Sion Power Batteries for EV and Aerospace Applications

Yuriy Mikhaylik*, Igor Kovalev, Charlie Scordilis-Kelley, Lily Liao, Michael Laramie, Urs Schoop, Tracy Kelley
After years of being at the forefront of lithium-sulfur technology advancement, Sion Power shifted to a new chemistry—Licerion technology. The result of such a dramatic shift in chemistry has resulted in the development of a new battery chemistry that is poised to be a market disrupter.

* Energy projections from 0.4 – 1.8 Ah development cells
Sion Power’s Transition From Li-Sulfur to Licerion® Technology

**INTRODUCTION OF LITHIUM METAL ANODE**
- Understanding Li-S Limitations Led to a Li-Metal Anode and Traditional Li-ion Cathodes (e.g. NCM)
- Large Improvements in Energy and Cycle Life were Observed

**LITHIUM SULFUR (LI-S) EXPERTISE**
- Proven Li-S Technology used in HAPS Application
- Li-S was Great on Cost and Wh/kg, but Limitations to Wh/L and Cycle Life

**SHIFT TO LI-METAL & COLLABORATION WITH BASF**
- Decision Made to Transition Company to Licerion Technology in 2015
  - Used existing knowledge of lithium-ion battery manufacturing, testing and evaluation
  - Accelerated development with BASF cathode expertise
  - Discovered other key concepts necessary to optimize Li-metal batteries

**PERFORMANCE DEMONSTRATED**
- Decision to Commercialize Licerion Product five Years after Bench-top Demonstration Made, 2018
- Performance proven on 6 – 20 Ah Large Format Cell

**BATTERY PACK DEVELOPMENT**
- Modular Battery Pack Prototype Completed, 2019
- Safety testing underway

**NASA Electrified Powertrain Flight Demonstration, November 30, 2020**
Key Elements of Licerion® Technology

Sion Power owns key proprietary elements needed to practice lithium metal technology

1. **Protective Barrier**
   - Stabilized electrodes enhancing cycle life and increasing energy

2. **Ultra Thin Li-Metal**
   - Physical protection of lithium metal anode with thin, chemically stable and ionically conductive ceramic/polymer barriers

3. **Separator**
   - Positioned between the electrodes, an ultra thin and porous separator is moistened with electrolyte to allow ionic conductivity while preventing electronic short circuits

4. **Standard Lithium Metal Oxide Cathode**
   - Standard cathode soaked in liquid electrolyte

5. **Life Extending Electrolyte**
   - Optimized electrolyte solvent system and additives protecting the electrodes for extended cycle life

6. **Cell and Pack Design**
   - Battery management system, circuitry, and compression

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Licerion® design maps to key patents

- Anode: 24 (Issued), 2 (Pending)
- Electrolyte: 44 (Issued), 6 (Pending)
- Cathode: 41 (Issued), 15 (Pending)
- Separator: 25 (Issued), 8 (Pending)
- Other: 74 (Issued), 51 (Pending)
Licerion® Protected Li Anode (PLA) Leads to Low Cell Electrical Resistance

Licerion protected Li anode coupled with metal oxide intercalation cathode has area specific resistance of $9 - 18 \text{ Ohm}^{*}\text{cm}^2$

\[ \frac{dV}{dI} \times \text{Electrodes Area} = \text{Area Specific Resistance} \]

at steady state conditions
High Combination of Power and Energy
Licerion® High Energy (HE) Achieves 450 Cycles

1000 Wh/L, 500 Wh/kg, 450 Cycles

- Licerion HE Exceeded 500 Wh/kg, 1000 Wh/L, and >450 Cycles in 0.4 Ah Development Cells
  - Projected specific energy and energy density were confirmed in the actual large cells

- Scale-up and Commercialize in Large Cell Format
  - 26 Ah cell capacity
  - 10 cm x 10 cm x 1 cm

Specific energy and energy density projected to 10 cm x 10 cm x 1 cm cell design using same active materials balance as 0.4 Ah cells and accounting for weight and volume of all large cell components.
First Licerion® Cell Used for Prototyping and Sampling

<table>
<thead>
<tr>
<th>Cell Design</th>
<th>Wh/kg</th>
<th>Wh/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licerion-1 6 Ah</td>
<td>425</td>
<td>750</td>
</tr>
<tr>
<td>Licerion-1 20Ah</td>
<td>486</td>
<td>850</td>
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</table>

UN DOT 38.3 Test Requirements

<table>
<thead>
<tr>
<th></th>
<th>Testing Phase</th>
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<tbody>
<tr>
<td>Altitude Simulation</td>
<td>Passed</td>
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<tr>
<td>Thermal Test</td>
<td>Passed</td>
</tr>
<tr>
<td>Vibration</td>
<td>Passed</td>
</tr>
<tr>
<td>Shock</td>
<td>Passed</td>
</tr>
<tr>
<td>External Short Circuit</td>
<td>Passed</td>
</tr>
<tr>
<td>Impact</td>
<td>Passed</td>
</tr>
<tr>
<td>Forced Discharge</td>
<td>Passed</td>
</tr>
<tr>
<td>Other Tests</td>
<td></td>
</tr>
<tr>
<td>Nail penetration</td>
<td>Passed</td>
</tr>
<tr>
<td>Overcharge</td>
<td>Passed</td>
</tr>
<tr>
<td>Thermal ramp / hot box</td>
<td>Passed</td>
</tr>
</tbody>
</table>

6 Ah Cell Testing

**Bold** = Passed internal and external tests, others performed internally and in process externally.
### Requirements for Licerion® Cell Design by Application and Outlook to Meet Requirements

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Licerion HE</strong> (High Energy)</td>
<td>HALE HAPS UAV</td>
<td>Slow cycling (C/5 max)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy density critical (400 – 600 Wh/kg)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimum 100 – 200 cycles</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Licerion HP</strong> (High Power)</td>
<td>eVTOL UAV</td>
<td>High discharge rate capability (5C for 120 sec for take off phase)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy density critical (&gt; 400 Wh/kg)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+200 cycles</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Licerion EV</strong> (Electric Vehicle)</td>
<td>Automotive EV (2025)</td>
<td>650 Wh/L→1000 Wh/L</td>
<td>Lab</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quick charging ability (80% in 15 min)</td>
<td>Lab</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+800 cycles</td>
<td>Lab</td>
<td>✓</td>
</tr>
</tbody>
</table>
Performance of Licerion® HE Cells

High energy cells up to 700 Wh/kg and 1400 Wh/L

(Projections based on 400 mAh cells)

(Projections based on 400 mAh cells)
Performance of High Power Licerion® HP Cells

Evaluated on 0.4 Ah cells

ENERGY OVER 70% AT 20C DISCHARGE RATE

CAPACITY OVER 75% AT 20C DISCHARGE RATE
Lab tests demonstrate the feasibility of Licerion technology to meet fast charge and cycle life requirements

- 700 Cycles at 80% and 750 Cycles at 70% Cut-Off
- Advanced Electrolyte Improves Low Temperature Performance
  - At 0 °C: 450 cycles to 70% of RT capacity
  - At -40 °C: 70% of RT capacity at 1C discharge rate

- Cells Charged in 15 Minutes from 0 to 100% SOC
  - Charge efficiency at 15 min charge was 99.7%
  - > 300 cycles using intermittent extreme fast charge conditions

0.12 Ah Development Cell
Projected 10x10x1 cm Large Cell Energy
420 Wh/kg
700 Wh/L

Advanced Electrolyte
Baseline Electrolyte

Charge
Discharge
0.7C
2.7C

Discharge Capacity (mAh)
Cycle
Proven Scalability for EV and eVTOL Applications

Cycle life reproduced in large format cell

- 700 Cycles to 80% in Large Format Cell
  - 10 cm x 10 cm Pouch Cell, 10 layers
  - 1.8 Ah, Advanced Electrolyte
  - 90 min charge
  - 23 min discharge

- Charge in 60 Minutes to 100% SOC
- Discharge 15 min down to 25% SOC at Combination of Rates
  - 5.5 C for take-off and landing
  - 2.2 C for cruising
Low Temperature Performance was Evaluated in the Prototype 10x10 cm Cells

- 4C Discharge at -25 °C and 1C Discharge at -40 °C Showed 70% of Retained Capacity
- Cycle Life Approached ~500 cycles at 0 °C Compared with ~800 Cycles at RT
Module Power Pack, Made with Licerion® Cells

Twelve Licerion cells per standard module

- **Large Format Licerion Modules**
  - Proprietary compression system
  - Custom designed BMS
  - Pack characterization including continuous cell monitoring, safety controls, performance, cycle life, and thermal management
  - Preparing for UN and DO-311 testing

- **Module Power Pack, Single Unit**
  - 917 Wh, 12 V
  - 80 Ah pack capacity
  - 11.5 V (nominal)

NASA Electrified Powertrain Flight Demonstration, November 30, 2020
Licerion® is Compatible with Traditional Li-Ion Plants

80% of existing lithium-ion factory can be utilized to make Licerion

**CELL COMPARISON**

**Current Lithium-Ion Cell**
- Anode piece is key differentiator
- Graphite or Silicon Composite Anode
- Separator
- High Levels of Electrode
- Cathode
- Thickness: 150-200μm

**Licerion Lithium Metal Cell**
- Less Weight, Less Volume: Next-Generation
- Ultra Thin Li-Metal
- Ceramic / Polymer Barrier
- Separator
- Life Extending Electrode
- Intercalated Li-Metal Oxide Cathode
- Thickness: 36-46μm

**LICERION PRODUCTION LINE**

- Minimal impact to supply chain
- Licerion technology increases capacity

- Change in Production Line Process
  - Anode
  - Separator
  - Cathode
  - Cell Assembly
  - Electrolyte Fill
  - Formation & Seal
  - Test

Traditional Production Line Process
Licerion® Technology Addresses Requirements of Many Markets
High-volume Licerion production through licensing for EV

- **Aerospace Markets**
  - HAPS/HALE
  - eVTOL
  - Satellites and space vehicles
  - Electric aircraft

- **Electric Mobility Markets**
  - Automobiles
  - Motorcycles, scooters
  - Three-wheeled vehicles

- **Energy Storage Systems**
  - Other terrestrial and maritime applications
State-of-the-Art Facility Supported by World-Class Team

**KEY STATISTICS**

- **Facility** in Tucson, Arizona
  - R&D, engineering, analytical lab, machine shop, cell testing and validation
  - Pilot line to produce large format sample and customer cells
  - 12,000 sq. ft. Dry Room

- **90 Employees**
  - 33 Engineers and Scientists
  - 8 PhDs

**UNIQUE CAPABILITIES**

- Industrial Roll-to-Roll Coaters for Metal Lithium Anode Deposition
- State-of-the-Art Cathode Coating
- Large Format Metallic Lithium Cell Assembly Pilot Line
- Cell Test Facility for Electrical Performance and Stress Testing
- Battery Pack Development and Prototype Assembly
- Engineering Excellence and Machine Shop for Rapid Prototyping
Licerion® — Highest Energy
Highest combination of specific energy, energy density, and cycle life of any rechargeable battery

- Licerion Technology Offers Extended Ranges for Diverse Electrified Mobility Applications through the Application of Advanced Metallic Lithium Protection Systems at 500 Wh/kg and 1000 Wh/L
- Current Cell Offered for Testing: Licerion 6 Ah
- Contact Us Today!
  - info@sionpower.com
  - Connect with us on LinkedIn
  - www.sionpower.com