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Lithium-ion Batteries for Perpetual Stratospheric Platforms

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Ionel Stefan

CTO, Amprius Technologies, Inc. 1180 Page Ave., Fremont, CA UND SOaRS Symposium, April 25, 2025

AMPRIUS – THE SILICON PIONEER

A History of Innovation and Achievements

- Organic growth into electric flight markets
- Highest available energy density in commercial products
- Over 200 customers and >700k cells sold in 2024



Factory site in

Brighton Colorado

2024

Commercial Anode Platforms

SiMaxx™

100% Silicon Anode Technology



100% Silicon without Other Active Anode Material

SiCore™

Silicon Oxide Anode Technology



Up to 100% Silicon without Other Active Anode Material (can be mixed with other active materials)



SIMAXXTM SILICON ANODE STRUCTURE

Enabling Superior Energy Density for High-Performance Applications

100% Silicon Nanowires⁽¹⁾ Allow Volume Expansion without Binders, Graphite, or any Inactive Materials







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



SICORETM SILICON ANODE STRUCTURE

Properties

BOTTOM-UP Unique Structure

4-layer structure innovation

ELASTIC Si-Nanostructure Interior Structure

 Highly isotropic, discontinuous structure

MULTILAYER surface

protection

 In-situ growth, complete encapsulation, fast lithium conduction



Fast Ion Conductor

Highly Conductive Carbon Layer

Structure Stabilization Layer

Ultra-fine Silicon Nanostructure

Advantages

- Alleviates expansion stress and reduces surface side reactions
- Extends cycle life and improves high temperature stability
- High-speed charge transfer, high-rate performance



Amprius Batteries Deliver Twice the Mission Time



- (1) Survey of 18650 technical datasheets (ex. Panasonic NCR18650G) and iFixit reports on iPhone and Samsung batteries.
- (2) Actual battery cell energy densities measured by Amprius for an energy cell design.



- (3) Flight Time estimated based on customer-generated models for a balanced power and energy cell design
- (4) Talk Time customer-reported data for an energy cell design.
- (5) Mission Time results from Conformal Wearable Battery developed for U.S. Army for an energy cell design.
- (6) Range estimated for a Tesla Model 3 long-range battery specifications for an energy cell design.



"PERPETUAL" SOLAR POWERED FLIGHT – ENABLING TECHNOLOGIES

Fixed wing HAPS coverage – Voltitude 2023



- Battery energy density defines longest survivable night minimum 400 Wh/kg energy density rechargeable batteries required (current commercial batteries have an energy density of about 275 Wh/kg)
- Battery cycle-life defines flight endurance (number of nights)
- Aircraft wingspan and battery energy density define payload capability



Multiple form factors and applications



Volumetric Energy Density @ C/5



Max Pulse Discharge Rate 30 sec

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450 Wh/kg Batteries for HAPS

Gravimetric Energy Density @ C/5





Volumetric Energy Density @ C/5

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450 Wh/kg SiMaxx PRODUCTS RELEASED IN 2023

UN38.3 Certified

SA75 SiMaxx** Rechargeable Lithium	n-Ion Cell	ar PR		SA76 SiMaxx [™] Rechargeable Lit	hium-Ion Cell	aı Pr		SA77 SiMaxx~ Rechargeable Lithi	um-Ion Cell	a PI	
11.8 Ah High Energy Ce	ii l			4.2 Ah High Energy (Cell			5.8 Ah High Energy Ce	,II		
	Specifications		-		Specifications				Specifications		-
	Capacity	Typical @ C/10	11800 mAh		Capacity	Typical @ C/10	4200 mAh		Canadity	Timical @ C/10	E900 41-
			40.7 Wh				14.5 Wh		Capacity	Typical & C/TO	20.0 W/h
		Minimum	11500 mAh			Minimum	4000 mAh			Mainun	20.0 Wh
1			40.6 Wh				14.0 Wh			winimum	5000 mAn
	Cell Voltage	Nominal	3.45 V		Cell Voltage	Nominal	3.45 V		@ 1111 h	N	19.4 Wh
SiMaxx.		Charge	4.20 V	SiMaxx.		Charge	4.20 V	Silvary	Cell Voltage	Nominal	3.46 V
		Discharge	2.50 V			Discharge	2.50 V			Charge	4.20 V
	Discharge Current	Max Continuous	11.8 A (1C)		Discharge Current	Max Continuous	4.2 A (1C)			Discharge	2.50 V
and the second se		Max Pulse (≤ 30 seconds)	23.6 A (2C)	artiprius		Max Pulse (≤ 30 seconds)	8.4 A (2C)		Discharge Current	Max Continuous	5.8 A (1C)
	Charge Current	Typical	2.36A (C/5)		Charge Current	Typical	0.84 A (C/5)	amprius		Max Pulse (≤ 30 seconds)	11.6 A (2C)
amonus		Maximum (0% to 100% SOC)	11.8 A (1C)			Maximum (0% to 100% SOC)	4.20 A (1C)		Charge Current	Typical	1.16 A (C/5)
arnprida	Temperature Range	Discharge	-20 to 50°C		Temperature Range	Discharge	-20 to 50°C			Maximum (0% to 100% SOC)	5.8 A (1C)
	Ambient	Charge	10 to 45°C		Ambient	Charge	10 to 45°C		Temperature Range	Discharge	-20 to 50°C
		Storage	-20 to 30°C			Storage	-20 to 30°C		Ambient	Charge	10 to 45°C
	Internal Resistance	ACIR (1 kHz @ 30% SOC)	20 mΩ		Internal Resistance	ACIR. 1 kHz @ 30% SOC	< 40 mO			Storage	-20 to 30°C
		DCIR	N/A			DCIR @ 30% SOC. 1C	< 36 mQ		Internal Resistance	ACIR (1 kHz @ 30% SOC)	≤ 22 mΩ
	Cycle Life	+0.2C/-0.2C, 100% DOD to 80% 5	SOH 150 cycles		Cycle Life	+0.2C/-0.2C. to 80% SOH	150 cycles			DCIR	N/A
	Weight		90.0 ± 2g		Weight		32 + 10		Cycle Life	+0.2C/-0.2C, to 80% SOH	150 cycles
A m	Packaging		Pouch		Packaging		Pouch		Weight		44.5 ± 1g
·******	Cathode		NMCA		Cathodo		NMCA		Packaging		Pouch
	Energy Density	Gravimetric	450 Wh/kg		Cathode Energy Density	Gravitattia	AFO MA A-		Cathodo		NMCA
	Including packaging	Volumetric (@ 30% SOC)	1100 Wh/I		Including packaging	Valumetric (@ 209/ SOC)	450 Wh/kg		Cathode	Consistentia	
	Special Note	Cell requires external clampin	ng of 30 PSI	12 11	Constal Nata	Volumetric (@ 30% SOC)	990 Wh/L		Including packaging	Gravimetric	450 Wh/kg
	Certifications	UN 38.3			Special Note	Cell requires external clampi	ng of 30 PSI			volumetric (@ 30% SOC)	1050 Wh/L
u					Certifications	UN 38.3			Special Note	Cell requires external clamp	ing of 30 PSI
	Dimensions				D: .				Certifications	UN 38.3	
12	Size	L1	127.0 ±1.5mm	W1	Dimensions			12			
		L2	123.5 ±1.5mm		Size	L1	56.5 ±1.5mm		Dimensions		
		W1	53.5 ±1.5mm			L2	52.5 ±1.5mm		Size	L1	65.5 ±1.5mm
W1		T1 (@ 30% SOC)	5.5 ±0.40mm			W1	49.5 ±1.5mm		T1	L2	62.3 ±1.5mm
						T1 (@ 30% SOC, Fresh)	5.3 ±0.4mm	W1		W1	53 5 +1 5mm

T1 (@ 30% SOC) 5.70 ±0.40mm

Cells delivered to three different HAPS customers/designs in 2024



SA102 - Preliminary TDS

Specifications

Capacity	Typical @ C/10	4390mAh	
		14.9Wh	
Cell Voltage	Nominal	3.40V	
	Charge	4.25∨	
	Discharge	2.20V	
Discharge Current	Max Continuous	4.39A (2C)	
	Max Pulse (≤ 30 seconds)	13.17A (3C)	
Charge Current	Typical	0.439A (C/10)	
	Maximum (0% to 100% SOC)	2.2A (0.5C)	
Temperature Range	Discharge	-10 to 50°C	
Ambient	Charge	0 to 50°C	
	Storage	-20 to 45°C	
Internal Resistance	ACIR, 1 kHz @ 30% SOC	$\leq 25 \text{ m}\Omega$	
	DCIR @ 30% SOC, 1C	\leq 67 m Ω	
Cycle Life	+0.2C/-0.2C, to 80% SOH	200 cycles	
Weight		33.2 ± 0.8g	
Packaging		Pouch	
Cathode		NMCA	
Energy Density	Nominal Gravimetric	449 Wh/kg	
Including packaging	Minimum Gravimetric	441 Wh/kg	
	Volumetric (@ 30% SOC)	940 Wh/L 5	
Special Note	Cell requires external clamping	of 30 PSI	
Certifications	UN 38.3		



Dimensions

Size

L1	56.5 ±1.5mm
L2	53.0 ±1.5mm
W1	49.5 ±1.5mm
T1 (@ 30% SOC, Fresh)	5.5 ±0.4mm

Additional form factors in development



450 Wh/kg SiCore PLATFORM

Voltage Traces: SA102 (SiCore) vs. SA76 (SiMaxx)



- •Mass: 33.13 g
- •Thickness: 5.51 mm
- •Nominal Voltage: 3.40 V



4.25 - 2.20 V	4.25 - 2.50 V
4.390	4.270
14.93	14.63
450.6	441.5

<u>SA76</u> (4.20 – 2.50 V)

- Capacity: 4200 mAh
- Energy: 14.5 Wh
- Mass: 32.2 g
- Nominal V: 3.45 V
- Thickness: 5.3 mm



450 Wh/kg SiCore PLATFORM

Cycle life



- Cycle life improvement relative to SA₇6
- Makes possible year-round operation
- Less than 100% SOC discharge likely to increase cycle life further
- Stratospheric operation requires light pressure, easy to achieve with elastomer materials

Discharge Rate Capability



C rata	Discharge Cap. Retention		Max	
C-late	Cap. (Ah)	(%)	Temp. (C)	
0.1	4.377	100.0%	27.1	
0.2	4.282	97.8%	27.6	
0.33	4.214	96.3%	28.8	
1	4.112	93.9%	33.9	
2	3.550	81.1%	44.8	



>500 Wh/kg Batteries for HAPS

Gravimetric Energy Density @ C/5





Volumetric Energy Density @ C/5

amprius ¹⁵

500 Wh/kg SiMaxx PLATFORM

Extending HAPS global coverage





KEY TAKEAWAYS

- Potential for 6 months of operation in Stratosphere
- 400 Wh/kg at 2C discharge
- ► 5.1 Ah in certification



500 Wh/kg SiMaxx PLATFORM

5.1Ah and 27Ah cells in prototype certification phase



*under development and evaluation

KEY TAKEAWAYS

- 27 Ah, 520 Wh/kg, 1300 Wh/L in 13.2(T) x 58(W) x 97(L) mm format
- ~176 g per cell
- In development for HAPS customer with support from xTechPrime



Electric Flight Applications Enabled by Amprius' Batteries







Thank you !

Amprius Technologies

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