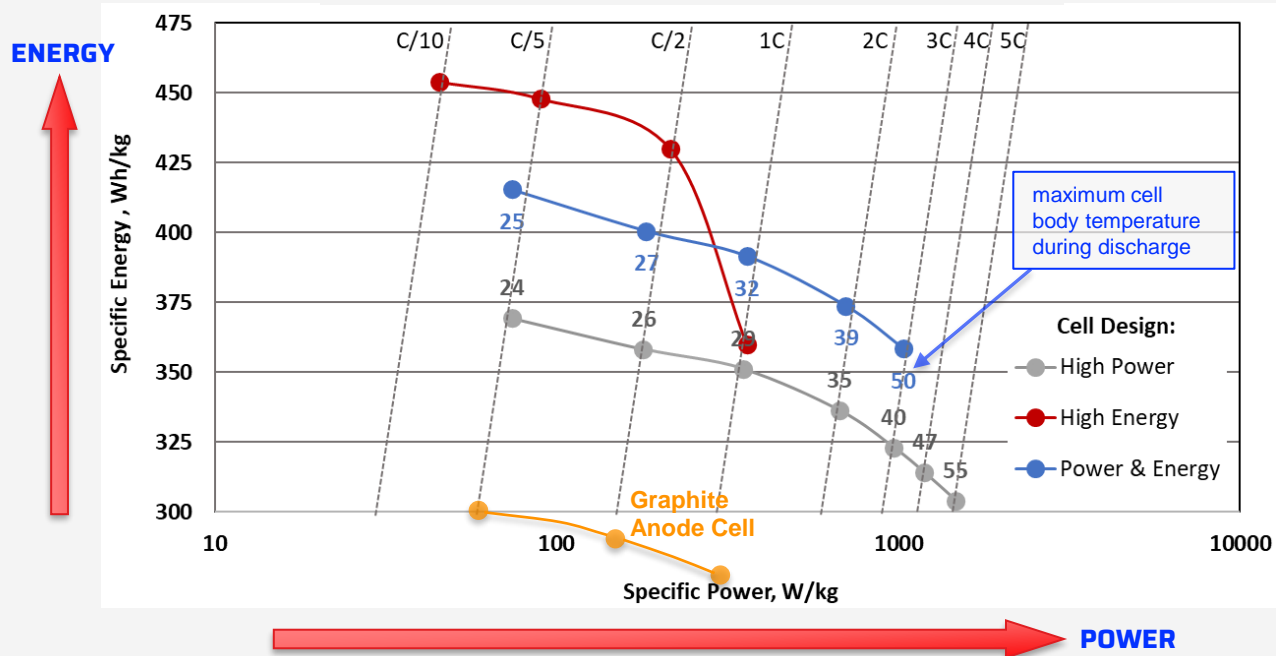
Replaces:

- powder mixing
- slurry preparation
- roll coating (2X)
- drying
- calendaring

HIGH ENERGY AND POWER CAPABILITY

Amprius' cells deliver high energy and power densities

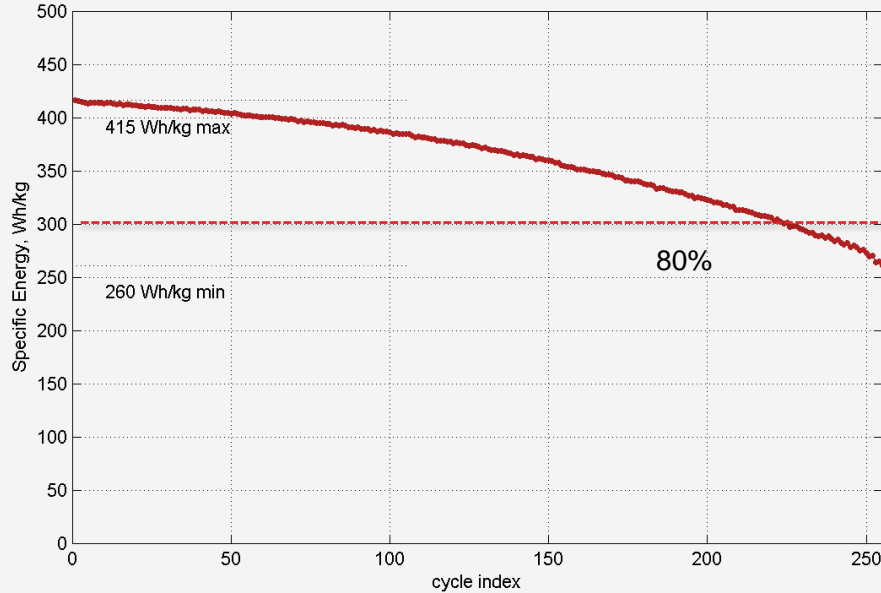
Silicon Nanowire//LCO Ragone Plot



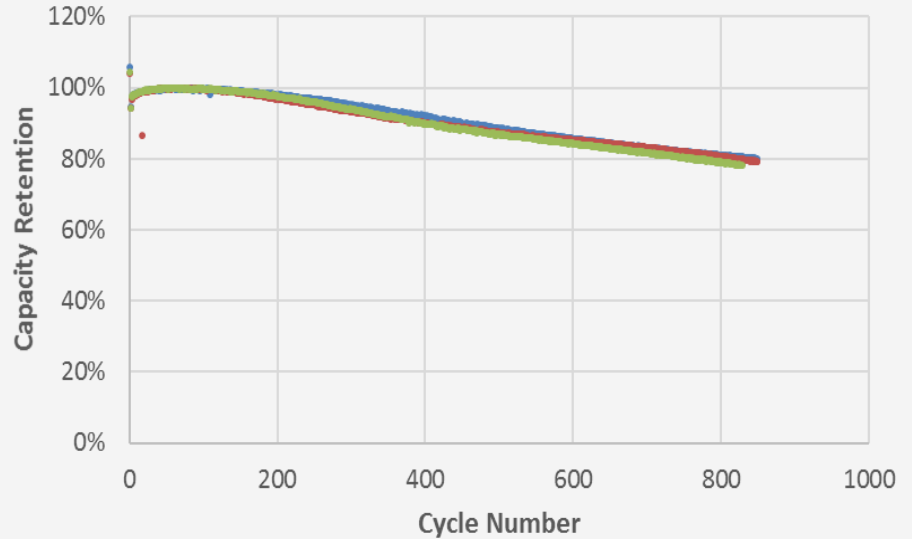
MULTIPLE CHEMISTRIES WITH LONG CYCLE LIFE

Electrolyte formulations and electrode matching critical to performance

Si/High Voltage LCO



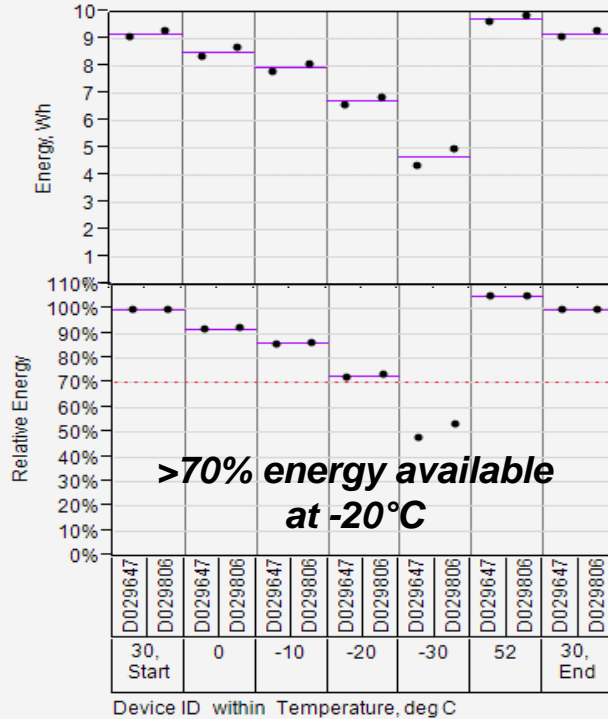
Si/NCA



Silicon cycle life can match graphite

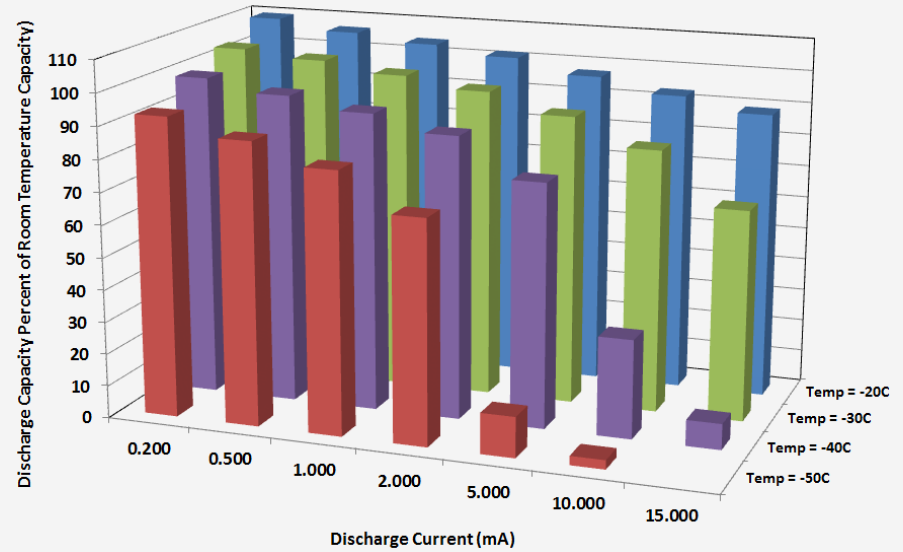
LOW TEMPERATURE PERFORMANCE

Cell designs for mainstream and niche applications



Si/NMC for EV

Charge and Discharge at -50°C

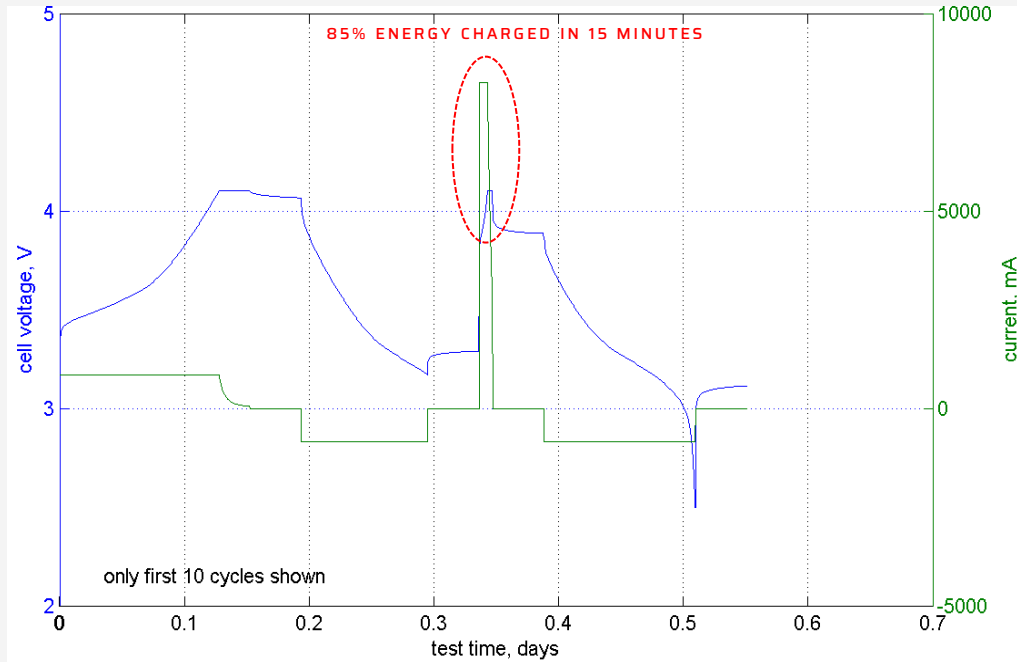


Si/NCA for space

HIGH RATE CHARGE

10 Ah cells, Si/NMC chemistry

Silicon nanowire anode is best for fast charging due to lower thickness



- Charge for 15 minutes at 3.2C rate
- 85% energy restored in 15 minutes
- 99.5% energy restored in subsequent normal full cycle

EXAMPLE PRODUCTS

High Power capability with highest energy density and specific energy

Applications	HAPS, portable power, CE	Long Endurance Drones, eVTOL, UAM	High power drones	EV, Electric Flight
Dimensions (T x W x H) mm	Si/LCO Platforms			Si/NMC
	High Energy 0.5C max rate	Power-Energy 3C max rate	High Power 6C max rate	Power-Energy 2C max rate
4.5 x 50 x 55	420 Wh/kg 1125 Wh/L	415 Wh/kg 1040 Wh/L	365 Wh/kg 875 Wh/L	400 Wh/kg 950 Wh/L
5.4 x 54 x 65	425 Wh/kg 1125 Wh/L	420 Wh/kg 1050 Wh/L		
4.5 x 50 x 105	430 Wh/kg 1240 Wh/L			

Operating temperature range: -20°C to 55°C. Cycle life 150-600 cycles, depending on operating conditions

USE CASES

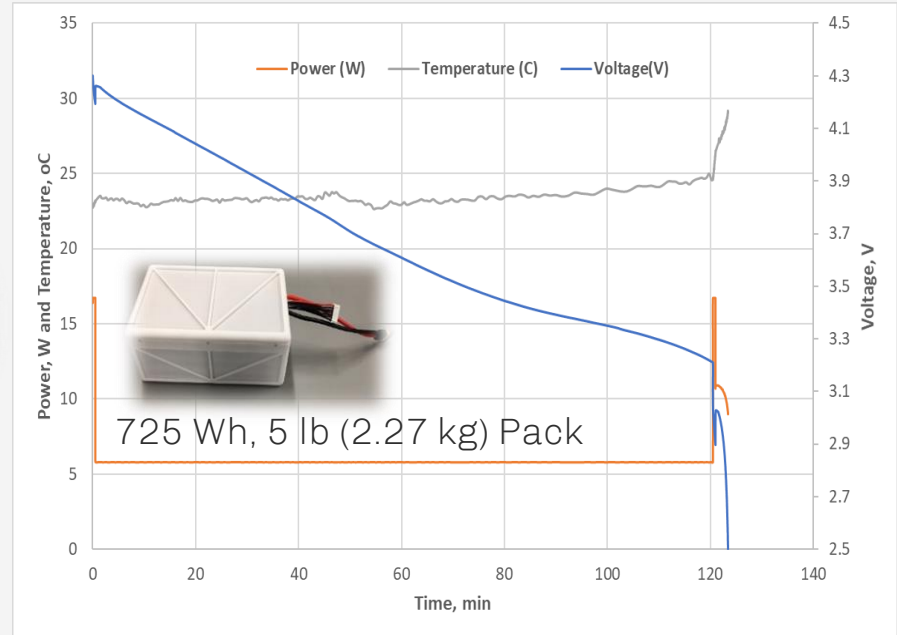
Energy Cells for High Altitude Pseudo Satellites set New World Record for Longest Endurance



"The aircraft has achieved an altitude of 74,000 ft in Arizona and, critically, has remained above 50,000ft at dawn, after a night's flying with no sun to charge its batteries."



USE CASES

High Power Cells Enable Endurance Record for Advanced Drone



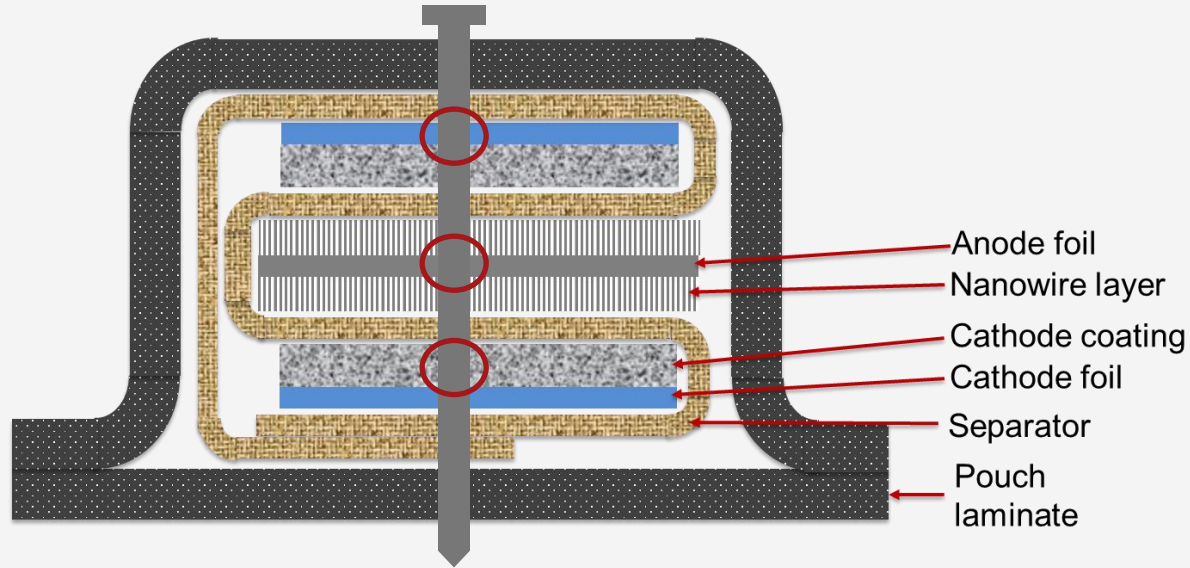
CONFORMAL-WEARABLE BATTERY

2X Energy Content

Specification	CWB-150 (Fielded Model)	Amprius/Inventus CWB (June 2020)
"Flexible" battery		
Energy	148 Wh	300 Wh
Weight	2.6 lb	2.6 lb
Dimensions	8.7" x 7.65" x 0.7"	8.7" x 7.65" x 0.7"
Cells specific energy	201 Wh/kg	395 Wh/kg

UN38.3 certified in 2020, confirmed performance in field test

NAIL PENETRATION MITIGATION STRATEGIES



Break/stop short circuit immediately after penetration – Sotera cathode foil

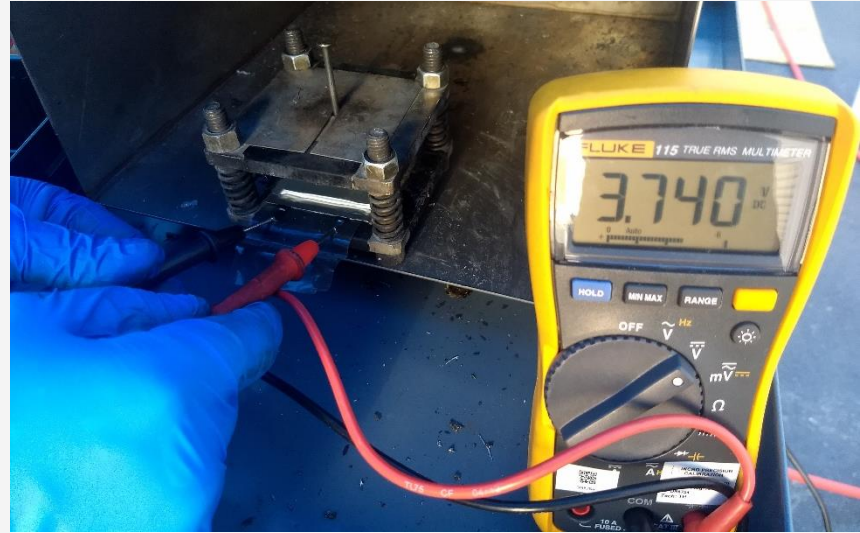
Increase the resistance of the short to allow for local heat to dissipate – cathode structure/formulation

Delay or increase the onset thermal run-away temperature – electrolyte conductivity

Mitigate thermal runaway effects by reducing temperature and flame generation of the process – electrolyte flammability

METALIZED PLASTIC CURRENT COLLECTOR (SOTERIA)

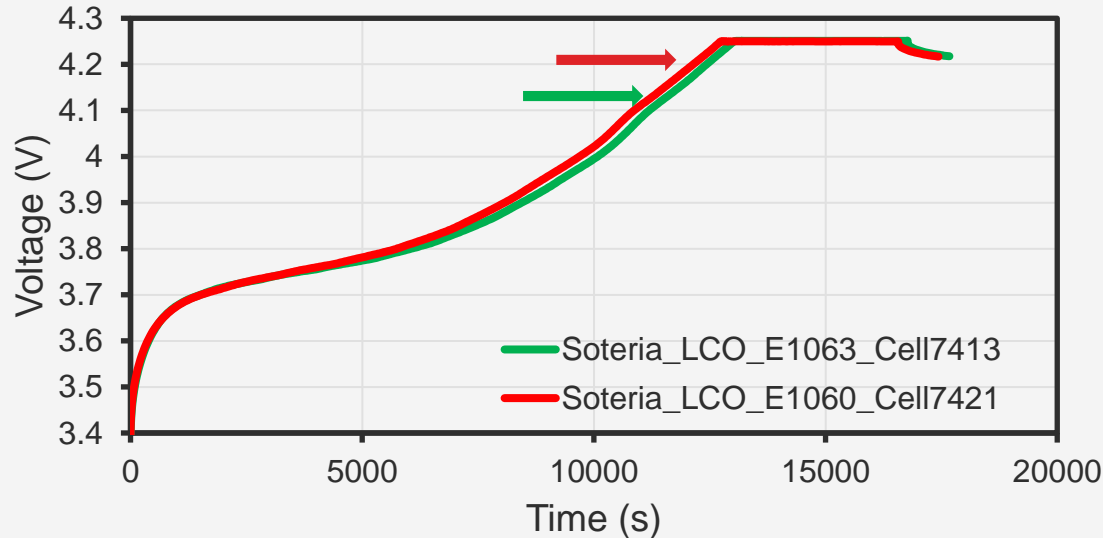
Welding solved for multilayer stacked cells



- Cells functional after penetration up to 80% SOC
- Thermal runaway above 80% SOC

SAFE CHARGING LEVEL

Si/LCO, 1.2 A_C/5



Cell SoC	m_{cell} (g)	Voltage (V)	t_D (min)	T_0 ($^{\circ}\text{C}$)
0% ^c	46.41	3.23	180	–
30%	46.52	3.79	126	175
50%	46.53	3.82	90	174
80%	46.39	4.01	36	140
100%	46.47	4.22	0	122

Chen, et al. *J. Power Sources* **318**, 200–209 (2016).

- Higher energy is not the only cause of faster onset at high SOC – the cathode/electrolyte reactions become exothermic at lower temperature with increasing cell voltage
- Available energy in the first pair of electrodes is important

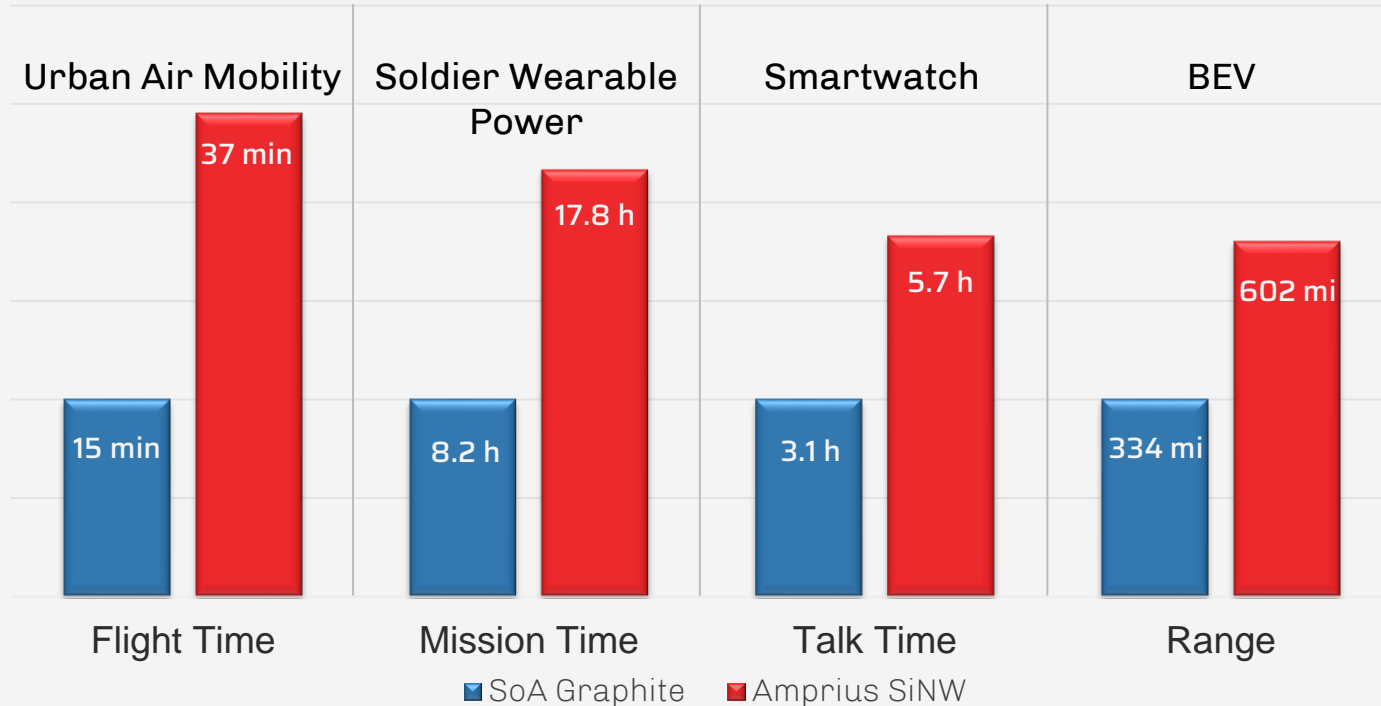
ARE THERE SOLUTIONS FOR 100% SOC ?

Combination of factors are needed – under development

- Electrolyte formulations can delay the onset of thermal runaway
- Separators affect short resistance, some with beneficial effects
- Soteria metalized foils need time to react – other mitigation factors should be added to cell design

SILICON NANOWIRE ANODE ENABLES MUCH GREATER IMPROVEMENT

Game-Changing Advantages in Advanced Applications



Notes:

UAM - estimated flight time based on customer models

Soldier Power - real data based on Conformal Wearable Battery developed for US Army

Smartwatch - customer reported data

BEV - estimated relative to Tesla Model 3 long range battery specifications



SOLUTIONS FOR ADVANCED APPLICATIONS

DISRUPTIVE MARKETS ENABLED BY 100% SILICON NANOWIRE

HAPS

Energy Cells for High Altitude Pseudo Satellites
(Endurance Record for Stratospheric Flight)

Wearables

Cells for Military and Consumer Electronics (future)

DRONES

Power Cells for Quads Enable Very Long Endurance
(World Record with Major Defense Contractor)

UAM

Power Cells for e-VTOL & Enable Urban Mobility

EV

Power Cells for advanced autonomous vehicles (future)

THANK YOU!