SOLID ENERGIES

A Novel Class of High-Energy/Power-Density, Long-Cycle-Life, Roll-to-Roll-Processed Solid-State Lithium-Air Batteries (SSLaB) for Aviation Applications

Timothy Lin, Solid Energies Inc.

Team Members: San Diego State University, The Boeing Company

Project Vision

We are solving the challenging issues of design/processing in new-generation Li-air battery to achieve both ultrahigh energy density (1000+ Wh/kg) and high power density (500+ W/kg), by using (1) innovative designs of solid-state electrolyte and catalyst/electrode and (2) low-cost, scalable process that can be implemented with today's Li-ion production line.

PROPEL-1K Program Annual Meeting
July 15, 2025

TECHNOLOGY CONCEPT – What is the Innovation?

Technology – **SSLaB with ultrahigh projected energy/power densities (1000+ Wh/kg & 500+ W/kg)**

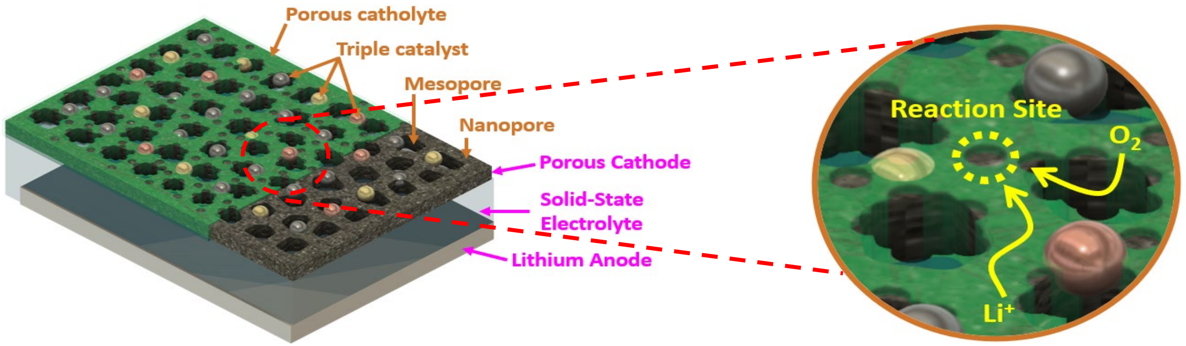
Projected SSLaB		State-of-the-art LiBs
1000+ Wh/kg	vs.	250 Wh/kg

Projected Li-O_2 (Air)

- **Reaction Product: Li_2O or Li_2O/ Li_2O_2**
  - Li_2O : 4-electron transfer, capacity: 1787 mAh/g
  - Li_2O_2: 2-electron transfer, capacity: 1165 mAh/g
- **Low-cost, scalable design/processing**

Key Innovations – **Novel-designed solid-state electrolyte (SSE) and multiscale porous cathode with embedded bifunctional multicomponent catalysts to enable the achievement of projected energy/power densities**

SSLaB Cell



Advantages over State-of-the-Art Approaches

– **Solid-state electrolyte** enables superior oxygen transport to reaction sites than liquid;

– **Low-cost, scalable design and process** enables new-generation of SSLaB that is highly compatible with today's Li-ion production technology, unattainable by other competitive approaches

TECHNICAL ACHIEVEMENTS –Key Enabling Technology Development

1. High-performance SSE

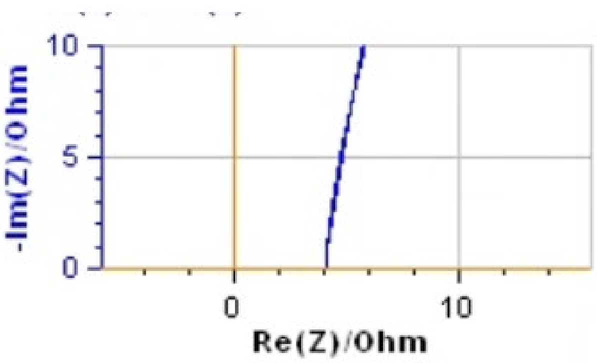
- Ultrahigh current density achieved to enable both high energy and power
- Excellent Chemical/Electrochemical stability
- Low-cost in material and processing

2. High-efficiency Air Cathode

- A multiscale porous architecture to facilitate O_2 diffusion
- in-situ polymerization (vs free-standing SSE layer) and MPL cathodes (vs GDL+MPL cathodes) to reduce weight
- Triple catholytes to enable the formation of LiO_2/Li_2O_2

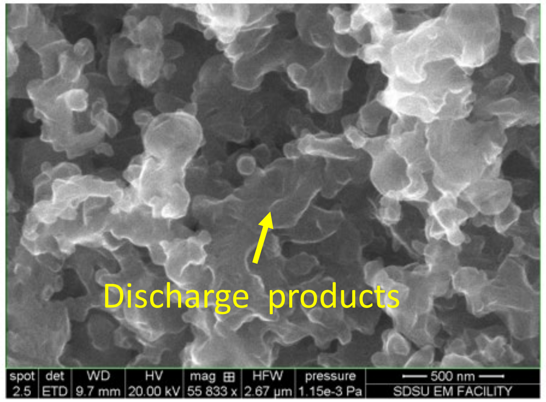
- ***Higher ionic conductivity***

σ = **2.4** mS/cm @ RT

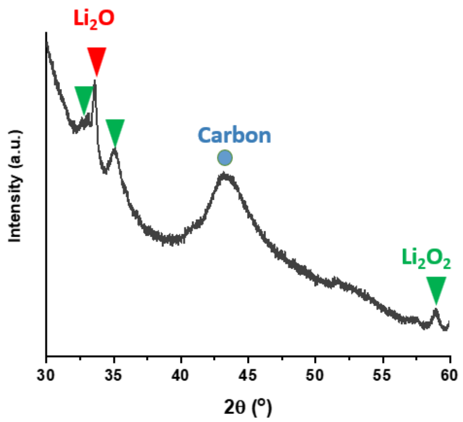


$$\sigma = \frac{l}{A * R}$$

l =125µm
A=1.27cm^2
R=4ohm



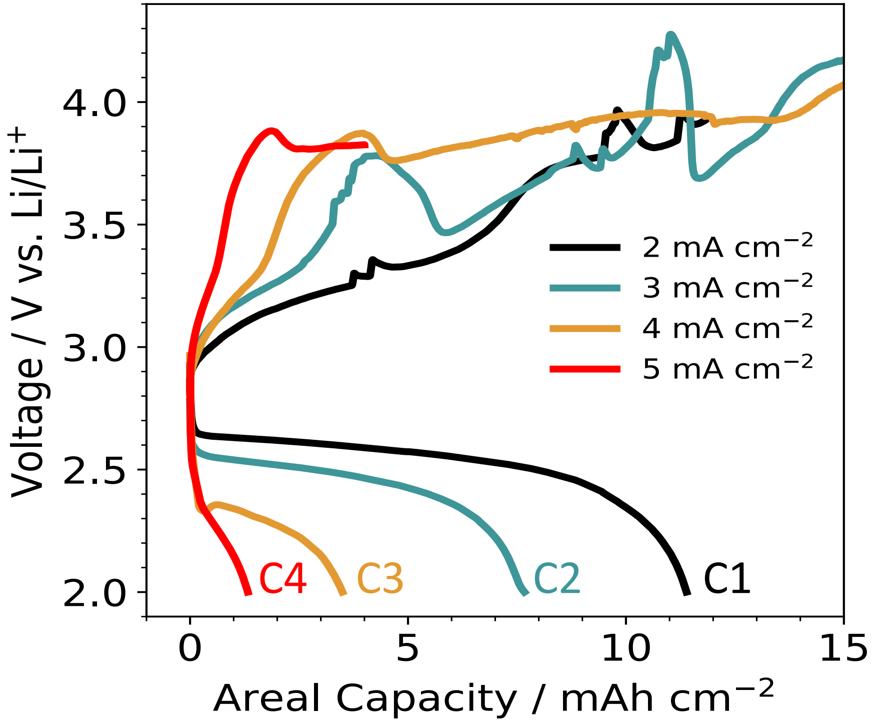
Discharged cathode MPL



XRD – Li_2O and Li_2O_2 with a mass ratio of 3:1

TECHNICAL ACHIEVEMENTS (cont.)

3. High Energy (1k+) /Power Densities Demonstrated at Coin-Cell Level



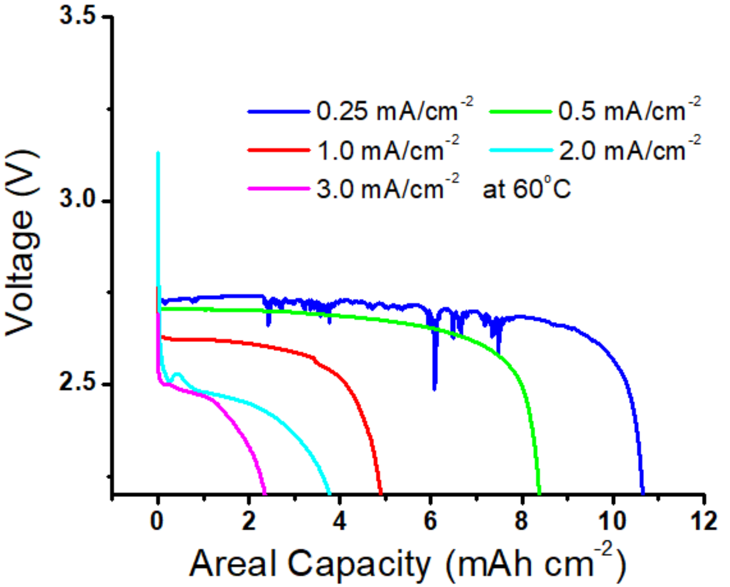
Curve #	Energy Density (Wh kg^{-1})	Power Density (Wh kg^{-1})
C1	1150	210
C2	775	300
C3	353	402
C4	176	502

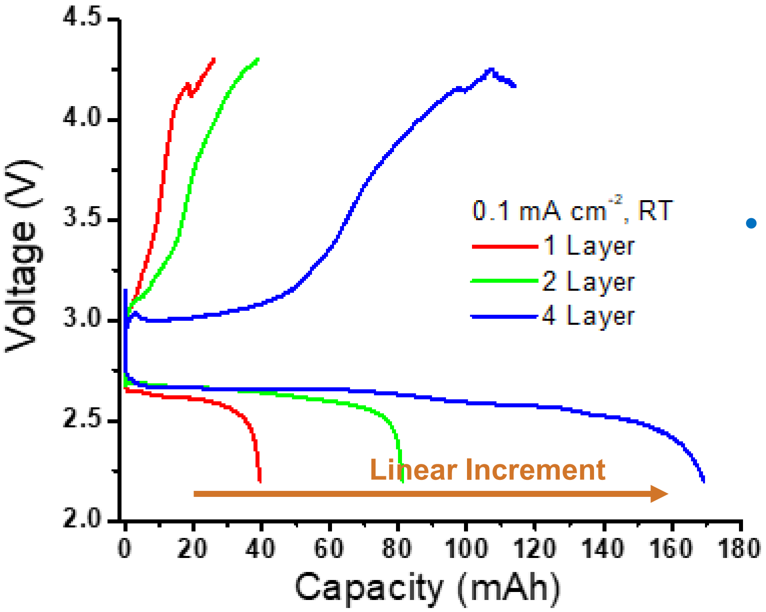
- Achieved 1150 Wh/kg of Energy Density at a Power Density of 210 W/kg.
- Demonstrated >500 W/kg of continuous Power Density.
- Demonstrated a good combination of **775 Wh/kg and 300 W/kg.**

TECHNICAL ACHIEVEMENTS (cont.)

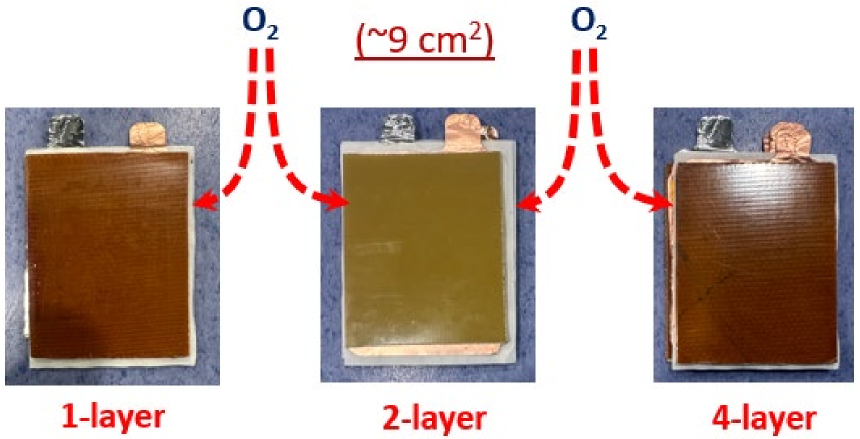
4. Demonstration of Li-Air Pouch Cell Prototypes with Promising Performance

- 1-layer, 2-layer, and 4-layer pouch cell prototypes.
- Single-layer pouch cell: energy density ~460 Wh/kg in 2nd-batch prototypes (~120 Wh/kg in 1st batch).





- Excellent scalability: linear increment in capacity from 1-layer, to 4-layer prototypes



- Single-layer cell demonstrated 10.5 mAh/cm^2 (Corresponding to, energy density: **~460 Wh/kg***) at the 2nd batch, 3rd batch for further increment is ongoing.
- Scalable multi-layer design with O_2 access from the sides enables SSLaB packs with a similar design to that of SOFCs.
- Highly compatible with today's Li-ion battery production line.

*Note: Based on the total weight of GDL + SSE + Li

Project Challenges

Main Challenge: Achieving 1k+Wh kg^{-1} at 500+ W kg^{-1}

Strategy being explored	Implications	Energy density (Wh kg^{-1})	Power density (W kg^{-1})
Detailed methods		**775 (baseline)**	**300**
1. Utilize GDL-free cathode	20-30% less overall mass	70-100%	70-100%
2: Increase porosity of MPL coating	15-20% improvement		
3: Utilize nanoscale triple catalysts	15-20% improvement		
4. Reduce SSE thickness/weight	20-30% less overall mass		
Overall increase		**1300-1550**	**510-600**

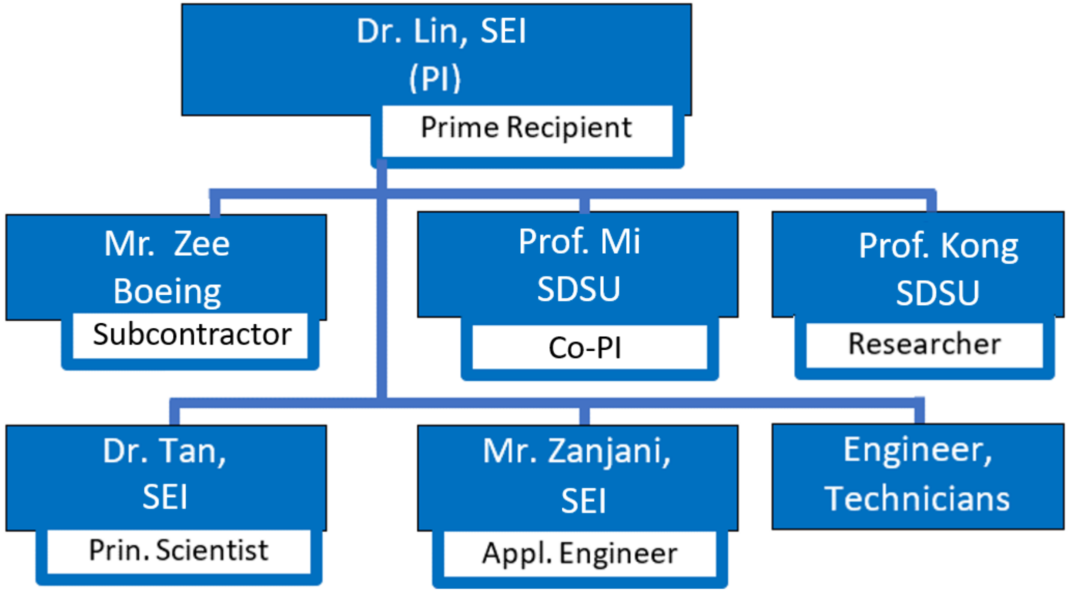
Other Challenge: Transition from Coin Cell to Pouch Cell (from single-layer to multi-layer)

Potential Collaboration for Supply Chain, System Design and End User

- Material companies/vendors
  - Nano-catalysts / Li metal foils / Separators
- Battery pack/system companies
  - Design of SSLaB-based power source and energy storage systems
- Potential End-users
  - Aircraft/Drone & UAV/EVs /Robotics/ Energy/Consumer Electronics

Team and Potential Partnerships

1. Key Personnel and Organization



2. Core Competencies

- SEI focuses on the development and commercialization of solid-state battery technologies since 2017, through nation/state sponsored projects and private investments.
- Profs. Lingping Kong and Chris Mi from SDSU are leading experts in energy device materials and BESS.
- Boeing, a technical partner (Phase II) and potential end-user, will assist in SSLaB pack tests/evaluations.

3. Well-established Facilities

a) R&D Lab; b) Pilot Production Line


Glovebox for R&D


Cleanroom for Pilot Line


DoE ARPA-E Site Visit

Technology To Market Considerations

Value Proposition

- Energy Density - Exceeds 1,000+ Wh/kg or ~4-5x energy density of current Li-ion batteries, enabling ultra long range for drones, EVs and extended run-times for electronics equipment
- Enhanced Safety Profile - Solid electrolyte eliminates thermal runaway, and stable electrode prevents short circuiting
- Extended Operational Life

Anticipated First and Long-term Users

- Aerospace/Defense - Military drones, satellites, and portable soldier equipment requiring maximum energy density, where costs is secondary and current battery weight limits mission duration
- Aviation/Marine Transport – Electric aircraft
- EV Manufacturers - Enhanced energy density required to achieve 1,000+ miles per charge, and to reduce vehicle weight
- Grid-Scale Energy Storage – Powering micro-grid and AI based data centers
- Beachhead Market -- Drones/Robotics Batteries

Infrastructure Requirements

- High Power Charging Networks to leverage fast charge capabilities
- Controlled atmosphere processing including clean rooms/dry rooms for cell and battery fabrication

Safety Profile

- Thermal stability – Solid-state electrolyte stable at ultra-low and ultra-high temperatures, no gas emissions.
- Mechanical Robustness – Solid-state resists physical damage/puncture

Other T2M Activities

- **Conferences**
  - ❖ DoE ARPA-E Conference – March 17th-March 19th, 2025, Booth Exhibition
  - ❖ International Battery Seminar, Orlando Florida – March 17th-March 20th, 2025; Conference Presentation - From Lab Research to Commercialization: High-Voltage, High-Energy-Density, Low-Cost (Co-Free) Solid-State Batteries
  - ❖ Battery Tech 2025 – Torrance, CA – Torrance Marriott Redondo Beach, CA; https://usa.battery-technology-conference.com
  - ❖ AABC Europe – June 23rd to June 25th, 2025, Conference Presentation - "Progress in Scaled-Up Manufacturing of High-Energy-Density, Low-Cost, Solid-State Li-ion Batteries: From Semi-Solid State to All-Solid State".
- **Meeting with Calstart PowerForward (Pending - $6M)**
  - ❖ Company interviewed twice after submission of proposal, awaiting notice
- **AIRBUS Letter of Intent**
  - ❖ Evaluating company's solid-state battery technologies and initial sample purchasing
- **Participation in NSF I-Corps Program**
  - ❖ Solid Energies spent March, April, and May 2025 participating in the NSF I Corps program.
  - ❖ Sponsored by NSF to those companies that have previously received SBIR/STTR funding work with instructors to evaluate the company's value proposition. Conducted over 100+ interviews with potential customers, er users, stakeholders, and partners.
- **Meetings with Sunstone Investment (https://www.sunstoneinvestment.com/**
  - ❖ In discussions with Sunstone Investment located in Irvine, California. Sunstone has invited Solid Energies to present the company to potential investors that the organization invites to its office each month.

The End

Thank You Very Much!

Questions and Comments?