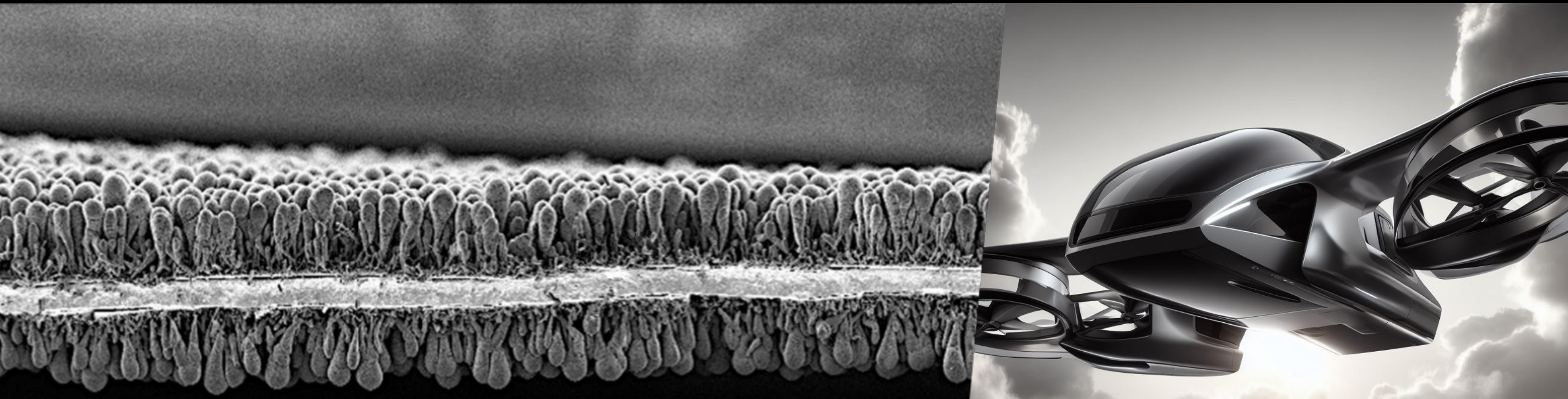


Silicon enabled energy storage with extreme energy and power density

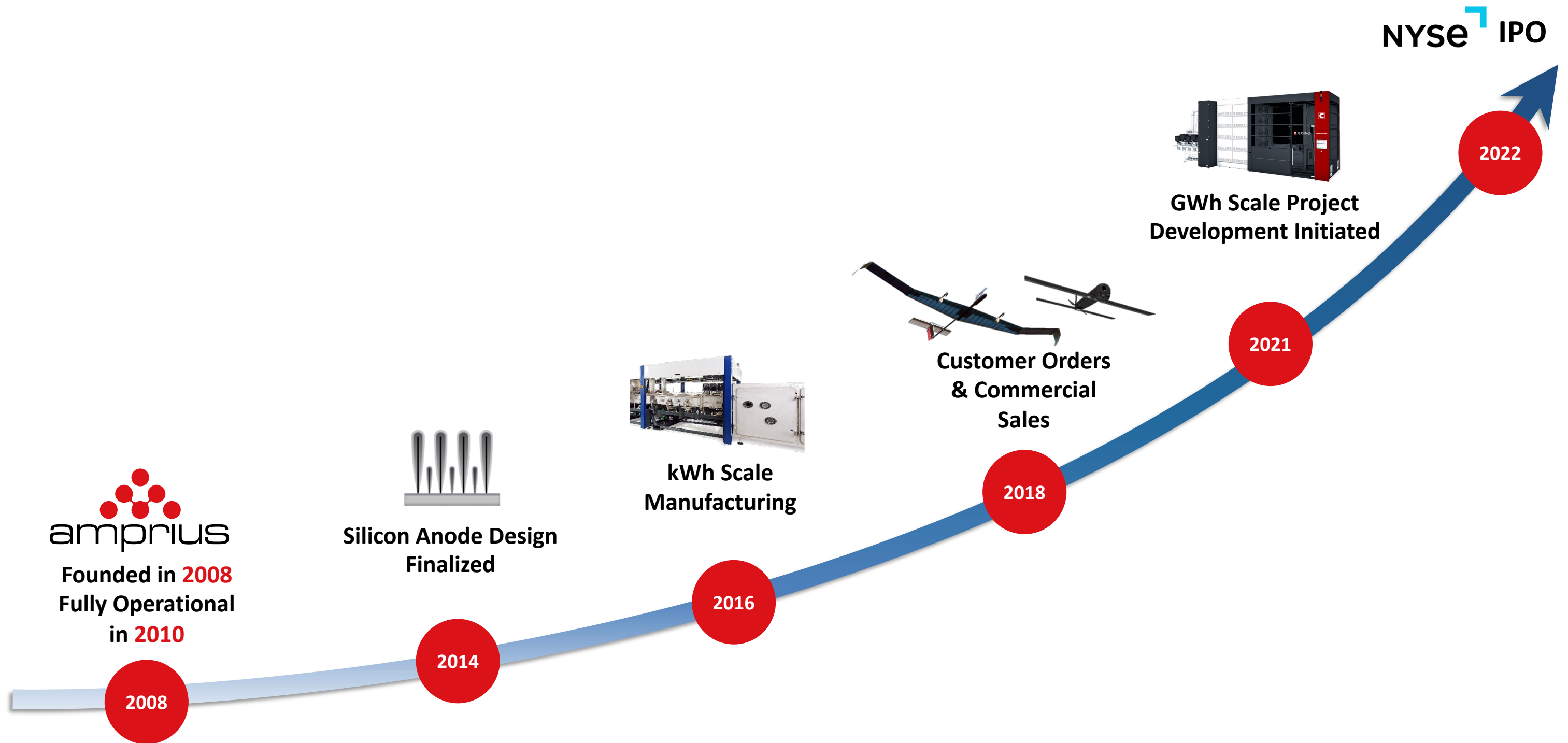


Ionel Stefan
CTO, Amprius Technologies, Inc.
1180 Page Ave., Fremont, CA

2023 NASA Aerospace Battery Workshop

November 2023

A History of Innovation and Achievements



amprius
Founded in 2008
Fully Operational
in 2010

**Silicon Anode Design
Finalized**

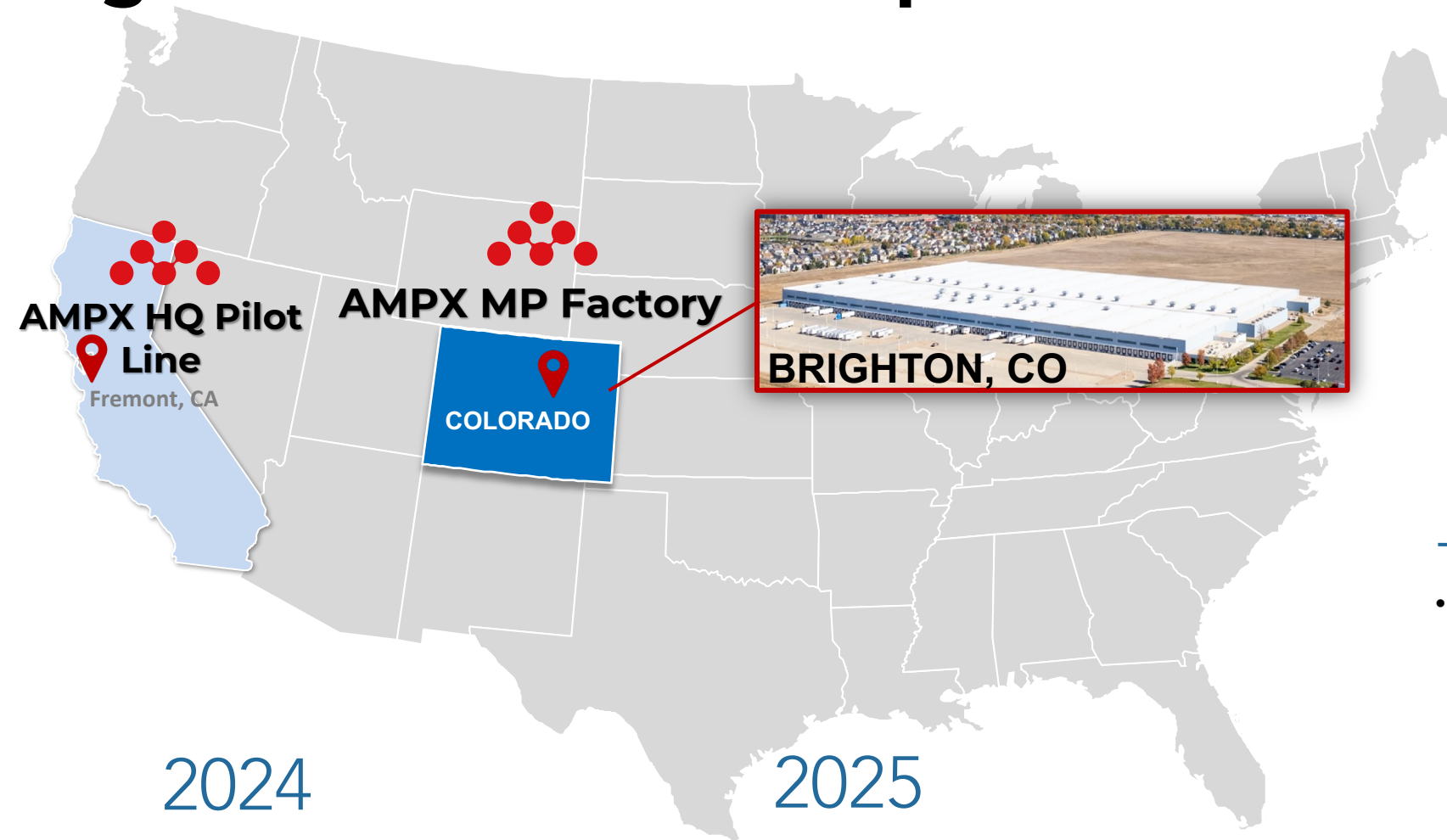
**kWh Scale
Manufacturing**

**Customer Orders
& Commercial
Sales**

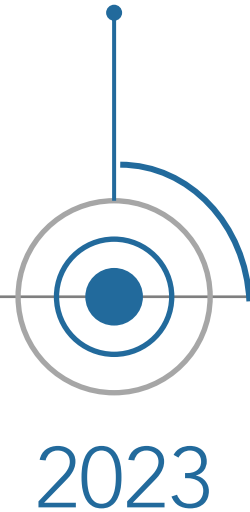
**GWh Scale Project
Development Initiated**

NYSE IPO

US Manufacturing Production Scale Up



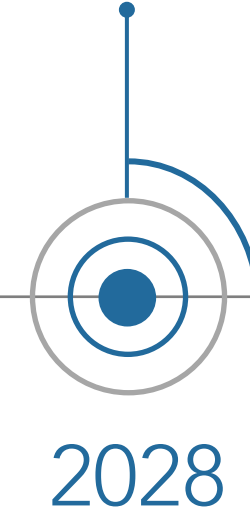
- Lease Signed & Permits Approved in Brighton, CO
- Expansion of Fremont, CA



- 2024
- 2 MWh in Fremont, CA
 - Construction Build-Out in Brighton, CO

- 2025
- Brighton, CO Factory On-Line 500 MWh

- 8 GWh Production in Brighton, CO



Amprius Utilizes Existing Commercial Manufacturing Processes

- ▶ Only Change is to the Anode Manufacturing Line
- ▶ Cathode and Assembly Lines are Unchanged

SILICON NANOWIRE ANODE



Proprietary Deposition

STANDARD CATHODE



Mixing

Coating

Calendaring

STANDARD BATTERY ASSEMBLY



Slitting

Stacking

Formation

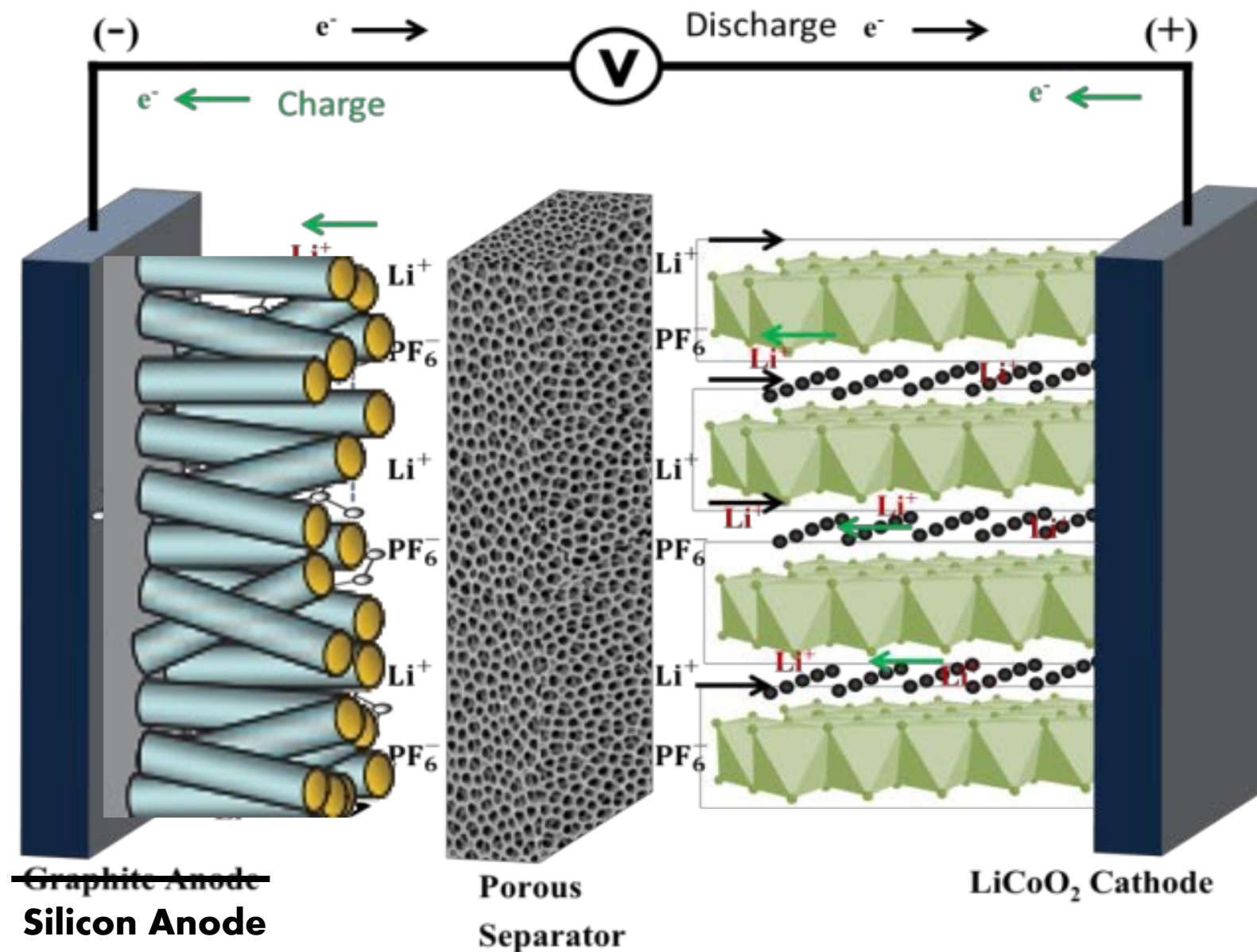


**SILICON NANOWIRE ANODE
MANUFACTURING LINE**

**STANDARD BATTERY
MANUFACTURING LINE**

AMPRIUS REPLACES GRAPHITE ANODE WITH SILICON

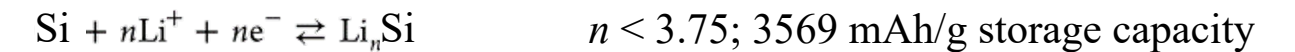
100% Silicon anode



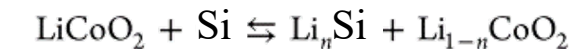
Cathode:



Anode:



Cell reaction:

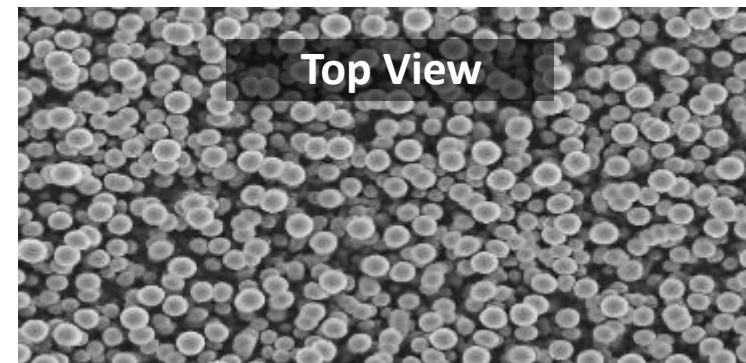
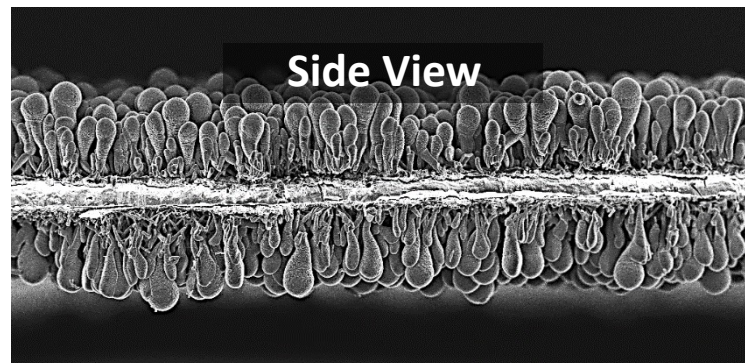
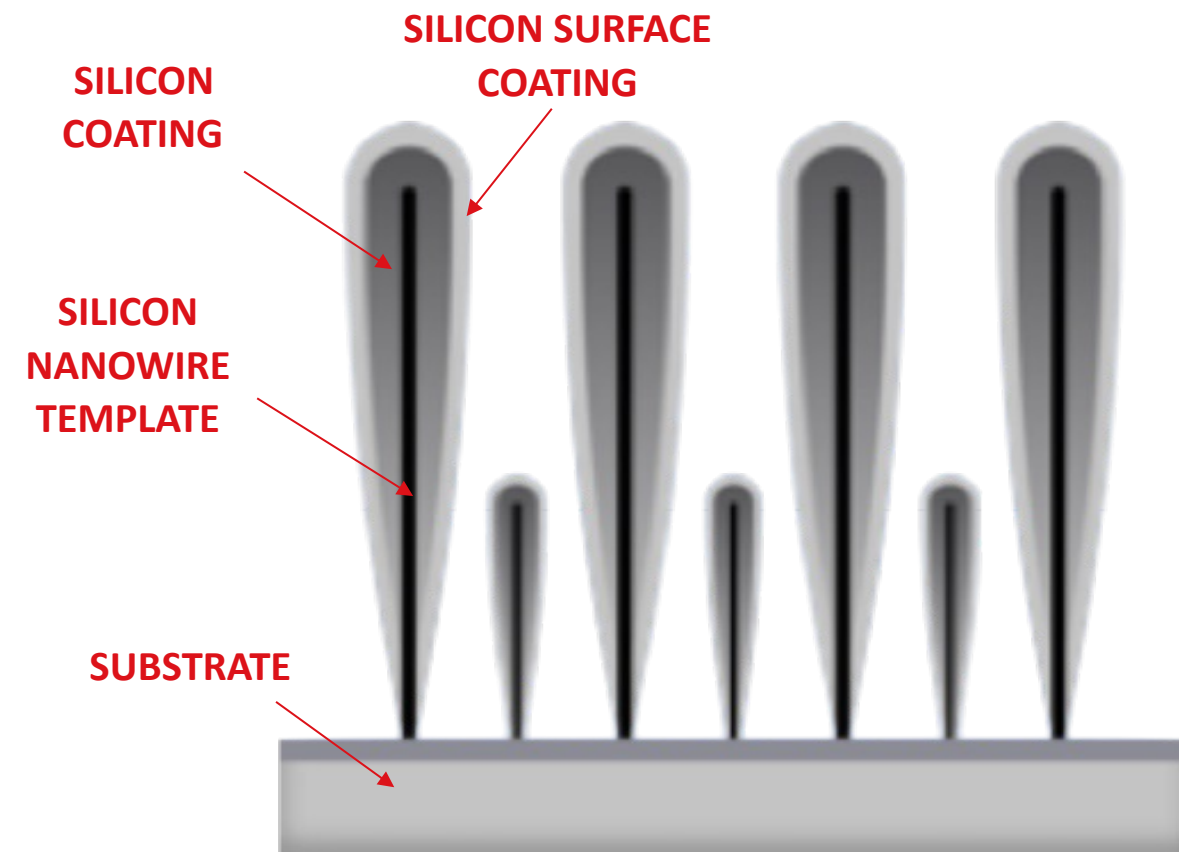


(www.electrochem.org)

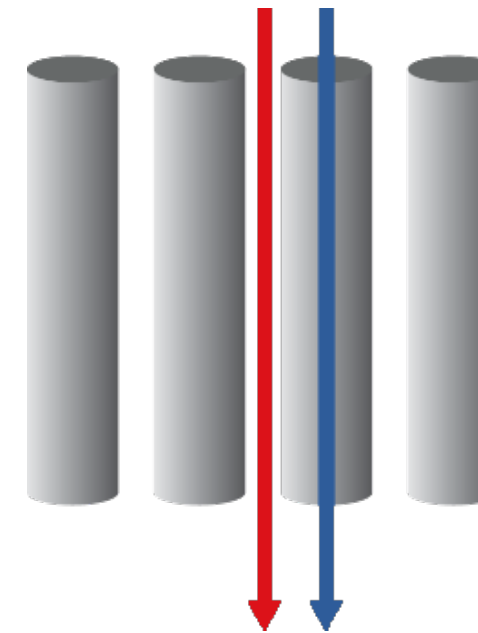
State of the art: intercalation active materials (graphite and metal oxides), liquid electrolytes and porous polymer separators

The Amprius Solution to Silicon Anode Expansion

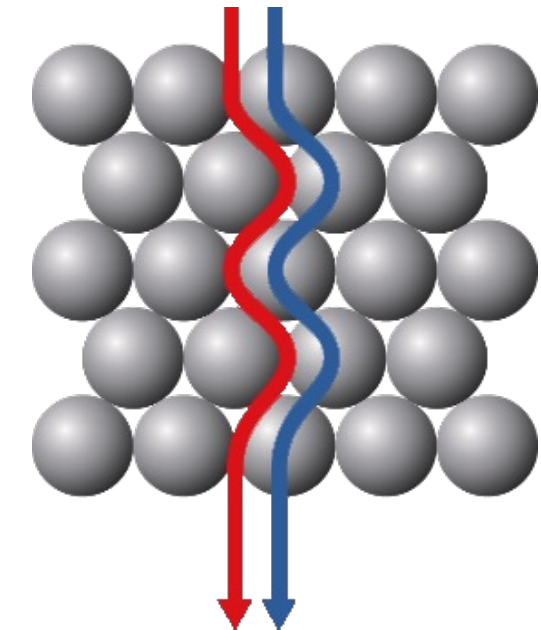
100% Silicon Nanowires Allow Volume Expansion without Binders, Graphite or any Inactive Materials



Silicon Nanowires



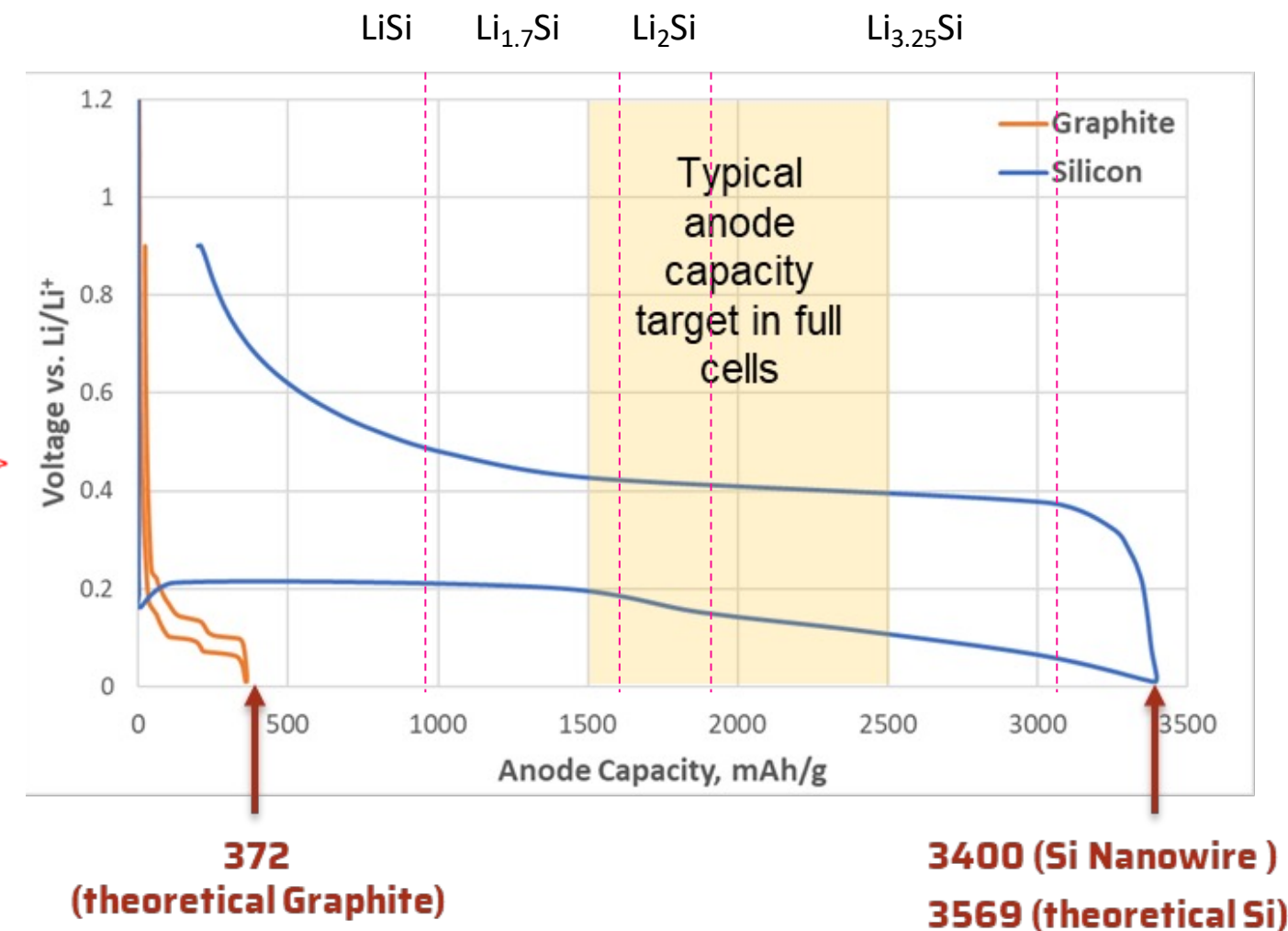
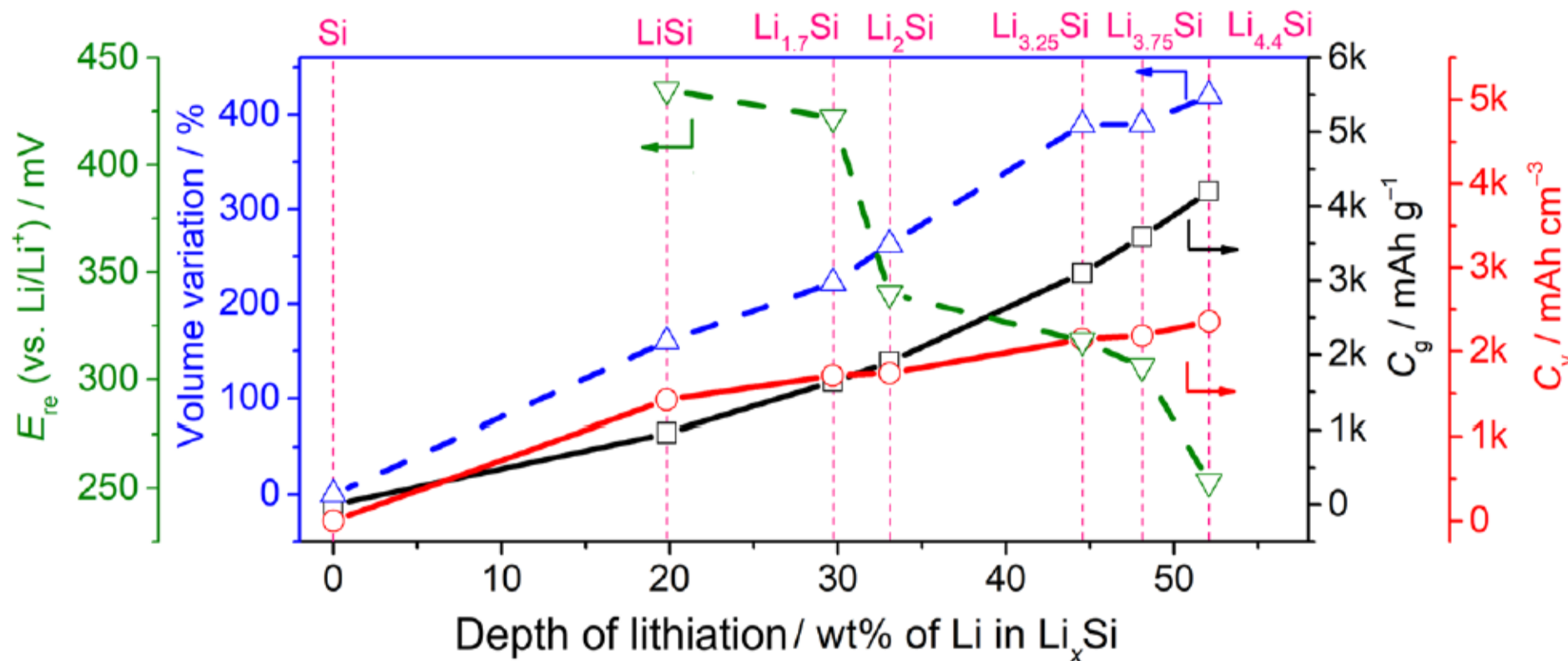
Conventional Graphite (and/or Silicon) Particles



- Spacing between nanowires and silicon porosity **accommodate silicon volume expansion**
- Ions and electrons travel straight paths
- Most conductive path for ions and electrons results in **high power capability and fast charge rate**

SILICON ANODE – HIGHEST LITHIUM STORAGE CAPACITY

Amprius silicon has near-theoretical capacity for a silicon anode



*Amprius Data

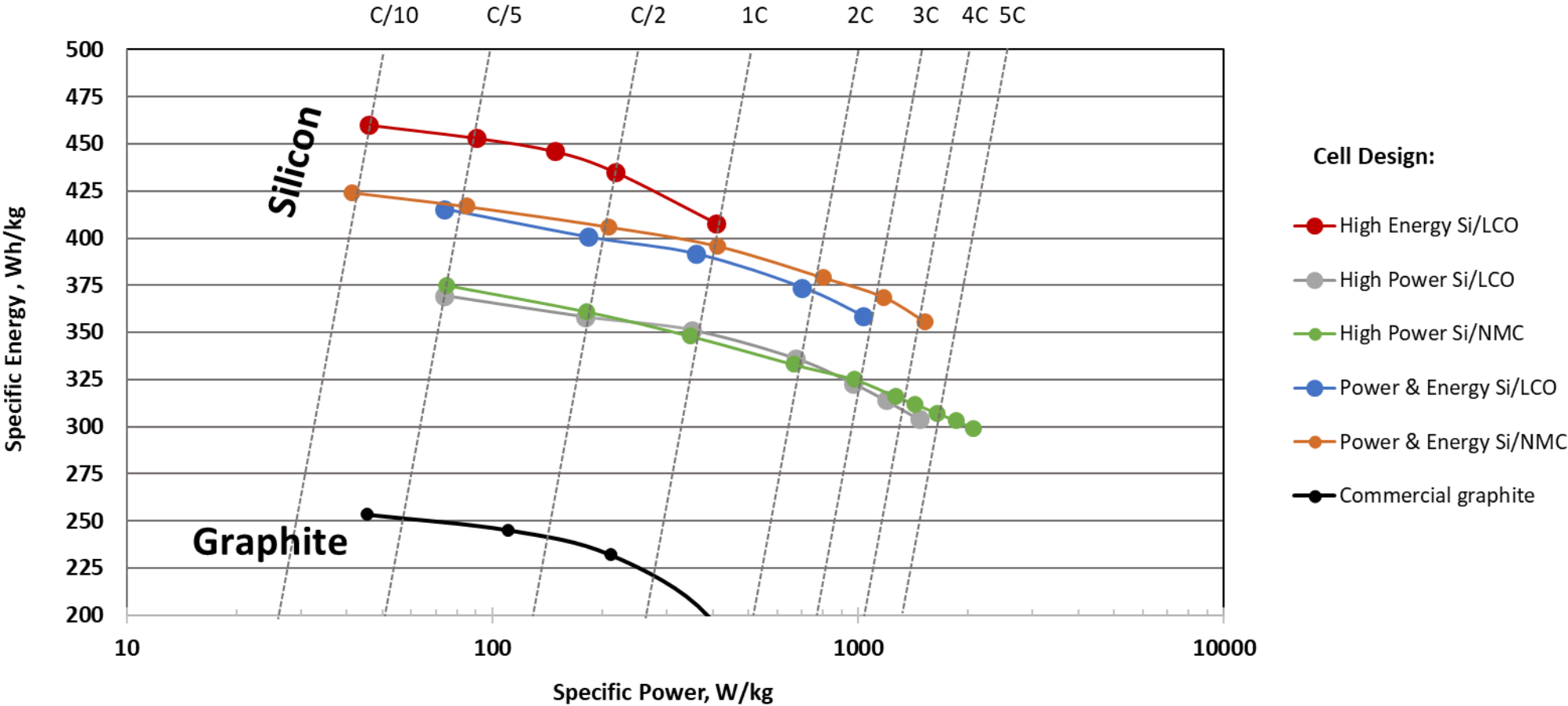
- High first cycle efficiency due to low surface area (typically 94%)
- Multiple cell designs (loading, capacity utilization, N/P ratio) are possible with silicon

Performance and Applications

Minimal trade off between specific energy and specific

Silicon Nanowire Power & Energy platforms

ENERGY



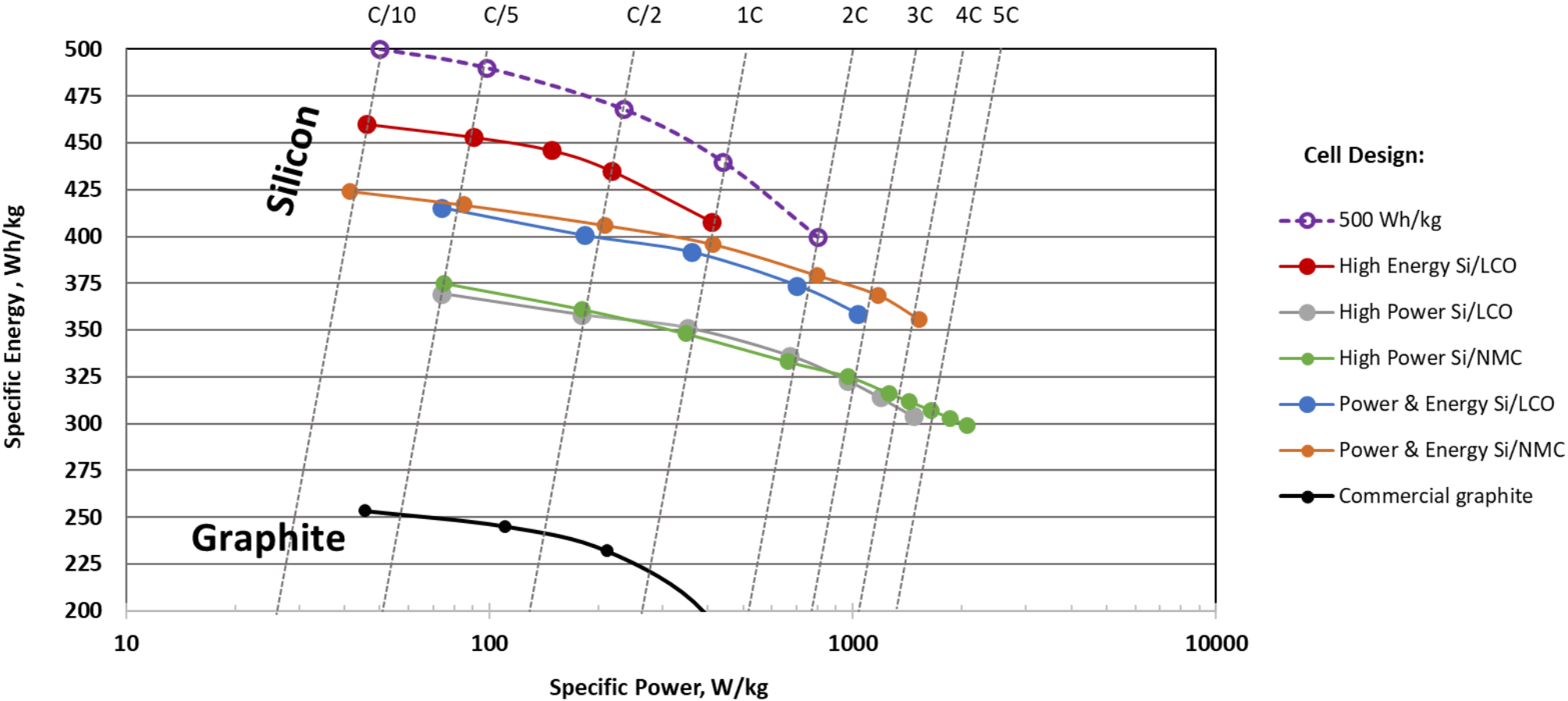
POWER



New energy cell design: 500 Wh/kg cells

Silicon Nanowire Power & Energy platforms

ENERGY

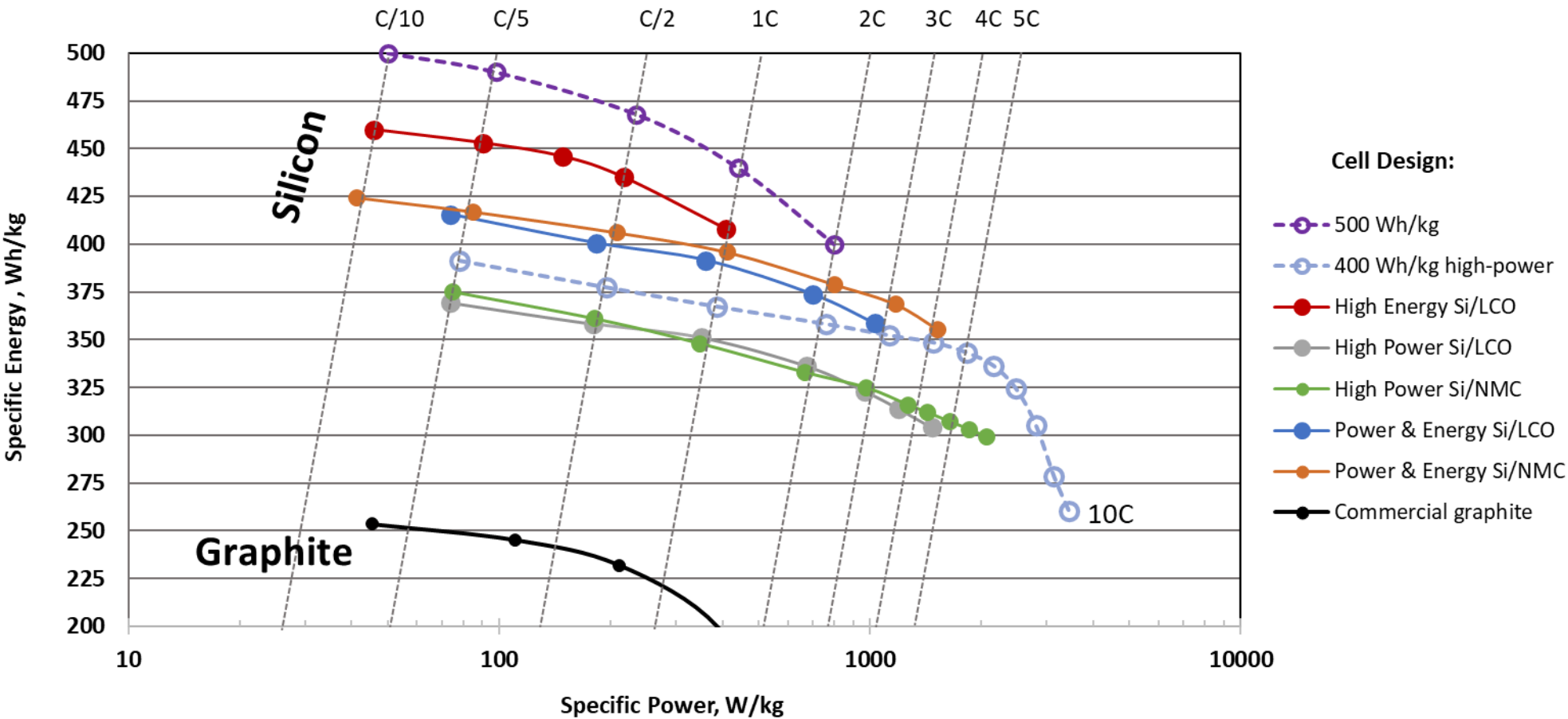


POWER

New power cell design: 400 Wh/kg with 4000 W/kg power density

Silicon Nanowire Power & Energy platforms

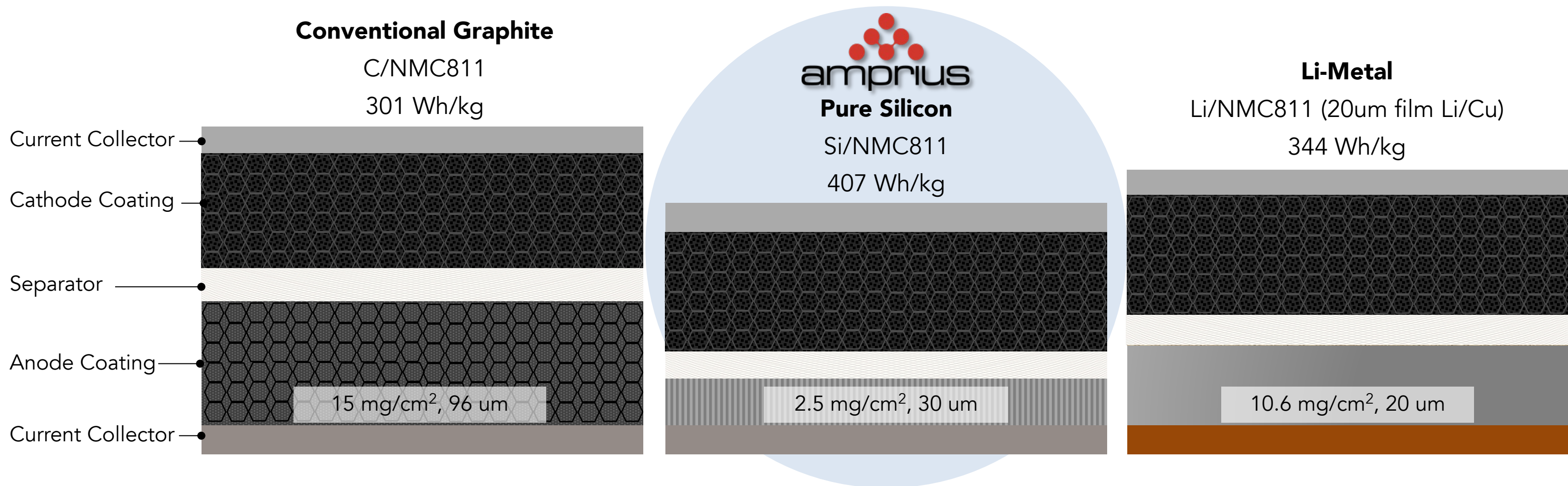
ENERGY



POWER

Pure Silicon Anode Mass is Lower than Alternatives

Example for 5 mAh/cm²

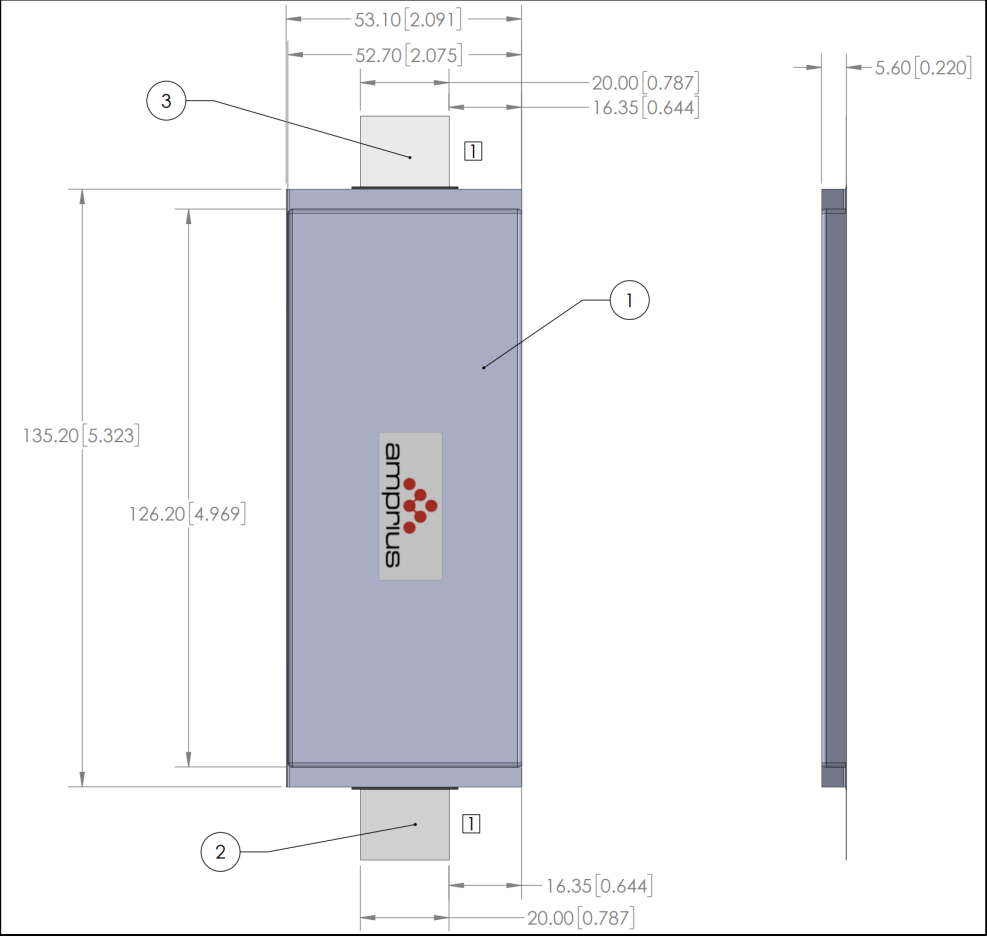


KEY TAKEAWAYS

- ▶ 2.5 mg/cm² Si has a reversible capacity of 9mAh/cm²
- ▶ Lithium metal electrode has to be thinner than 5μm to be equivalent in mass
- ▶ Solid-state electrolytes further increase cell mass
- ▶ First to reach 500 Wh/kg with commercial cathodes

EXAMPLE AMPRIUS PRODUCTS

High Power capability with high energy density and specific energy

Applications	HAPS, portable power, CE	Long Endurance Drones, eVTOL, UAM	High power drones	HAPS, portable power	EV, Electric Flight	High power drones, eVTOL
Dimensions (T x W x H) mm						
	High Energy 0.5C max rate					
4.5 x 50 x 55	420 Wh/kg 1125 Wh/L					
5.4 x 54 x 65	450 Wh/kg 1150 Wh/L					
5.5 x 54 x 135						

	Si/NMC Platforms	
High Energy 1C max rate	Power-Energy 4C max rate	High Power 8C max rate
450 Wh/kg 1100 Wh/L	410 Wh/kg 950 Wh/L	370 Wh/kg 820 Wh/L
455 Wh/kg 1100 Wh/L	415 Wh/kg 975 Wh/L	
460 Wh/kg 1150 Wh/L	420 Wh/kg 1020 Wh/L	

Operating temperature range: -30°C to 55°C. Cycle life 200-1200 cycles, depending on operating conditions

High Power capability with high energy density and specific energy

Applications	HAPS, portable power, CE	Long Endurance Drones, eVTOL, UAM	High power drones	HAPS, portable power	EV, Electric Flight	High power drones, eVTOL
Dimensions (T x W x H) mm	Si/LCO Platforms				Si/NMC Platforms	
	High Energy 0.5C max rate	Power-Energy 3C max rate	High Power 5C max rate	High Energy 1C max rate	Power-Energy 4C max rate	High Power 8C max rate
4.5 x 50 x 55	420 Wh/kg 1125 Wh/L	415 Wh/kg 1040 Wh/L	370 Wh/kg 920 Wh/L	450 Wh/kg 1100 Wh/L	410 Wh/kg 950 Wh/L	370 Wh/kg 820 Wh/L
5.4 x 54 x 65	450 Wh/kg 1150 Wh/L	420 Wh/kg 1050 Wh/L		455 Wh/kg 1100 Wh/L	415 Wh/kg 975 Wh/L	
5.5 x 54 x 135				460 Wh/kg 1150 Wh/L	420 Wh/kg 1020 Wh/L	

Operating temperature range: -30°C to 55°C. Cycle life 200-1200 cycles, depending on operating conditions

Pouch cells customized to application requirements

Certified designs



5x50x56mm
3700mAh
HAPS drone



6x54x65mm
5400mAh
CWB

Nano-UAS cell
in development



7x15x32mm
725mAh
nano-UAS

Prototypes



3x7x53mm
190mAh
Wearable



6x28x29mm
1200mAh
Smart watch



5x99x300mm
45 Ah
BEV

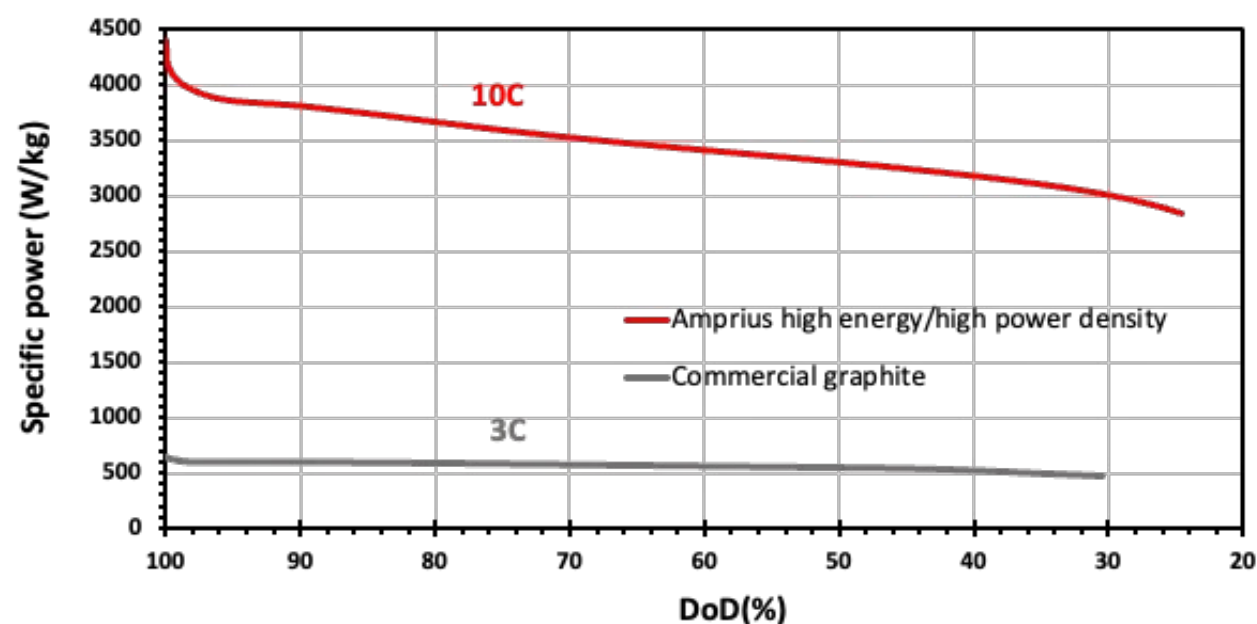
Capacities from 200 mAh to 80 Ah

X-TREME FAST CHARGING, HIGH POWER AND HIGH ENERGY- ALL IN ONE CELL

Ultra High-Power, High-Energy Cell Platform

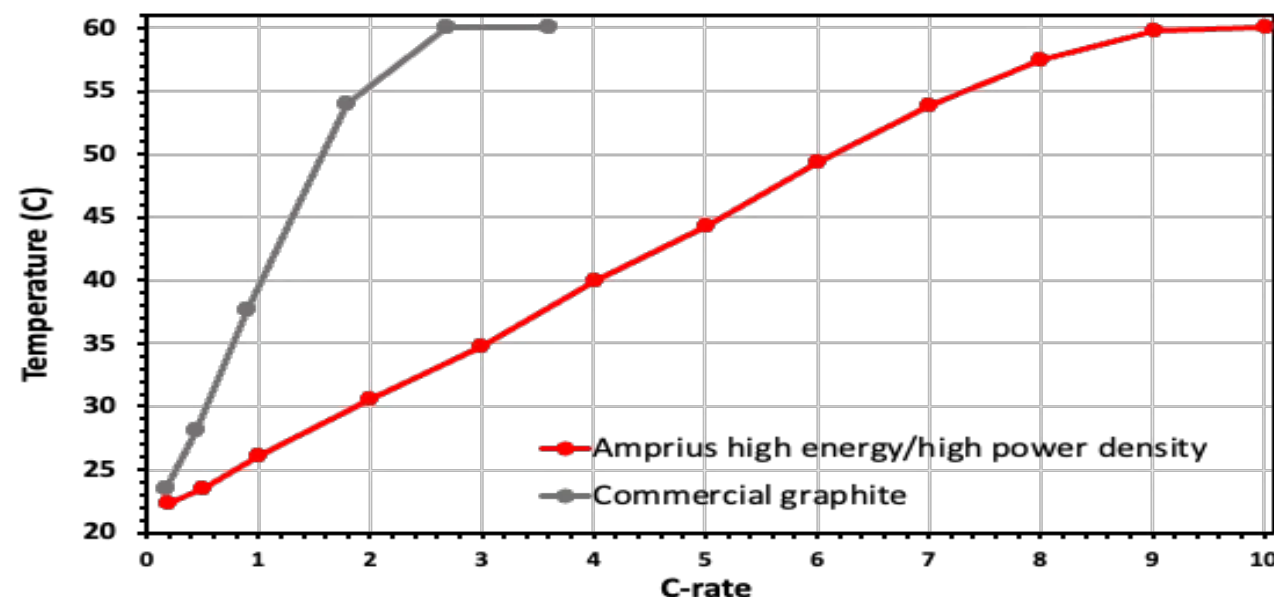
Power Density vs DoD%

Amprius Silicon Anode System vs. Commercial Graphite Anode System



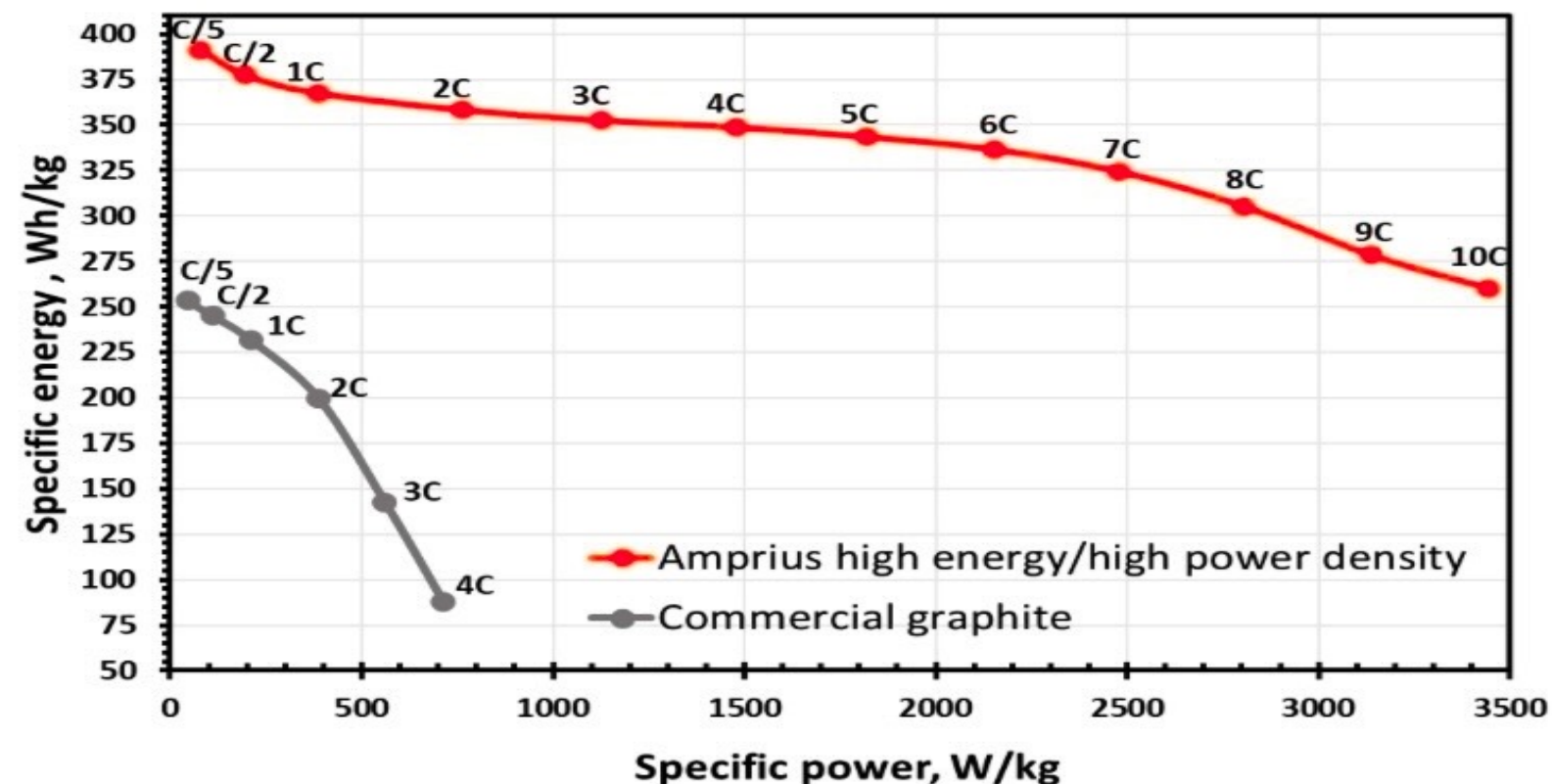
Maximum Cell Temperature vs. Discharge C-Rate

Amprius Silicon Anode System vs. Commercial Graphite Anode System



Gravimetric Energy Density vs. Power Density

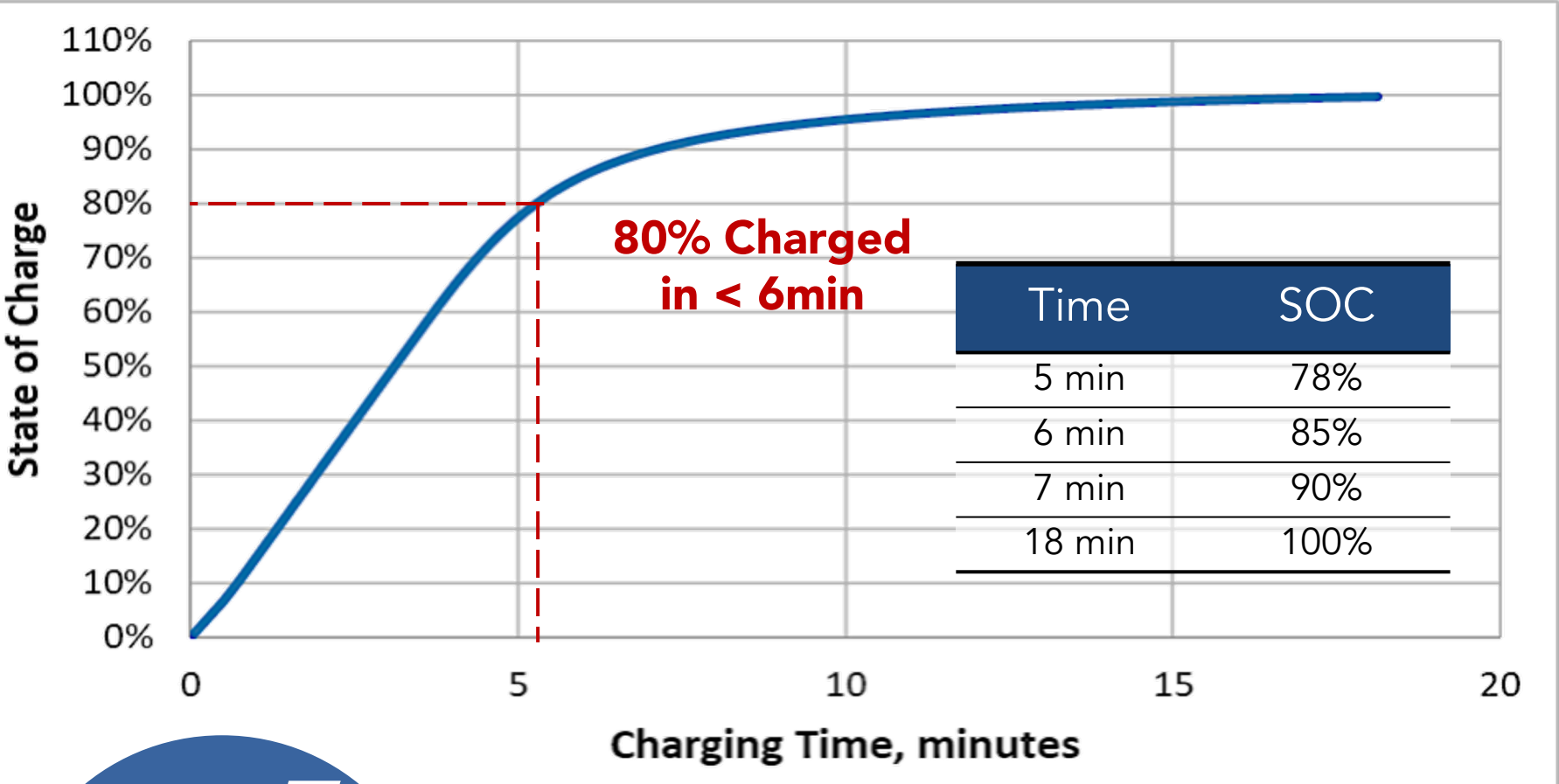
Amprius Silicon Anode System vs. Commercial Graphite Anode System



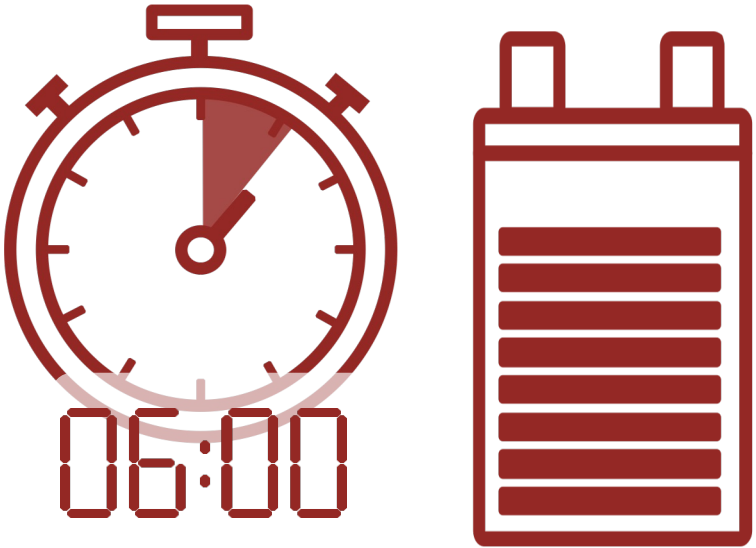
KEY TAKEAWAYS

- ▶ Amprius' cell is >3x the discharge rate while sustaining the power delivery at lower DoD; resulting in extended usable battery capacity.
- ▶ Amprius' cell has > 40% higher GED across a significantly wider range of discharge rates
- ▶ Amprius' cell has the ability to stay cooler at higher discharge rates allowing for fewer thermal management components

Enable Extreme Fast Charge (XFC)



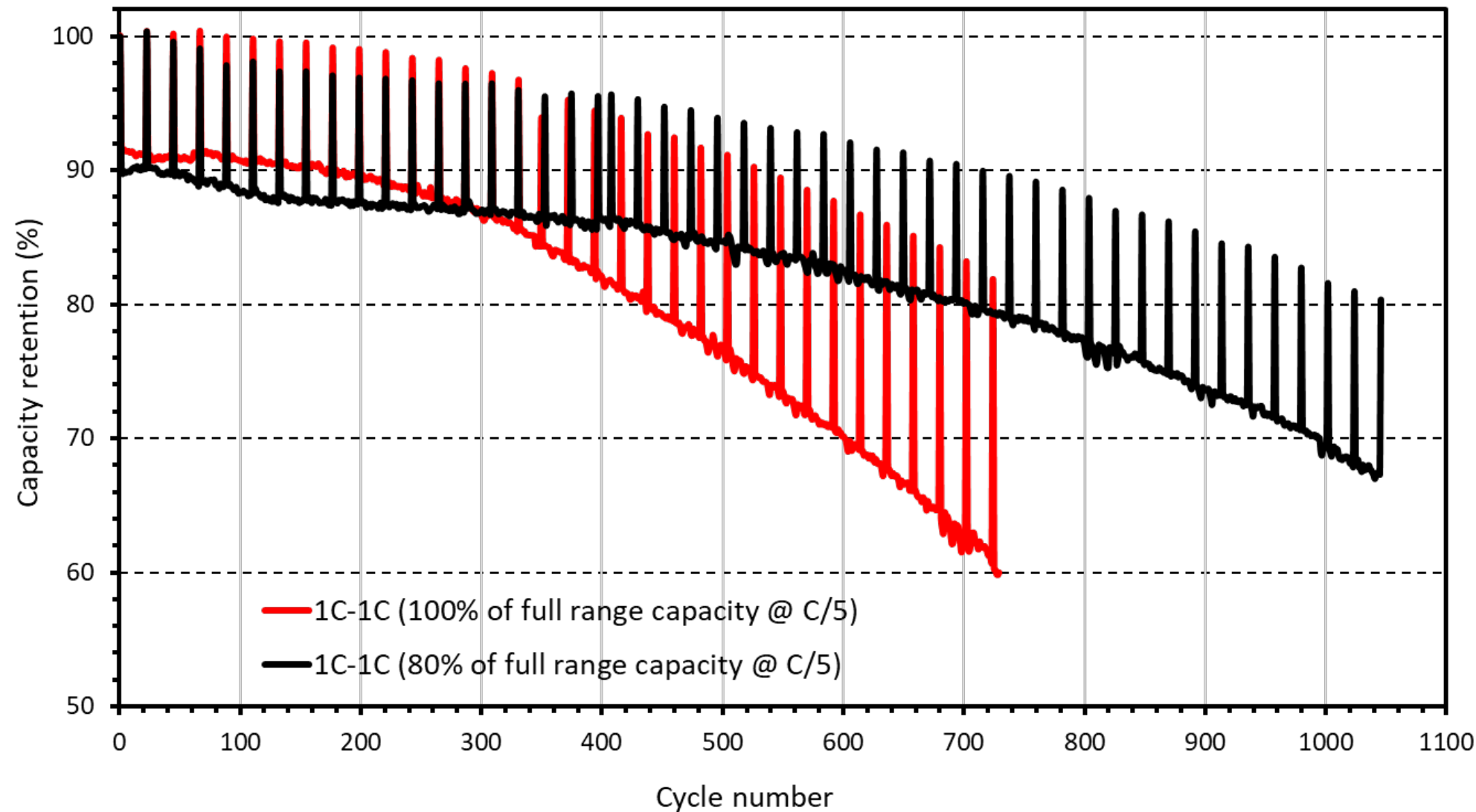
< 6 min
to 80% charged



Fast charging capability is essential to maximizing UAM uptime to drive profitability of the business model

Long cycle life with high energy density design

1C//1C cycling with 0.2C//0.2C capacity check at each 20 cycles

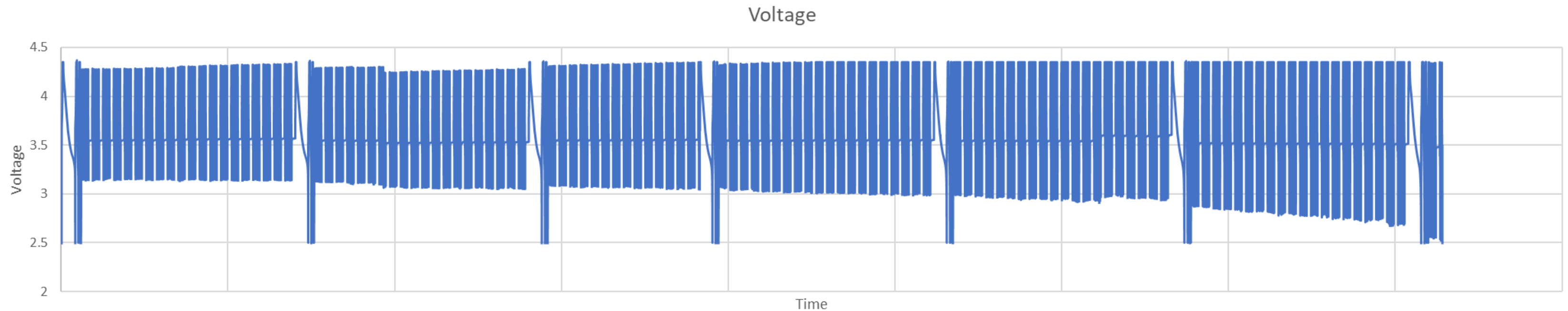


>300,000 miles life with 2/3rd battery weight (300 miles range)

Or 450 miles range with batteries like the current 300-mile EVs

Long cycle life in eVTOL flight protocol

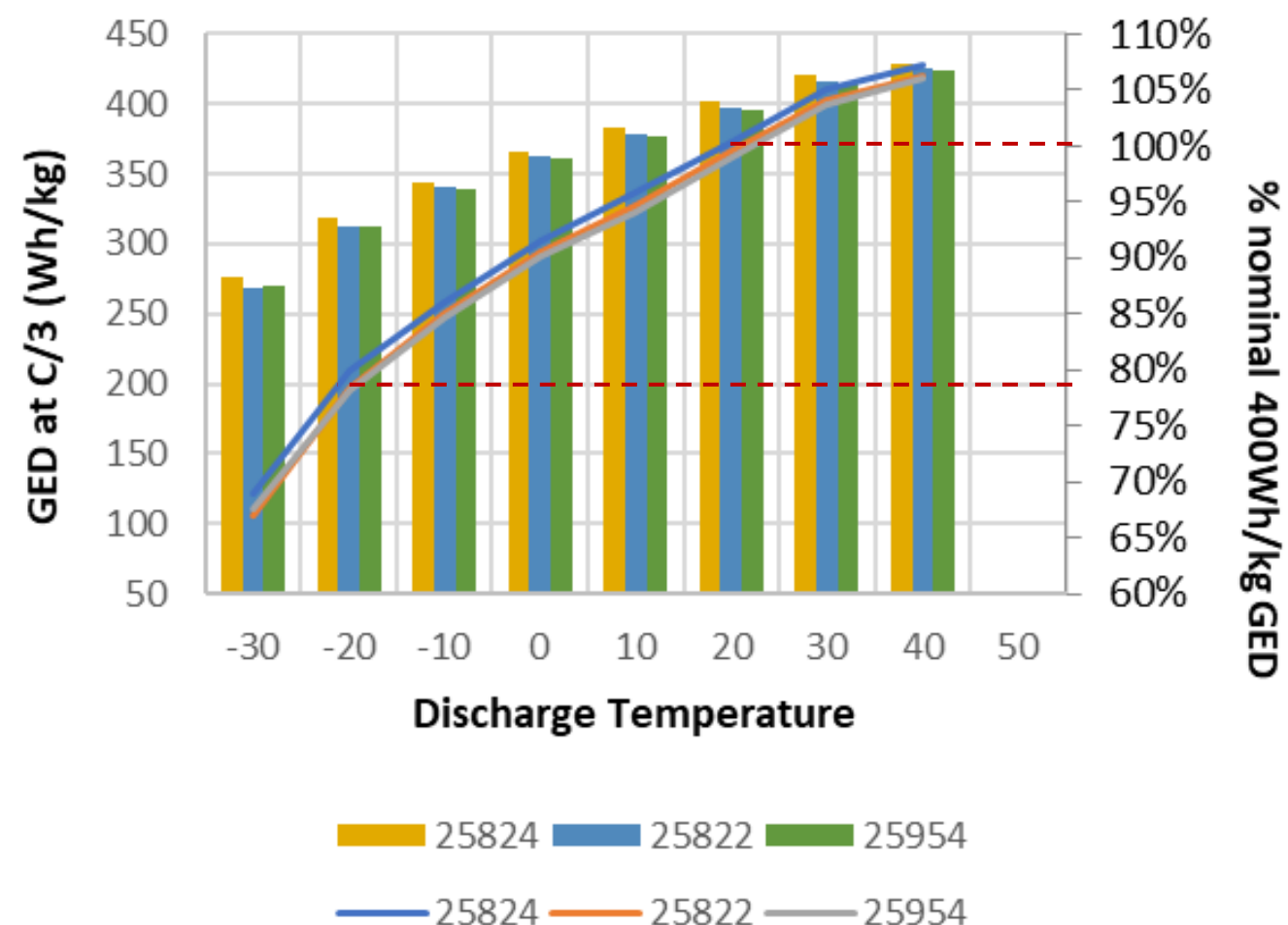
30-45 minutes trips, 15 minutes charge, 8-12 trips per day



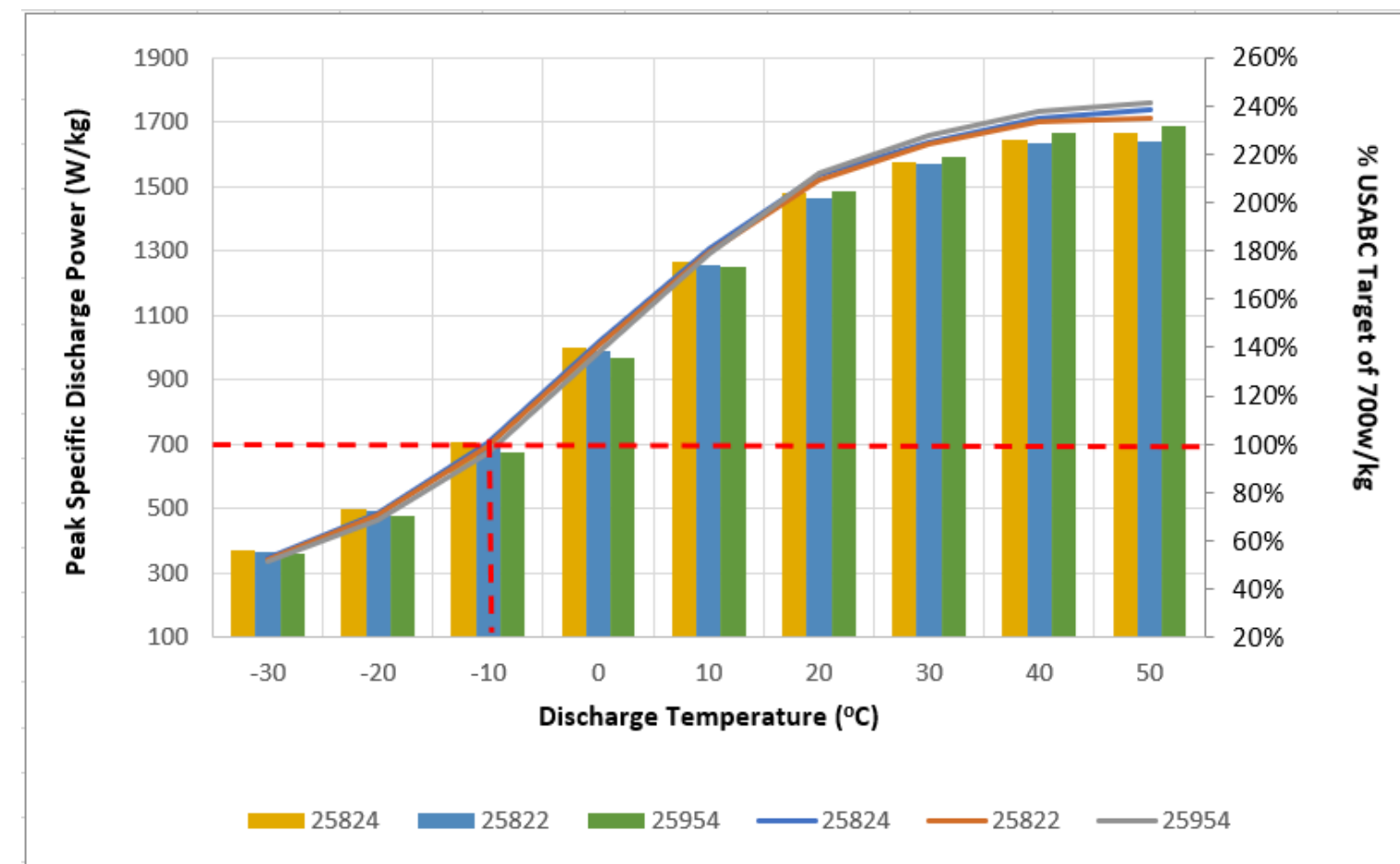
Constant power (eVTOL/Uber protocol): 2E charge, 1E discharge, 4E pulses (E=full energy), ~60% energy cycled; RPT every 200 cycles

1200 cycles performed with full power capability; 90% capacity available at end of test

Reduced loss at low temperature



~80% energy available at -20°C



700 W/kg power available at -10°C

3.7Ah cell, Si/NMC811, 410 Wh/kg

500 Wh/kg WITH AMPRIUS SILICON

External Validation of Early Prototypes by 3rd Party



Prepared for: Amprius
Test report numbers: AK-1823
Report date: 3/17/2023



MPS SN:	Cell SN	1st cycle		2nd cycle	
		Capacity (Ah)	Energy (Wh)	Capacity (Ah)	Energy (Wh)
AK-1823-CP-1	40546	6.8552	23.657	6.8482	23.632
AK-1823-CP-2	40544	6.8766	23.648	6.8636	23.602
AK-1823-CP-3	40574	6.8529	23.424	6.8432	23.389

MPS SN:	Cell SN	Weight (g)	L (mm)	W (mm)	T (600g plate) (mm)	Gravimetric Energy Density	Volumetric Energy Density
						(Wh/kg)	(Wh/l)
AK-1823-CP-1	40546	46.3604	59.72	52.31	5.667	509.7	1335
AK-1823-CP-2	40544	46.3627	59.81	52.37	5.693	509.1	1324
AK-1823-CP-3	40574	46.3638	59.76	52.32	5.662	504.5	1321

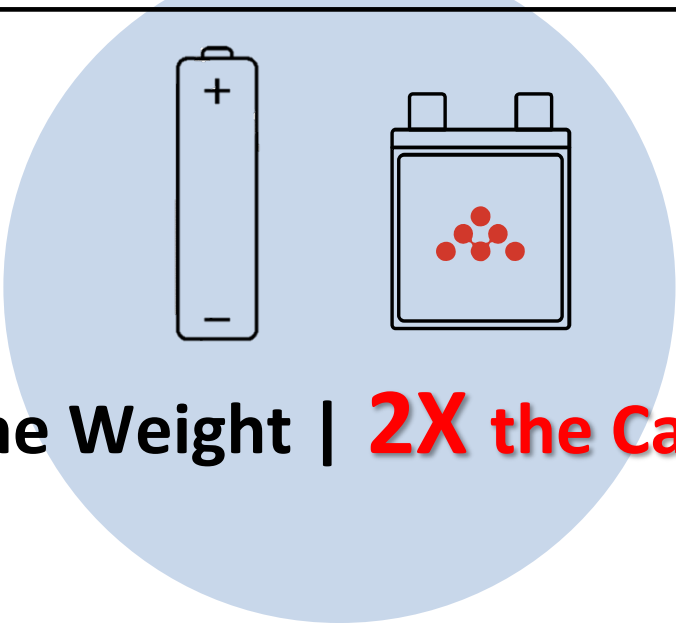
Executive Summary

Amprius Technologies Model RD1039-R49 cells were tested at MPS using a test regimen provided by Amprius. The results indicate that this cell model provides >504 Wh/kg and >1321 Wh/l at 25°C.

Industry Leading
500 Wh/kg Battery

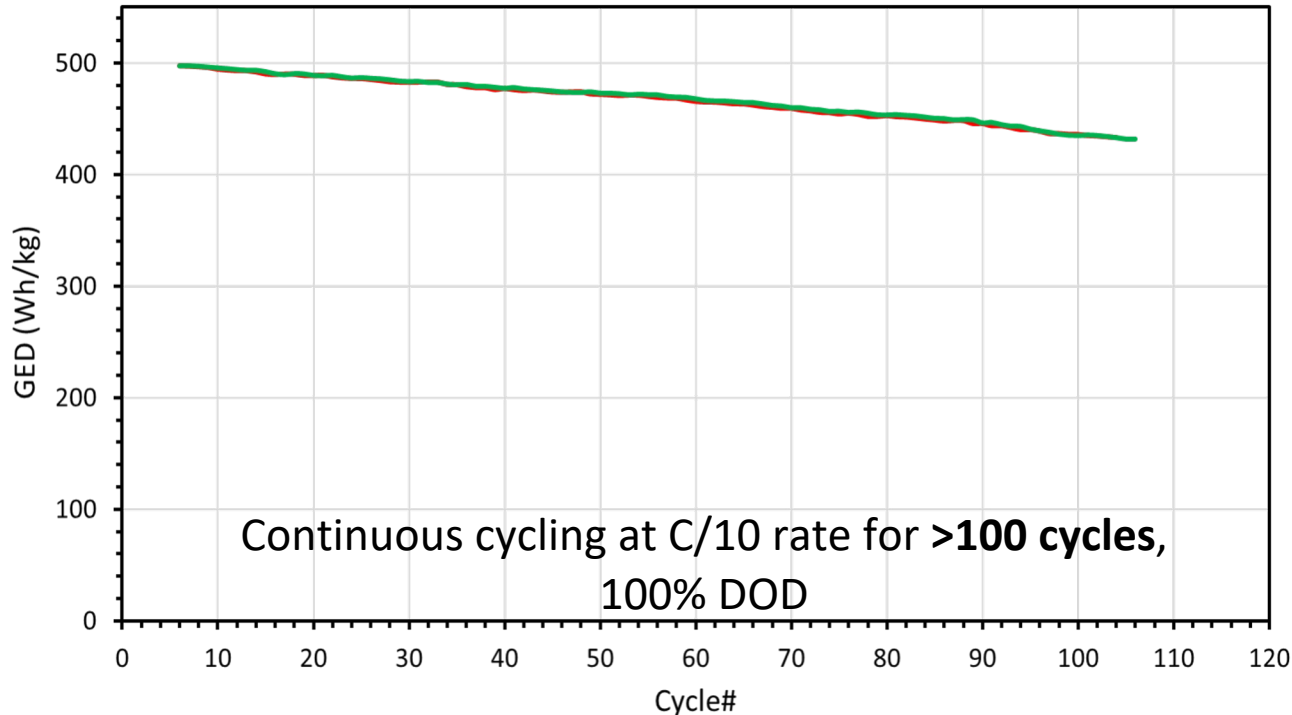
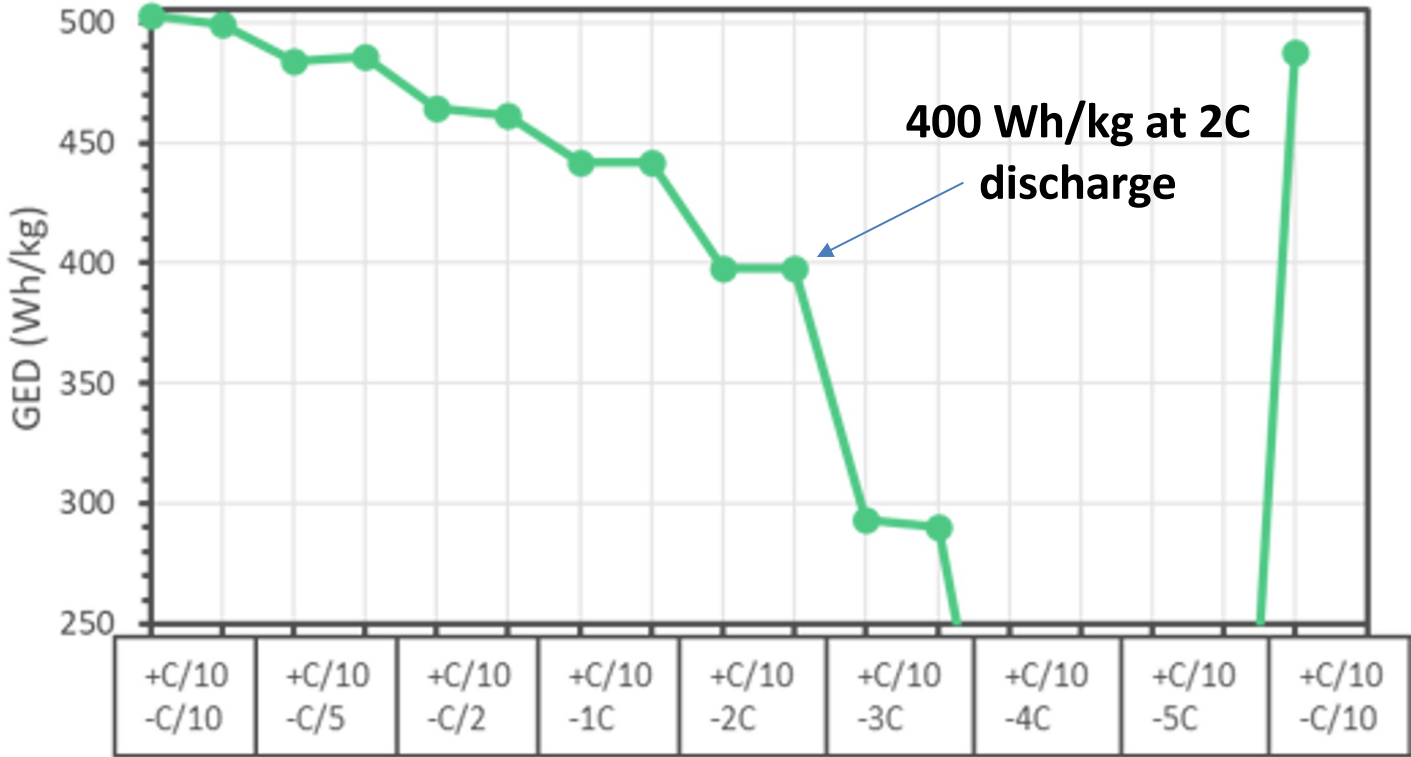
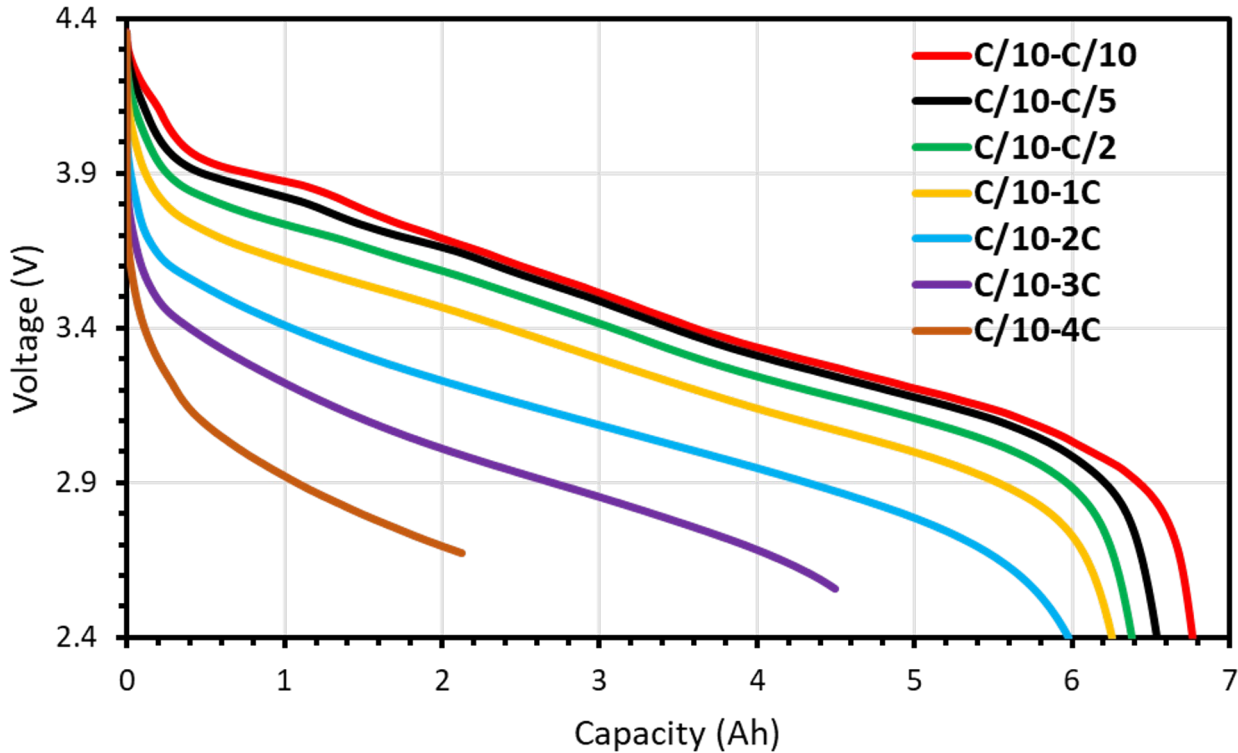
- ▶ Unprecedented Energy Density
- ▶ Unparalleled Run Time

Typical 18650 Cell vs. Amprius 500wh/kg Cell



Same Weight | 2X the Capacity

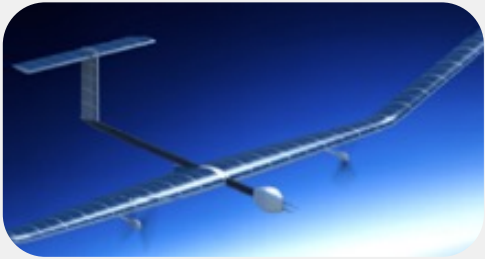
Products under development



KEY TAKEAWAYS

- ▶ The cell is still cycling past 100 cycles at 100% DOD
- ▶ 400 Wh/kg at 2C discharge
- ▶ Optimization of electrolyte formulation and amount & full electrical and safety evaluation underway for future product release

Electric Flight Applications Enabled by Amprius' Batteries

	Unmanned Aerial Systems (Drones)	High Altitude Pseudo Satellites	Air Transportation
Product			
Application	Recon Drone	Stratospheric Satellite	eVTOL ⁽¹⁾
Amprius Product	Balanced Energy/Power	High Energy	High Power
Performance Specification	1.4 Ah, 390 Wh/kg at C/5	5.8 Ah, 450 Wh/kg at C/10	15+ Ah, 380+ Wh/kg at C/5 with 6C long pulse
End User Benefit	Very long endurance and increased capacity with no increase in weight or volume	Ultra long sustained flight at high altitude with max payload	eVTOL with extreme-fast charge and greatly extended service radius

(1) Actively sampling with OEMs and continuing to pursue joint development agreements.

A large solar plane with a long, thin wing and a small fuselage is flying over a city at sunset. The city lights are visible in the foreground, and the sky is a mix of orange and blue. Another smaller plane is visible in the distance.

Thank you!

Contact Us

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Tel: (949) 574-3860

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US Army, DOE, USABC, NASA, and ONR