High Energy Density Lithium-Ion Cells with Silicon Nanowire Anode Technology

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AMPRIUS TECHNOLOGIES, INC.

Leader in Silicon Anode Technology
Highest Performance Li-Ion Cells in the Industry

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

- **2008** Company founded at Stanford
- **2009** Operations Started
- **2018** First Commercial Product

**COMPREHENSIVE PLATFORM**
Technology platform includes entire ecosystem for optimal performance:
- Silicon nanowire anode manufacturing
- Electrochemistry
- High energy cell designs

**BEST PERFORMANCE**
Highest energy density lithium-ion cells

- **1200 Wh/liter**
- **450 Wh/kg**
- **100%**
- **50+**

“Silicon Is Awesome and Inexpensive” - Tesla Battery Day 2020
A New Structure for 100% Silicon Based on Nanowires

**KEY BENEFITS**

- Micro & Macro porosity - prevents cracking and interference between nanowires
- Tolerates Expansion, Nanowire Rooted - mechanically and electrically connected to substrate
- Stable Solid Electrolyte Interphase (SEI) - stabilized interaction with electrolytes

310 - Conductive filament grown from substrate
340 - Bulk coating of low density, porous amorphous silicon
330 - Thin layer of high-density amorphous silicon
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

200 kWh per line
Products and Applications
HIGH ENERGY AND POWER CAPABILITY

Amprius’ cells enable the highest energy and power

Silicon Nanowire//LCO Ragone Plot
### PRODUCTS

High Power capability with highest energy density and specific energy

<table>
<thead>
<tr>
<th>Application</th>
<th>Dimensions (T x W x H) mm</th>
<th>Mass g</th>
<th>Capacity Ah</th>
<th>Energy Wh</th>
<th>Wh/L</th>
<th>Wh/kg</th>
<th>Capacity Ah</th>
<th>Energy Wh</th>
<th>Wh/L</th>
<th>Wh/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HAPS</strong></td>
<td>4.5 x 50 x 55</td>
<td>33.1</td>
<td>3.8</td>
<td>13.9</td>
<td>1125</td>
<td>420</td>
<td>3.8</td>
<td>13.9</td>
<td>1125</td>
<td>420</td>
</tr>
<tr>
<td><strong>Drones, High Power</strong></td>
<td>4.2 x 50 x 55</td>
<td>27.8</td>
<td>2.8</td>
<td>10.1</td>
<td>875</td>
<td>365</td>
<td>2.65</td>
<td>9.0</td>
<td>780</td>
<td>325</td>
</tr>
<tr>
<td><strong>Drones, Long Endurance</strong></td>
<td>4.6 x 50 x 55</td>
<td>31.7</td>
<td>3.6</td>
<td>13.2</td>
<td>1040</td>
<td>416</td>
<td>3.4</td>
<td>11.5</td>
<td>870</td>
<td>360</td>
</tr>
<tr>
<td><strong>High-Capacity Cells</strong></td>
<td>4.5 x 50 x 105</td>
<td>68.1</td>
<td>8.1</td>
<td>29.3</td>
<td>1240</td>
<td>430</td>
<td>8.1</td>
<td>29.3</td>
<td>1240</td>
<td>430</td>
</tr>
<tr>
<td><strong>Army Wearable Pack</strong></td>
<td>5.4 x 54 x 64</td>
<td>49.5</td>
<td>5.4</td>
<td>21</td>
<td>1125</td>
<td>425</td>
<td>5.4</td>
<td>21</td>
<td>1125</td>
<td>425</td>
</tr>
</tbody>
</table>

Charge-Discharge Rate: C/5-C/5 |
Charge-Discharge Rate: 1C-3C

Operating temperature range: -20°C to 55°C. Cycle life 150-300 cycles, depending on operating conditions.
CHEMISTRIES WITH LONG CYCLE LIFE

Long Endurance Batteries

Si/LCO

Cycling at C/5 for Long Endurance UAV applications

Si/NMC811
## SILICON NANOWIRE ANODE ENABLES MUCH GREATER IMPROVEMENT

Game-Changing Advantages in Advanced Applications

<table>
<thead>
<tr>
<th></th>
<th>Urban Air Mobility</th>
<th>Soldier Wearable Power</th>
<th>Smartwatch</th>
<th>BEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Time</td>
<td>15 min</td>
<td>37 min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mission Time</td>
<td></td>
<td>8.2 h</td>
<td>17.8 h</td>
<td></td>
</tr>
<tr>
<td>Talk Time</td>
<td></td>
<td></td>
<td>3.1 h</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td></td>
<td>334 mi</td>
<td>602 mi</td>
</tr>
</tbody>
</table>

**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
Energy Cells for High Altitude Drones Enable Longest Endurance

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

Lightweight battery pack for Stratosphere

• 406 Wh/kg battery pack
• Replaced incumbent Li/S
• Reduced battery size over 50%
• Light-weight, compliant compression system for stratosphere
USE CASES

Power Cells for Urban Air Mobility – Long Endurance
USE CASES

Endurance Record for Multi-Rotor Drone with Amprius Power Cells
USE CASES

Long Endurance Power Batteries

- 415 Wh/kg at C/5, 370 Wh/kg at 2C → doubles endurance
- Designed for eVTOL and multirotor drones

725 Wh, 5 lb (2.27 kg) Pack
HIGH POWER CELLS
Small, long endurance power drones

- >80% relative energy to 6C rate
- Small temperature increase and within operating limits to 10C rate
PORTABLE POWER APPLICATION

Conformal-Wearable Battery – 2X Energy Content
## CONFORMAL-WEARABLE BATTERY

### 2X Energy Content

<table>
<thead>
<tr>
<th>Specification</th>
<th>CWB-150 (Fielded Model)</th>
<th>Amprius</th>
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</thead>
<tbody>
<tr>
<td>&quot;Flexible&quot; battery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy (Pack)</td>
<td>148 Wh</td>
<td>320 Wh</td>
</tr>
<tr>
<td>Weight</td>
<td>2.6 lb</td>
<td>2.6 lb</td>
</tr>
<tr>
<td>Dimensions</td>
<td>8.7” x 7.65” x 0.7”</td>
<td>8.7” x 7.65” x 0.7”</td>
</tr>
<tr>
<td>Cells specific energy</td>
<td>201 Wh/kg</td>
<td>395 Wh/ kg</td>
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</table>

UN38.3 certified in 2020, confirmed performance in field test
USE CASES
EV – Future Market
EV CELLS

Exceed 2025 Goals

- Si/NCM811
- ISO form factor VIFB-99/300

Model based on results to date:
- Capacity: 60 Ah at C/3 rate (30°C)
- Energy: 450 Wh/kg and 1200 Wh/L
- Peak Power: 1000 W/kg and 2650 W/L
- 80% capacity charged in 15 minutes

50% higher specific energy than best EV cells
EV PERFORMANCE TESTS

Cycle Life – Dynamic Stress Test (DST)

>650 cycles, ongoing improvement to 1000

- DST pulse profile
- Constant energy discharged every cycle

>100,000 miles with 200-mile range battery
EV PERFORMANCE TESTS

Calendar Life – 50°C at Full Charge

Equivalent to about 8 years, ongoing improvement to 10 years

- Reference Performance Test verification every 32 days
- Calendar Life at 50°C equivalent to about 4x Calendar Life at 30°C
EV PERFORMANCE TESTS

High Rate Charge

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
ROAD MAP: SPECIFIC ENERGY

ACTIVE MATERIALS IMPROVEMENT AND ACTIVE/INACTIVE RATIO INCREASE

- HIGH LOADING, HIGH VOLTAGE LCO
- HIGH LOADING, Ni-RICH NMC
- LARGE FORM FACTOR, ADVANCED CATHODES
- HIGH SILICON LOADING, ADVANCED CATHODES, LARGE FORM FACTOR

SPECIFIC ENERGY

<table>
<thead>
<tr>
<th>WH/KG</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
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<tbody>
<tr>
<td>300</td>
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<td>350</td>
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<td>650</td>
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ENERGY CELL

POWER CELL

SILICON NANOWIRE ANODE

GRAPHITE ANODE
Thank You

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