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LiGas, the next generation electrolyte

2025 Space Power Workshop

SOUTH 8™

Approved for Public Release

South 8 is a domestic, innovative development stage battery electrolyte manufacturer based in San Diego, California with patented technology to improve battery cells

Company

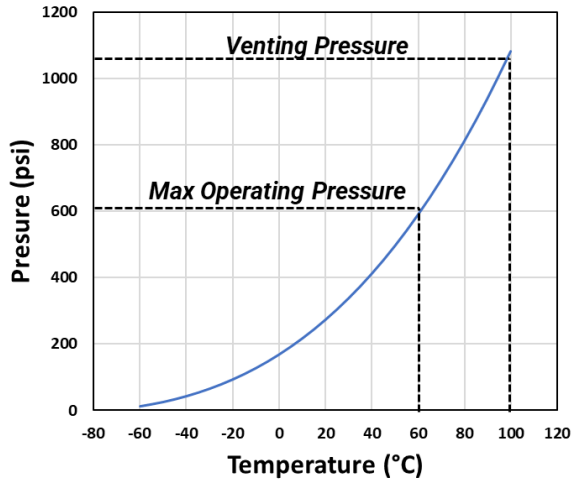
- Founded in 2016 as a spin out from UC San Diego
- Headquartered in San Diego, California
- 45 employees with a diverse leadership team
- 37 patents issued in 7 countries

Investors: ANZU PARTNERS · LG Technology Ventures · Shell Ventures · TAIYO NIPPON SANSO The Gas Professionals · LOCKHEED MARTIN · PORSCHE VENTURES

South 8 unique electrolyte technology: Liquefied Gas Electrolyte (LiGas®)

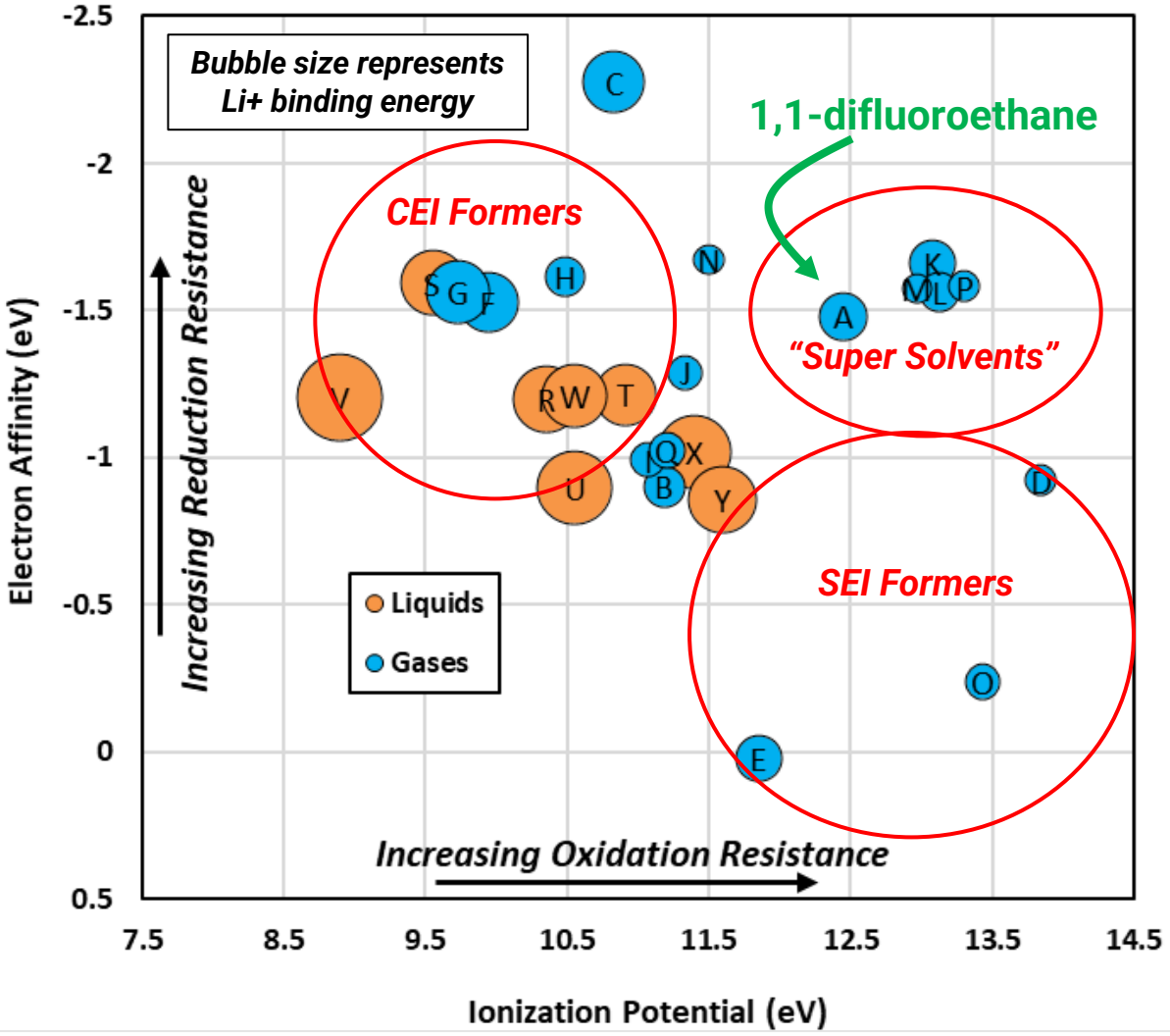
Liquefied Gas Electrolyte (LiGas®)

Conventional Liquid Electrolyte



LiGas is made of commercially available gases & salts

We have screened dozens of gasses via DFT calculations. We have identified several promising gaseous CEI, SEI formers and “super solvents”.



	Component
A	1,1-Difluoroethane
B	Confidential
C	Confidential
D	Confidential
E	Confidential
F	Confidential
G	Confidential
H	Confidential
I	Confidential
J	Confidential
K	Confidential
L	Confidential
M	Confidential
N	Confidential
O	Confidential
P	Confidential
Q	Confidential
R	
S	
T	
U	
V	
W	
X	
Y	

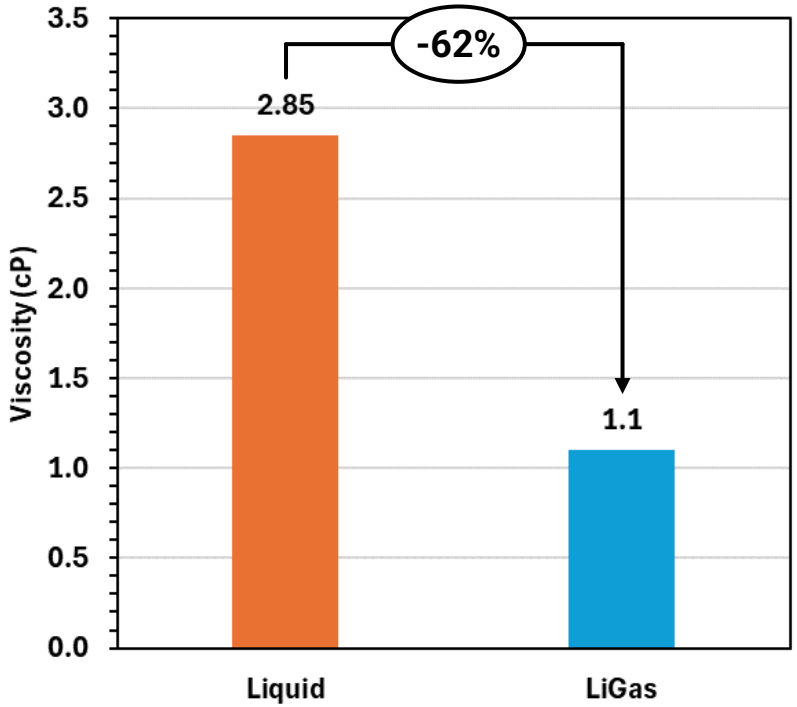
Gases

Liquids

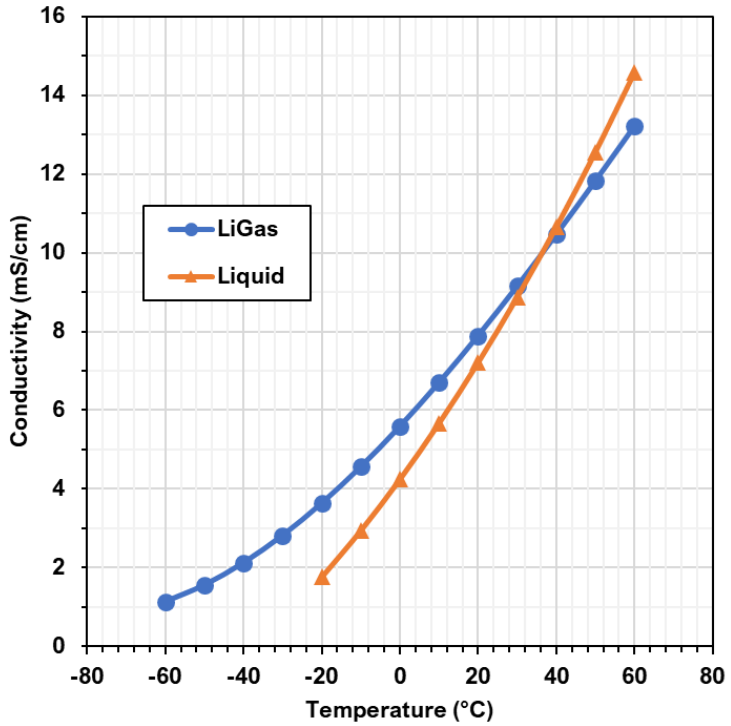
LiGas properties

- Low viscosity
- Low melting points
- Non-toxic, non-corrosive
- Low global warming potential
- Excellent electrochemical stability
- Commercially available in high purity
- Compatible with all common battery materials

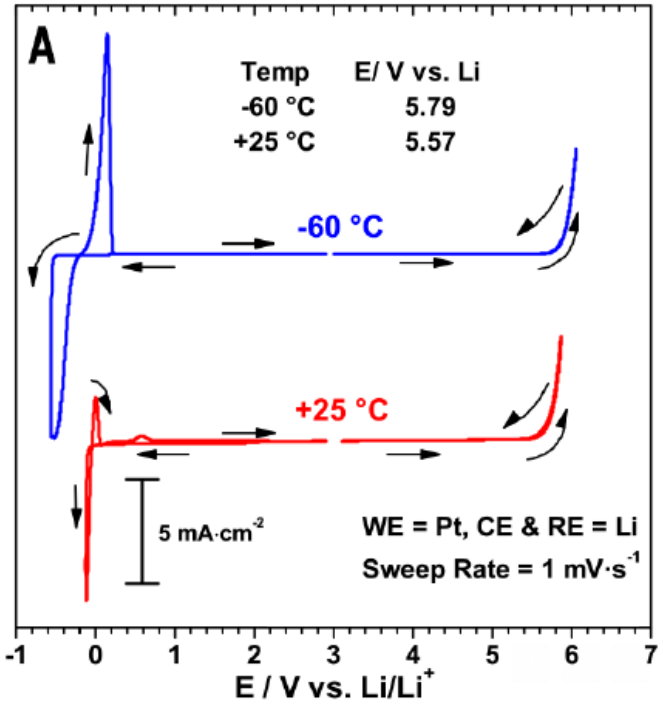
Low Viscosity



High Electrolyte Conductivity

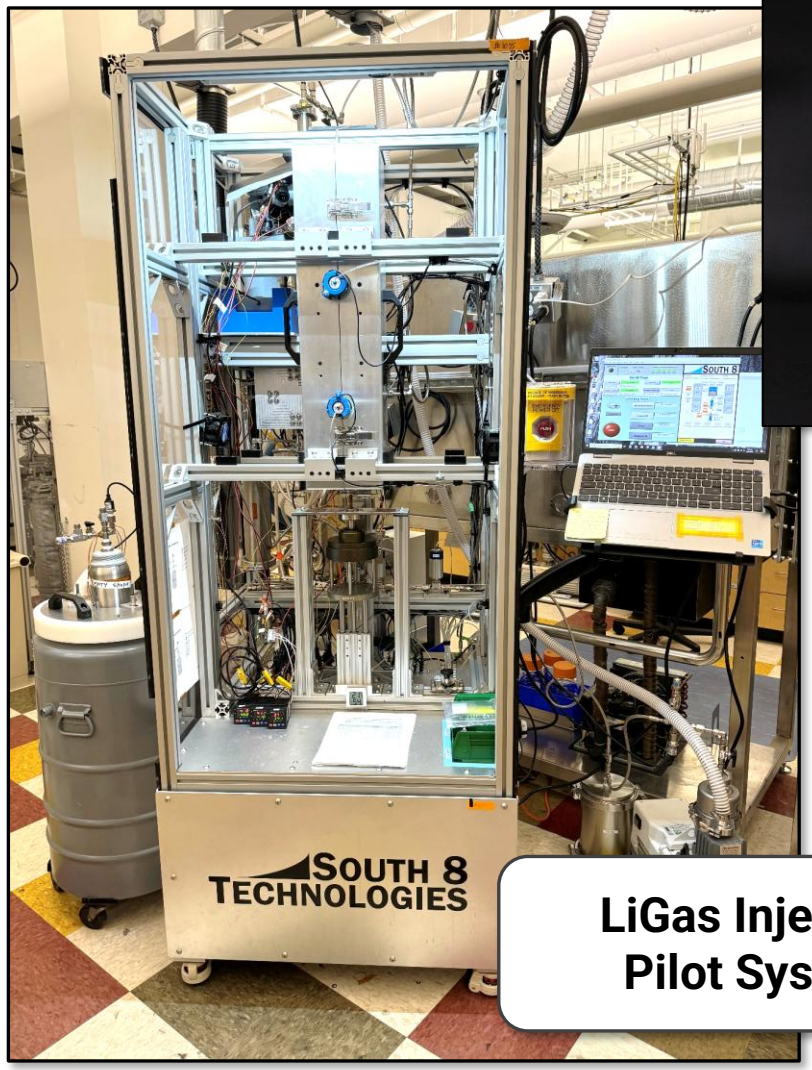


High Voltage Stability



South 8 pilot LiGas systems

Electrolyte Mixing Pilot System

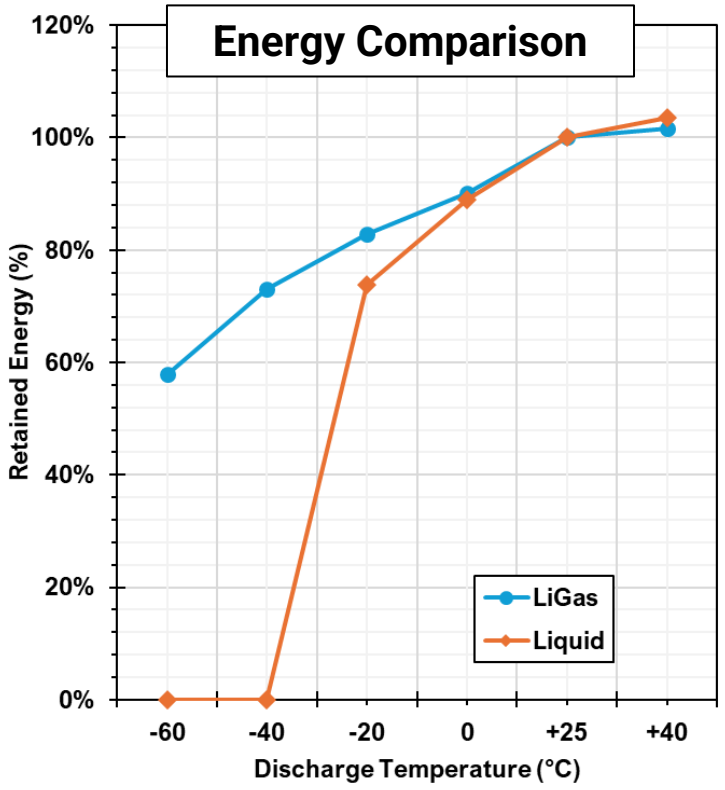


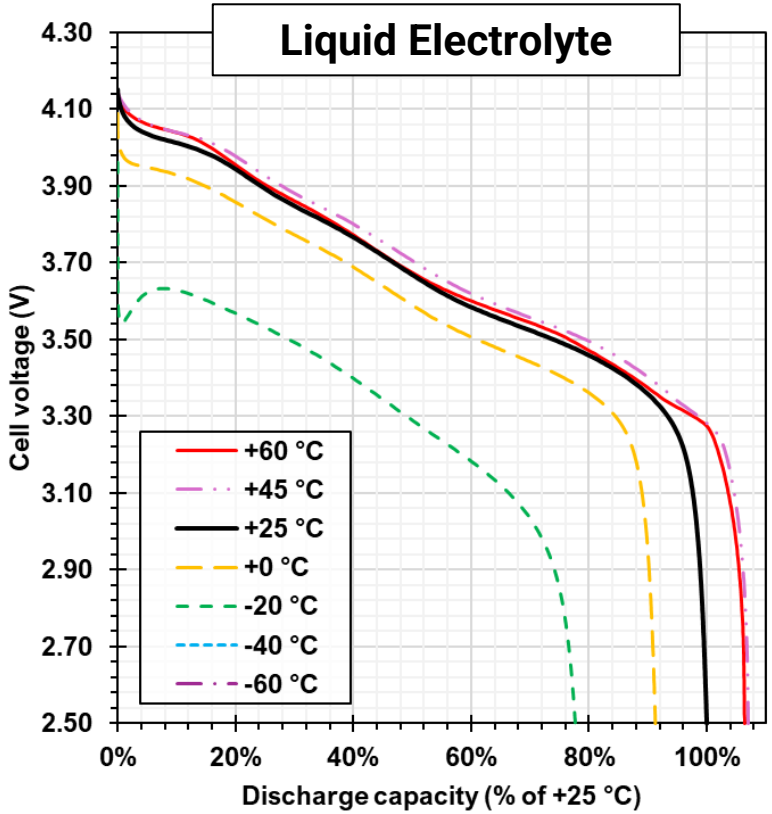
LiGas Injection Pilot System

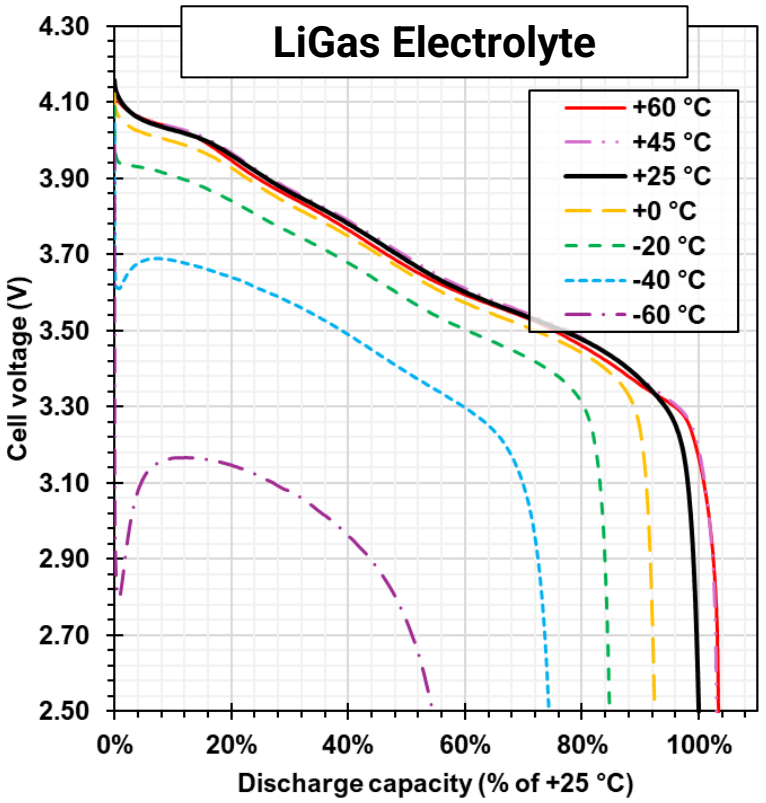
18650 & 2170 Capability Today

LiGas is superior to liquid electrolyte in low temperature testing

Temp Map: C/3 Charge at +25 °C, C/3 Discharge at Temperature





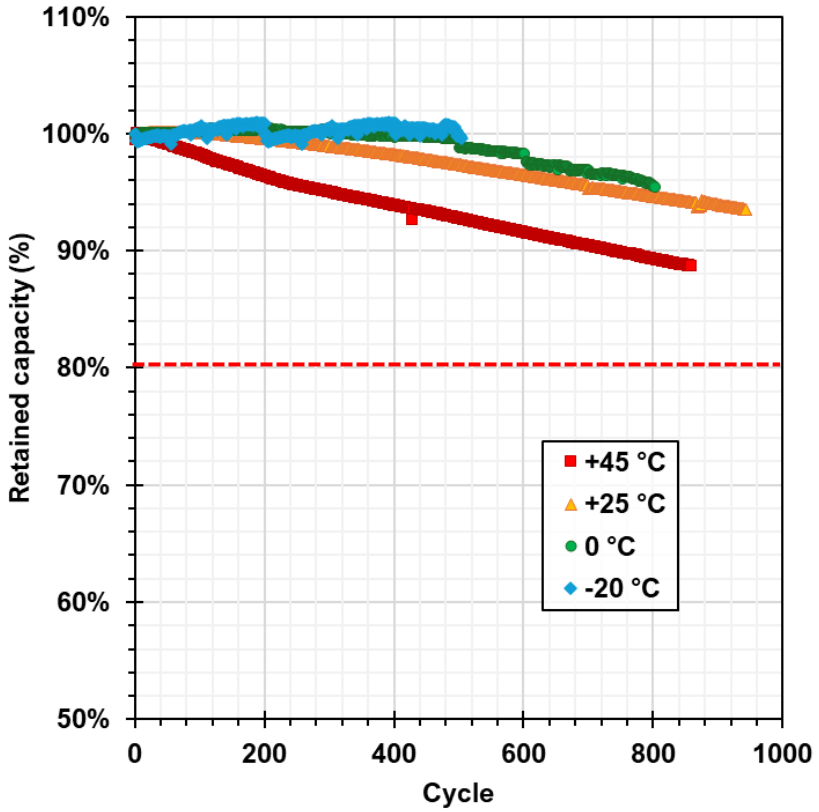


2.7 Ah 18650, Graphite / NMC811 (3.35 mAh/cm^2)

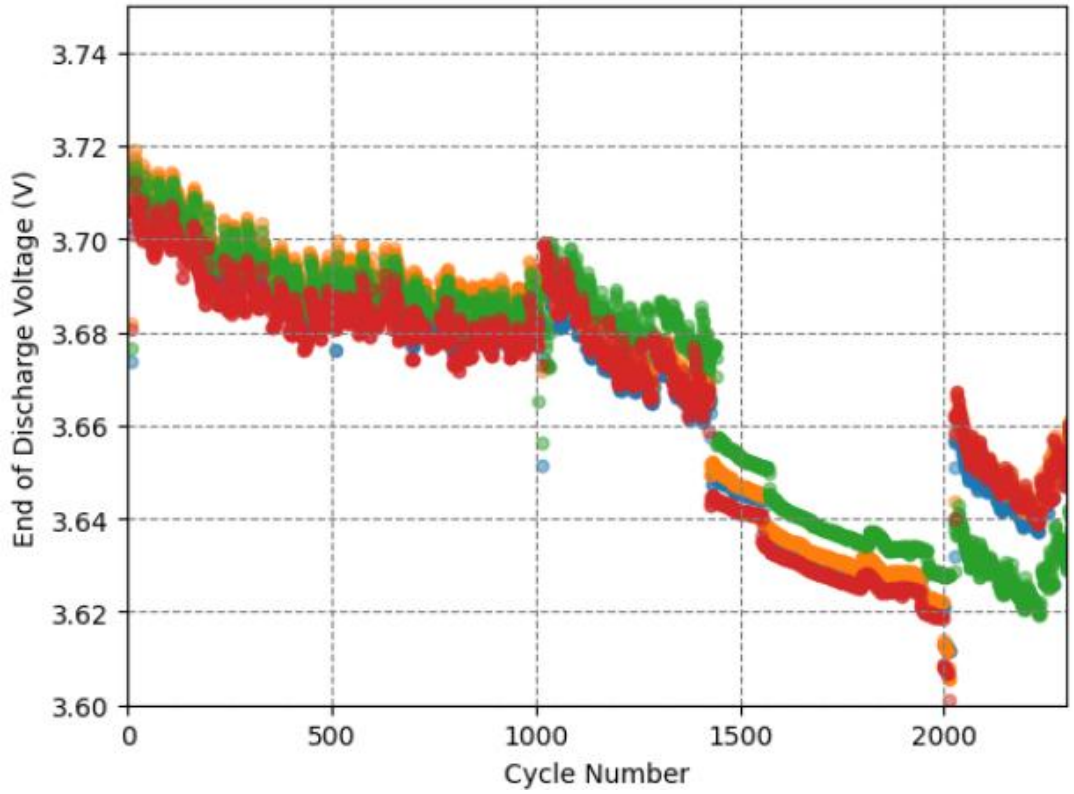
Wide temperature cycle performance

LiGas cells can be cycled below 0°C.

Cycle Life
C/3 Charge/Discharge at Temp.
2.5 – 4.2 V



LEO Cycle Life (25%DOD)
Performed by a 3rd party
-20 °C, 0.43C discharge / 0.28C charge



2.7 Ah 18650, Graphite / NMC811 (3.35 mAh/cm²)

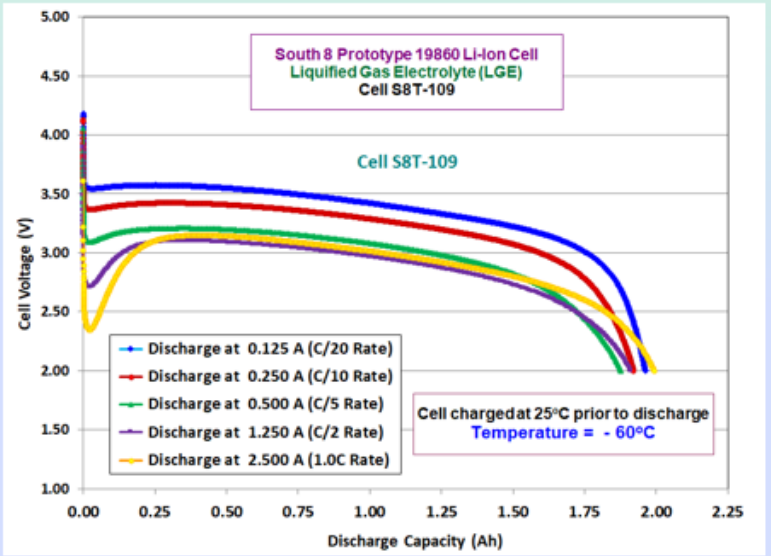
Low temperature performance validation by JPL (Courtesy of JPL/Caltech)

Performance Testing of South 8 LGE 18650 Li-Ion Cells

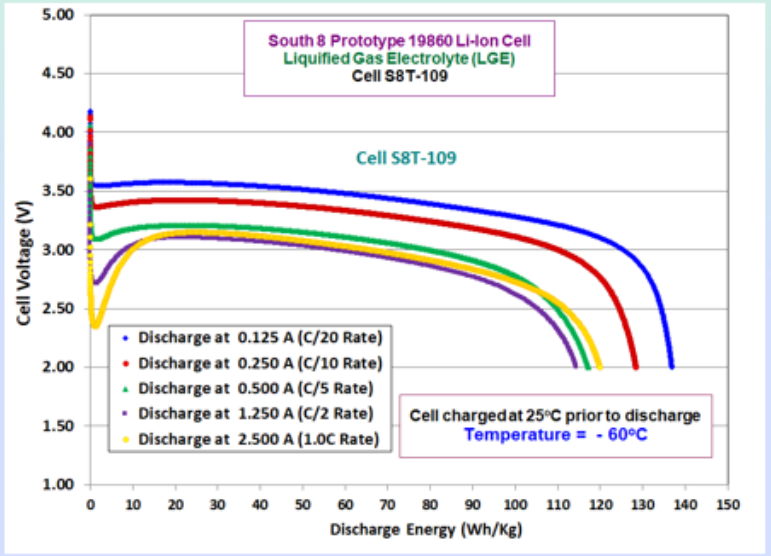
Low Temperature Discharge Rate Characterization of South 8 18650 Li-Ion Cells

Rate Characterization of South 8 18650 Li-Ion Cells at - 60°C

Discharge Capacity (Ah)



Specific Energy (Wh/kg)



Low Temperature Discharge Rate Characterization of South 8 LGE Li-Ion Cells

- Cells charged at +25°C prior to discharge at low temperature.
- Approximately 117 Wh/kg observed with a C/5 discharge rate at -60°C.
- Control cells delivered negligible capacity.

Reviewed and determined not to contain export-controlled CUI.

ELECTROCHEMICAL TECHNOLOGIES GROUP

2.7 Ah 18650, Graphite / NMC811 (3.35 mAh/cm^2)

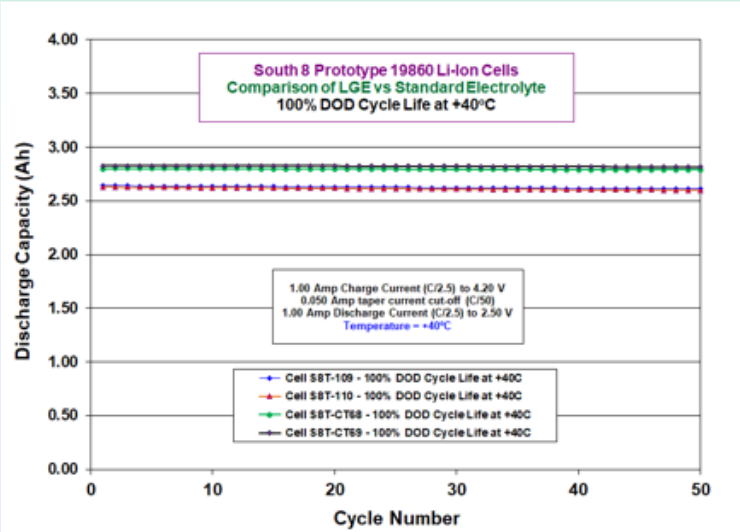
Low temperature performance validation by JPL (Courtesy of JPL/Caltech)

Performance Testing of South 8 LGE 18650 Li-Ion Cells

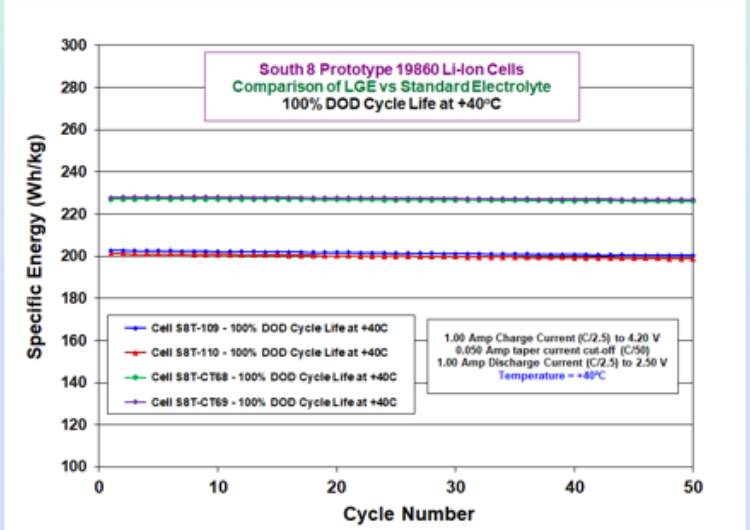
Low Temperature Discharge Rate Characterization of South 8 18650 Li-Ion Cells

Cycle Life Performance (100% DOD) of South 8 18650 Li-Ion Cells at +40°C

Discharge Capacity (Ah)



Specific Energy (Wh/kg)



High Temperature Cycling of South 8 LGE Li-Ion Cells

- Cells tested over the range of 2.50V to 4.20V at +40°C (50 cycles)
- Limited low temperature characterization was performed after completing 50 cycles at +40°C to determine if the cells retain their capability.

Reviewed and determined not to contain export-controlled CUI.

ELECTROCHEMICAL TECHNOLOGIES GROUP

2.7 Ah 18650, Graphite / NMC811 (3.35 mAh/cm^2)

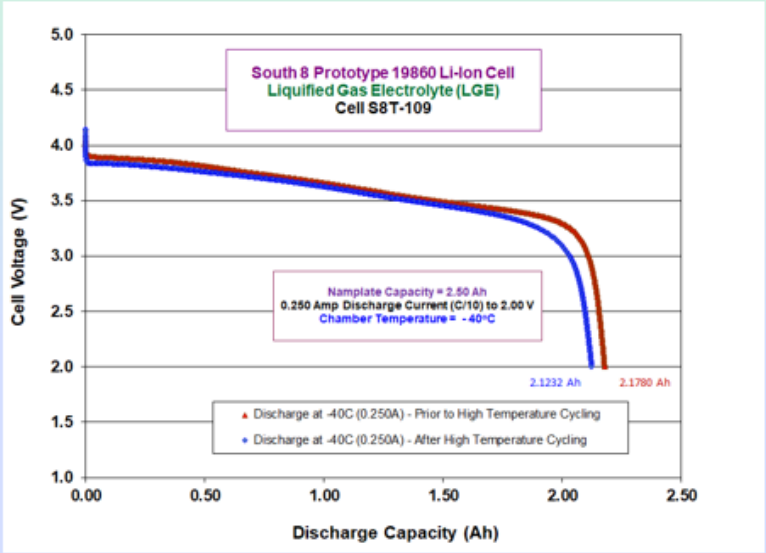
Low temperature performance validation by JPL (Courtesy of JPL/Caltech)

Performance Testing of South 8 LGE 18650 Li-Ion Cells

Low Temperature Discharge Rate Characterization of South 8 18650 Li-Ion Cells

Cycle Life Performance (100% DOD) of South 8 18650 Li-Ion Cells at +40°C

Discharge Capacity (Ah) at -40°C



- Limited low temperature characterization was performed after completing 50 cycles at +40°C to determine if the cells retain their capability.
- Overall, the cells retained their low temperature performance capability after +40°C cycling.
  - Modest decline in performance observed, being more pronounced at higher rate.
  - At C/10 at -40°C, approximately 2.5 % decline in capacity delivered observed.

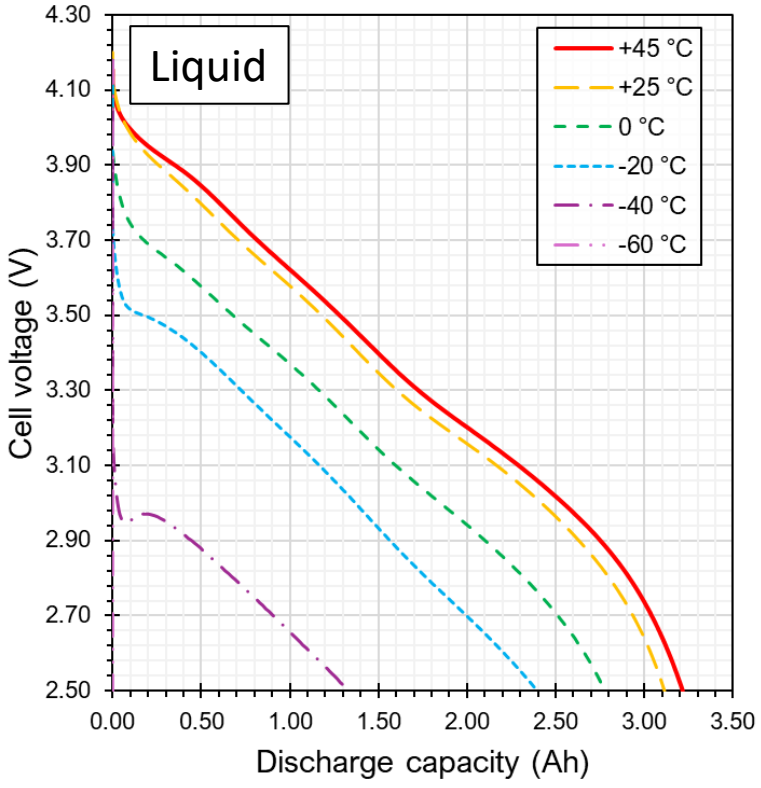
Reviewed and determined not to contain export-controlled CUI.

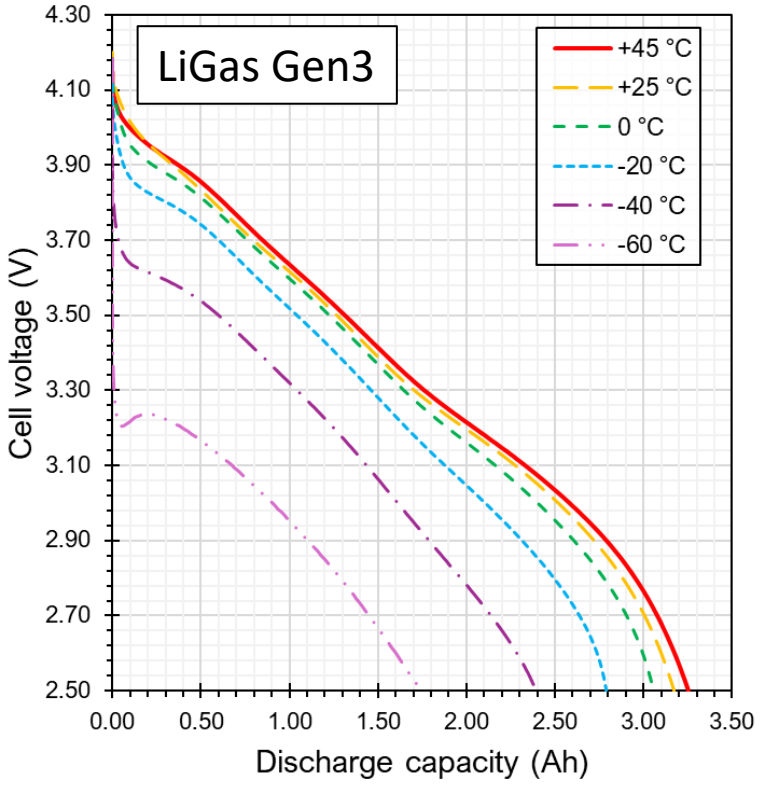
ELECTROCHEMICAL TECHNOLOGIES GROUP

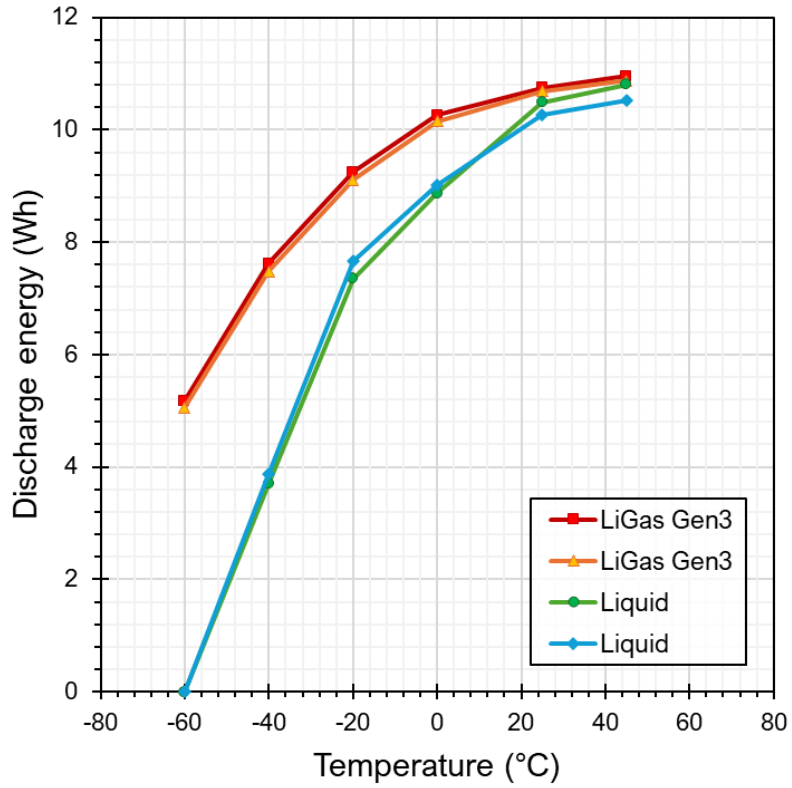
2.7 Ah 18650, Graphite / NMC811 (3.35 mAh/cm^2)

LiGas for silicon anode

Silicon cells also show significant improvement in low temperature performance.







- C/3 charge at +25 °C, C/3 discharge at +45 °C, +25 °C, +0 °C, -20 °C, -40 °C, and -60 °C

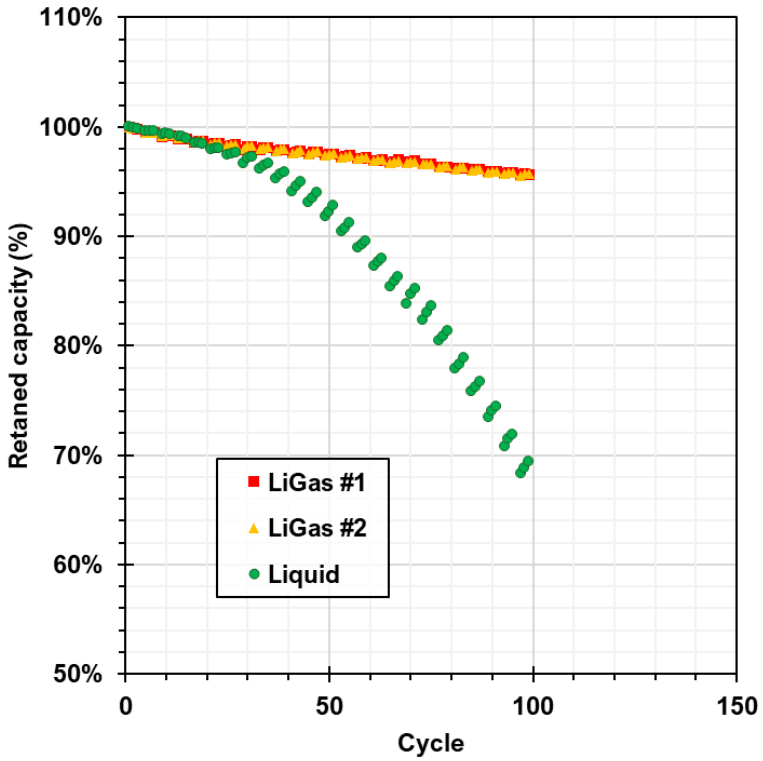
3.2 Ah 18650, Graphite + Si / NMC811

LiGas for silicon anode

LiGas shows improved metrics with the silicon anode vs. conventional liquid electrolyte.

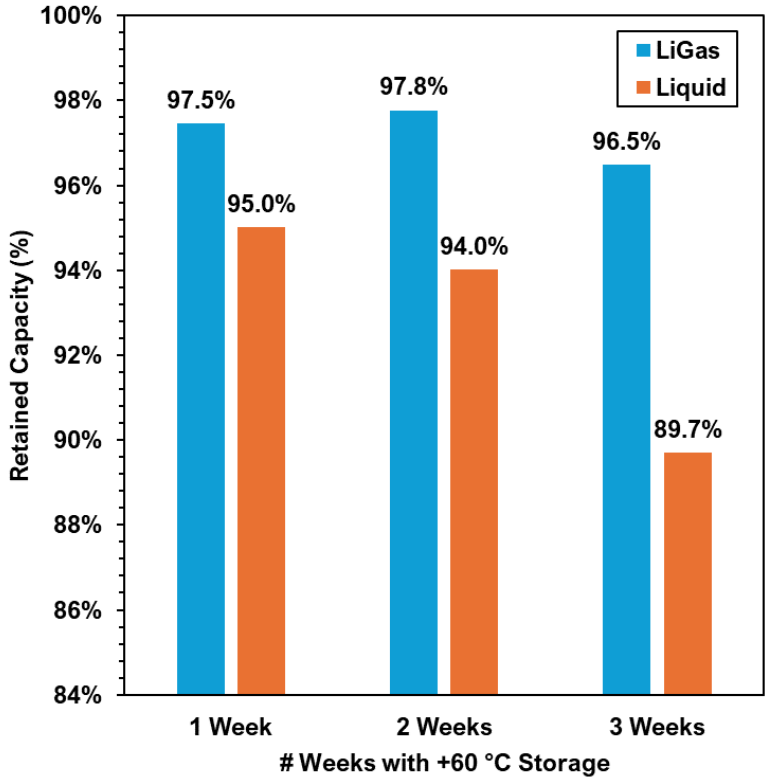
Fast-Charge at +25 °C, DOE Protocol

Charge C/3 (3 cycles) &
Charge 3.2C (every 4th cycle)
Discharge C/3 every cycle



High Temperature Storage

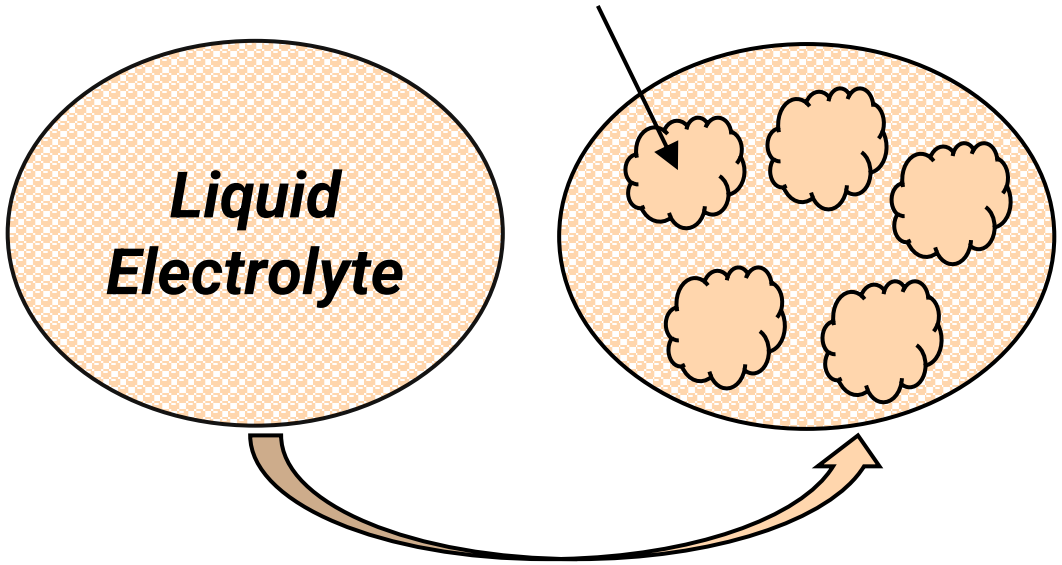
+60 °C, 100% S.O.C.



3.2 Ah 18650, Graphite + Si / NMC811

LiGas benefit ①: Generated gasses will be absorbed in LiGas

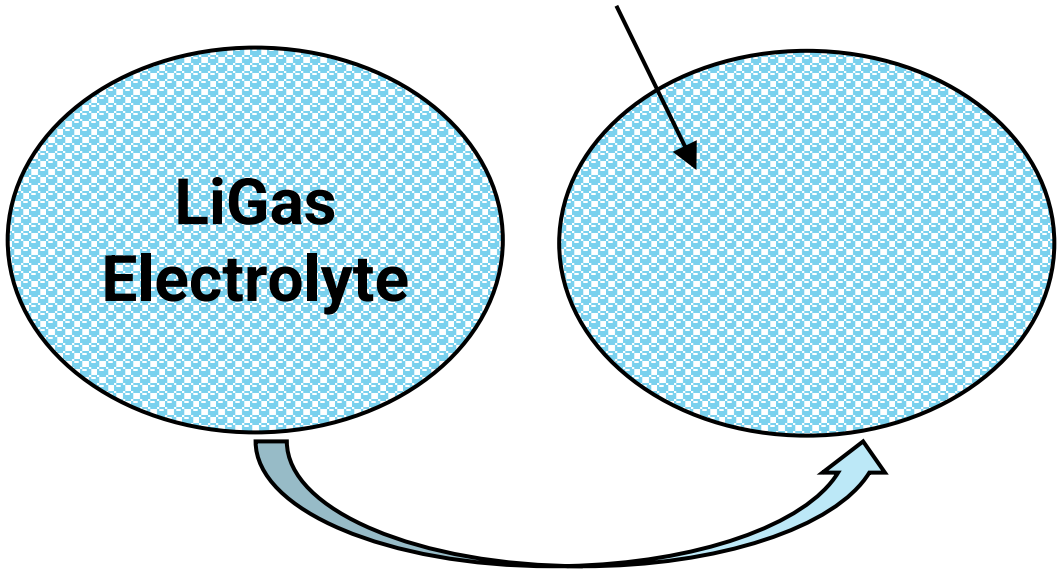
Liquid electrolyte is not under pressure →
Decomposition products form gas bubbles
Time needed for gas to diffuse away from surface



SOLID ELECTROLYTE INTERPHASE (SEI)

ELECTRODE ACTIVE MATERIAL

LiGas electrolyte is under pressure →
Decomposition products <u>do not</u> form gas bubbles
No wait time needed



SOLID ELECTROLYTE INTERPHASE (SEI)

ELECTRODE ACTIVE MATERIAL

LiGas benefit ②: LiGas forms more stable SEI

Compared to conventional organic electrolyte, LiGas forms inorganic type SEI.

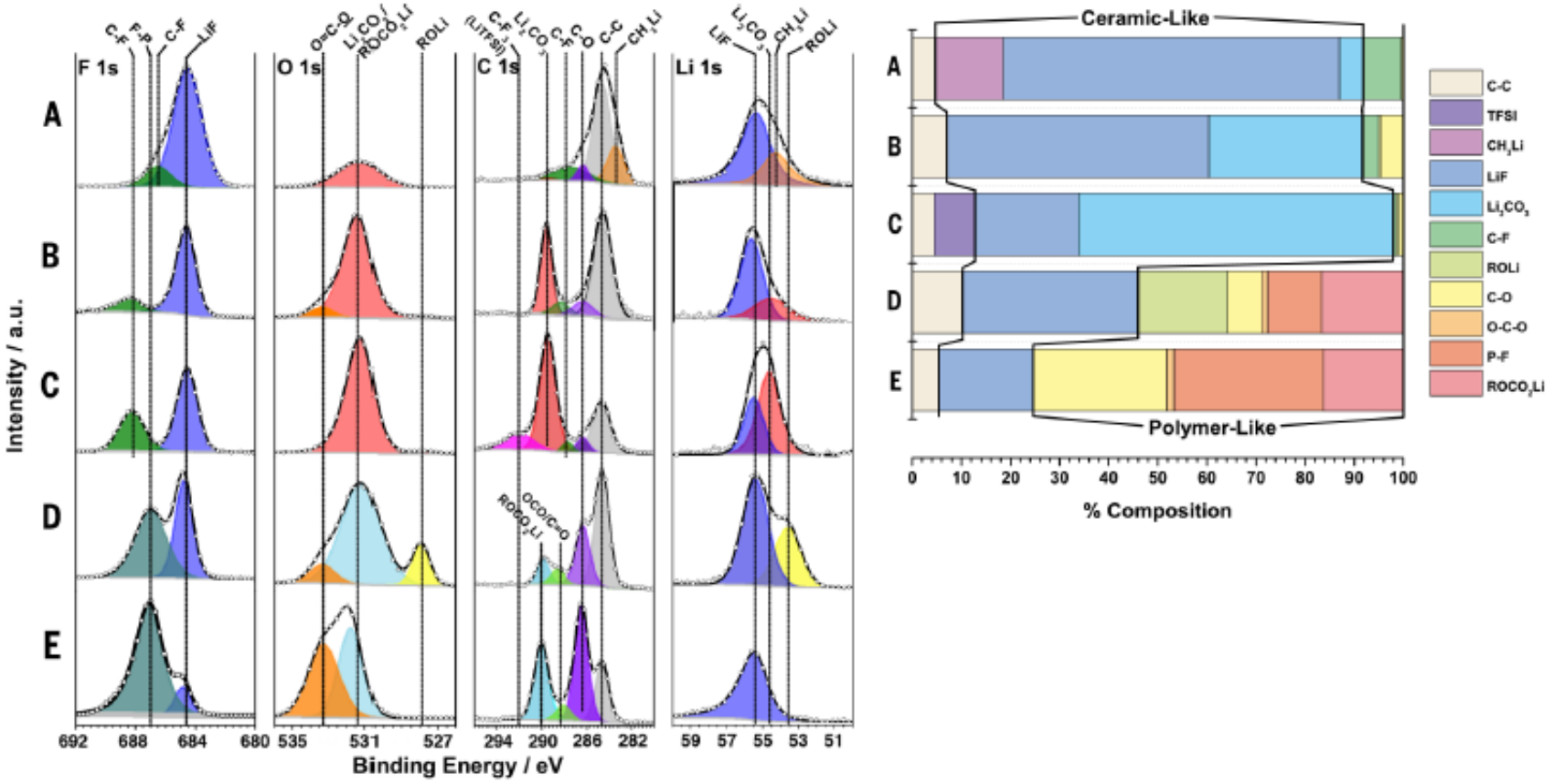


Fig. 5. XPS spectra and calculated percent composition of Li metal surface products. (**A** to **E**) Li metal after being (A) submerged in FM for three days, (B) submerged in FM:CO_2 19:1 for three days, (C) cycled 400 times in 0.2 M LiTFSI in FM:CO_2 19:1, (D) submerged in 1 M $LiPF_6$ in EC:DEC 1:1 for 3 days, and (E) cycled 400 times in 1 M $LiPF_6$ in EC:DEC 1:1. No washing of the Li electrode was done before XPS analysis.

Rustomji et al., Science 356, eaal4263 (2017)

LiGas benefit ③: LiGas prevents electrolyte depletion

BMW research indicates that a large format cell experiences issues such as electrolyte depletion, overpotential, lithium plating, and a reduced lifespan.

"A deviation in LiPF6 concentration at the edges and the center could be more than ±50% in comparison to the initial average concentration after only 18 fast charge cycles."

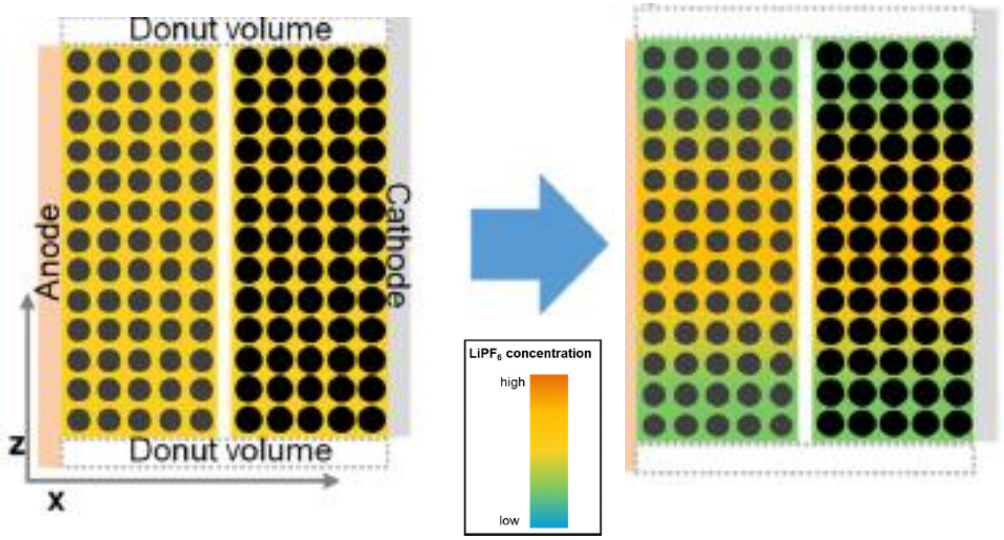
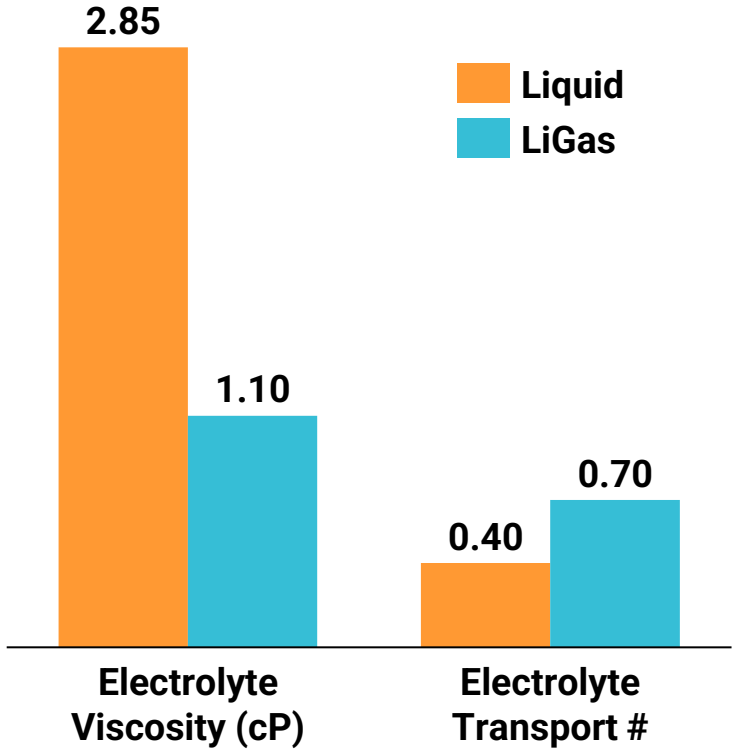


Fig. 7 Proposed mechanism for how electrolyte motion causes an in-plane (= along the z-axis) LiPF6 gradient along the jelly roll height.

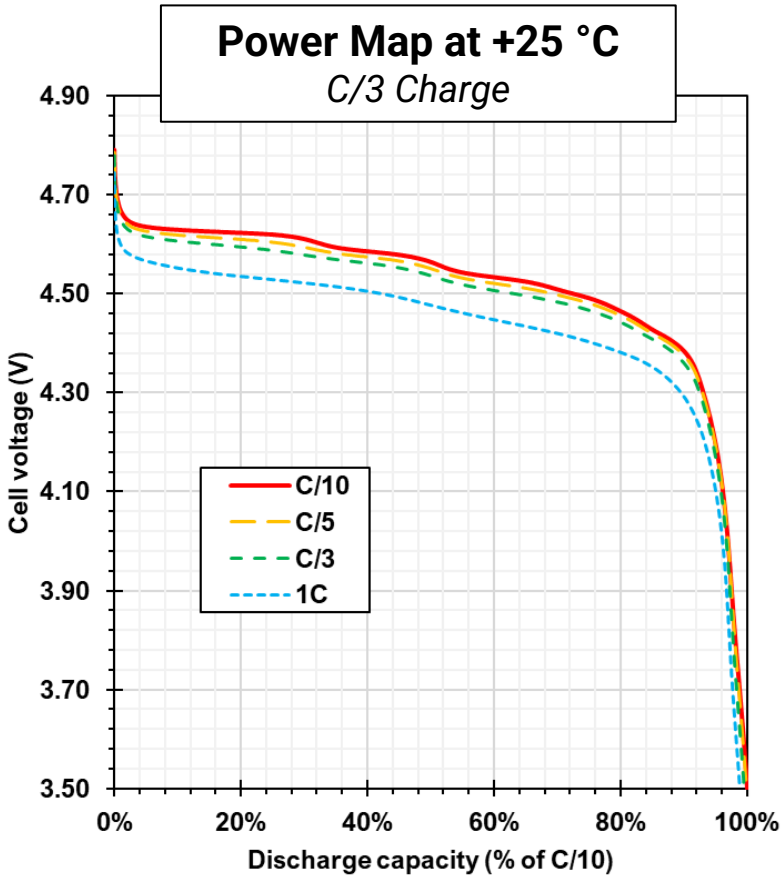
DOI: https://doi.org/10.1039/d4ee03211j

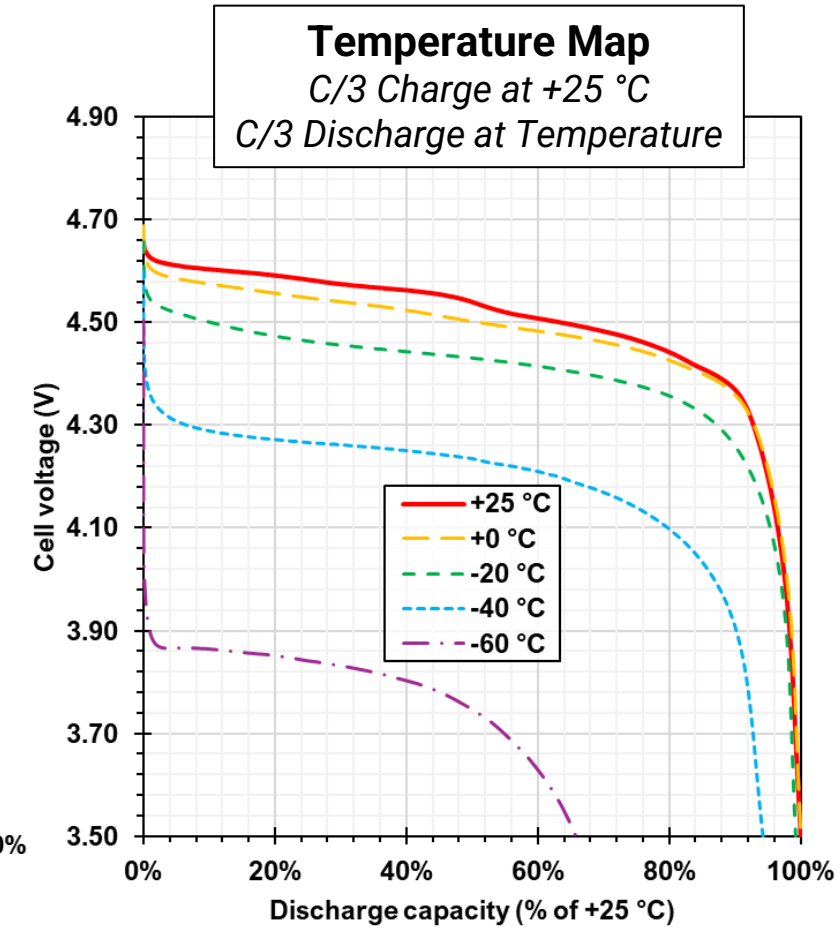
LiGas has low viscosity and high transport number, which could prevent uneven Li distribution.

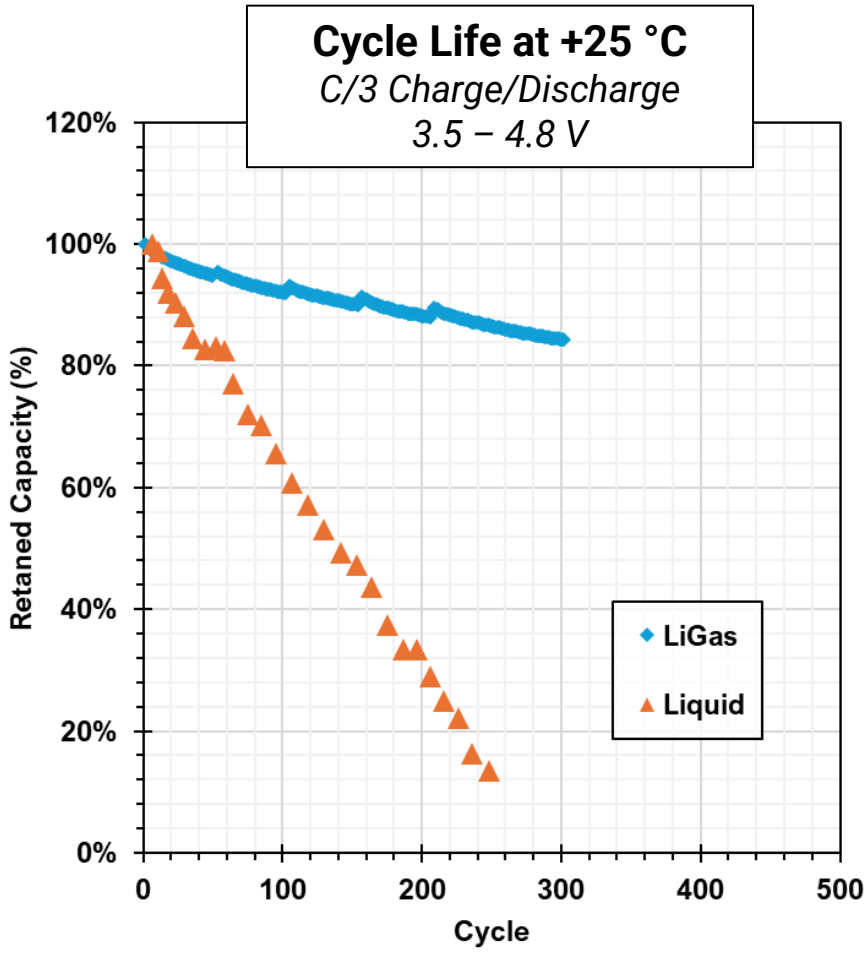


LiGas for LNMO cathode

LiGas enables high voltage (4.85V) charge and extends the cycle life in addition to the low temperature performance improvement.



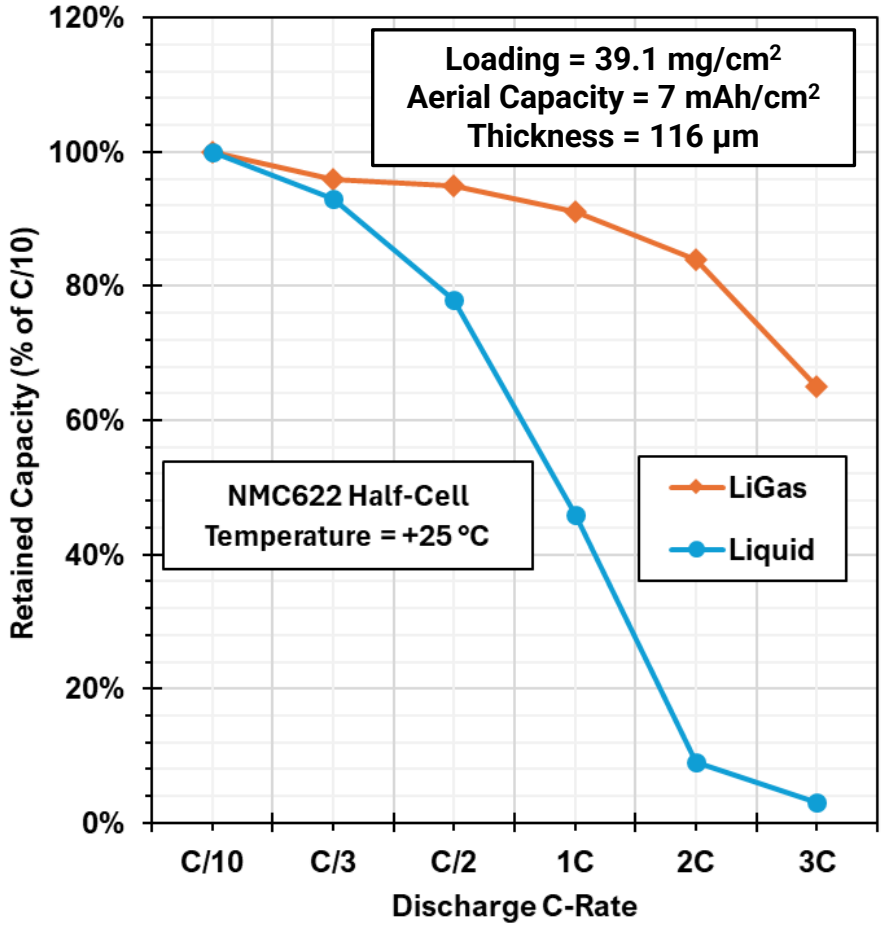


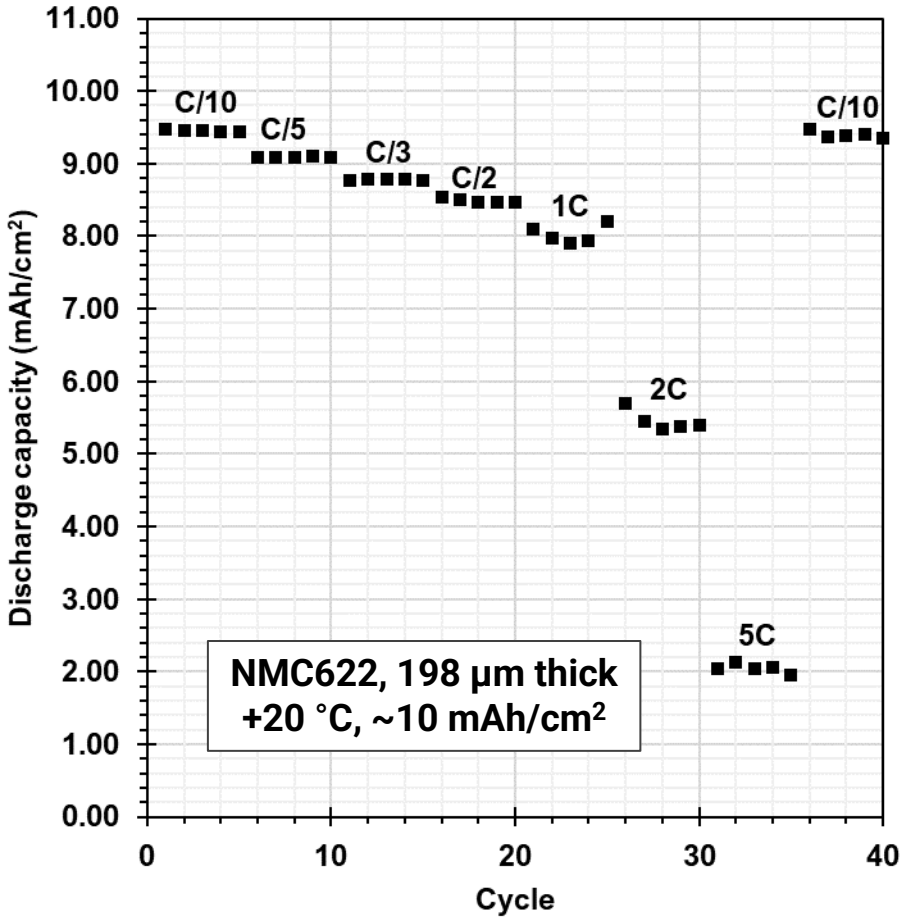


1.5 Ah 18650, Graphite / LNMO (2.2 mAh/cm^2)

Low viscosity and high pressure enables thicker and denser electrodes.

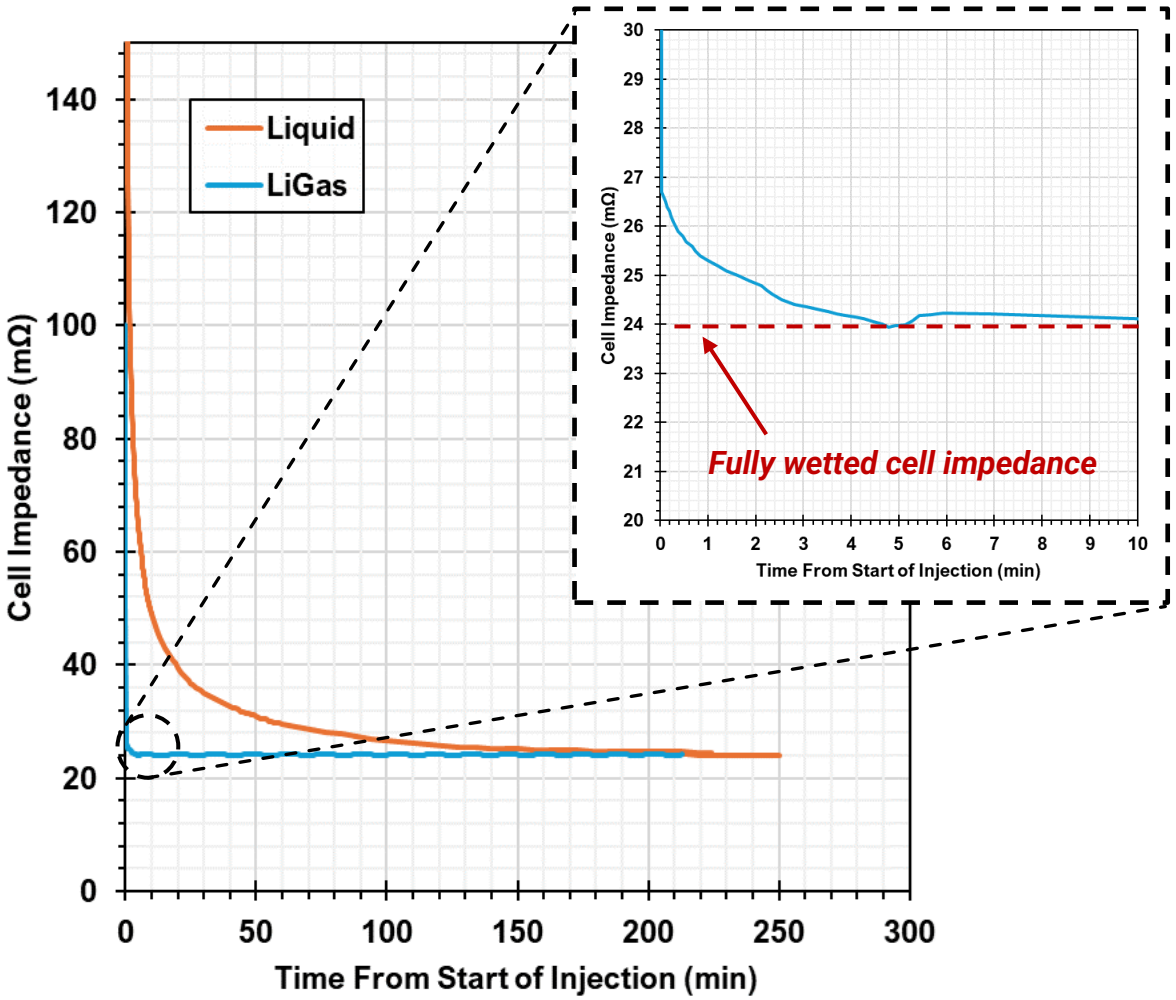
LiGas enables high energy design without sacrificing power.

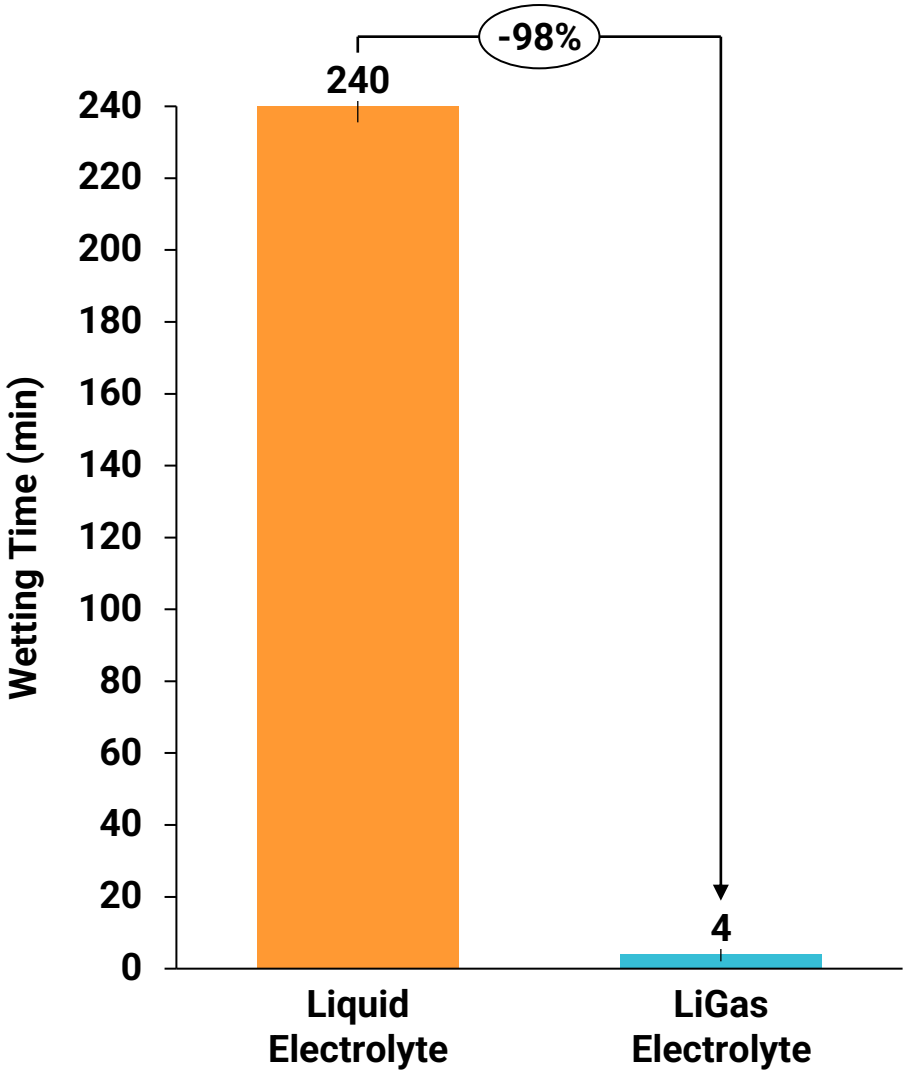




Soaking speed of LiGas after injection

LiGas electrolyte fully wets jelly roll in 4 minutes. Liquid takes 4 hours.

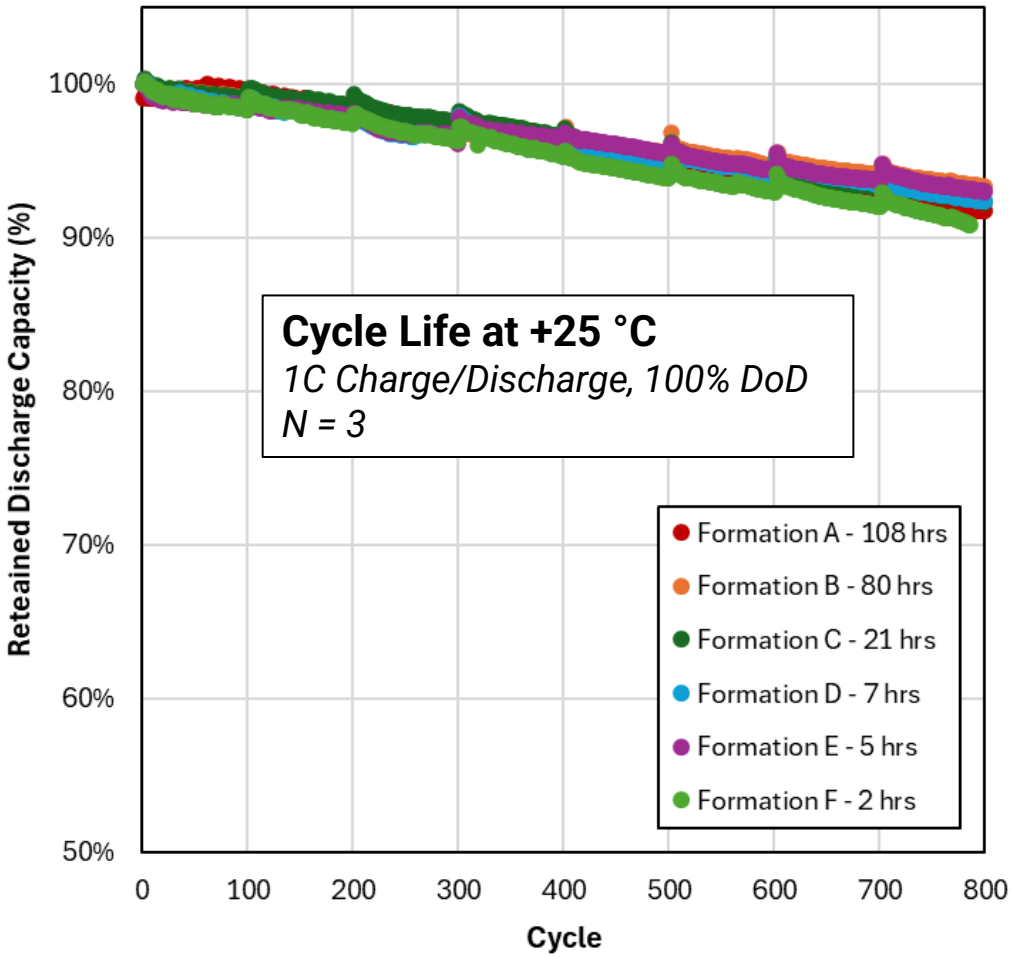


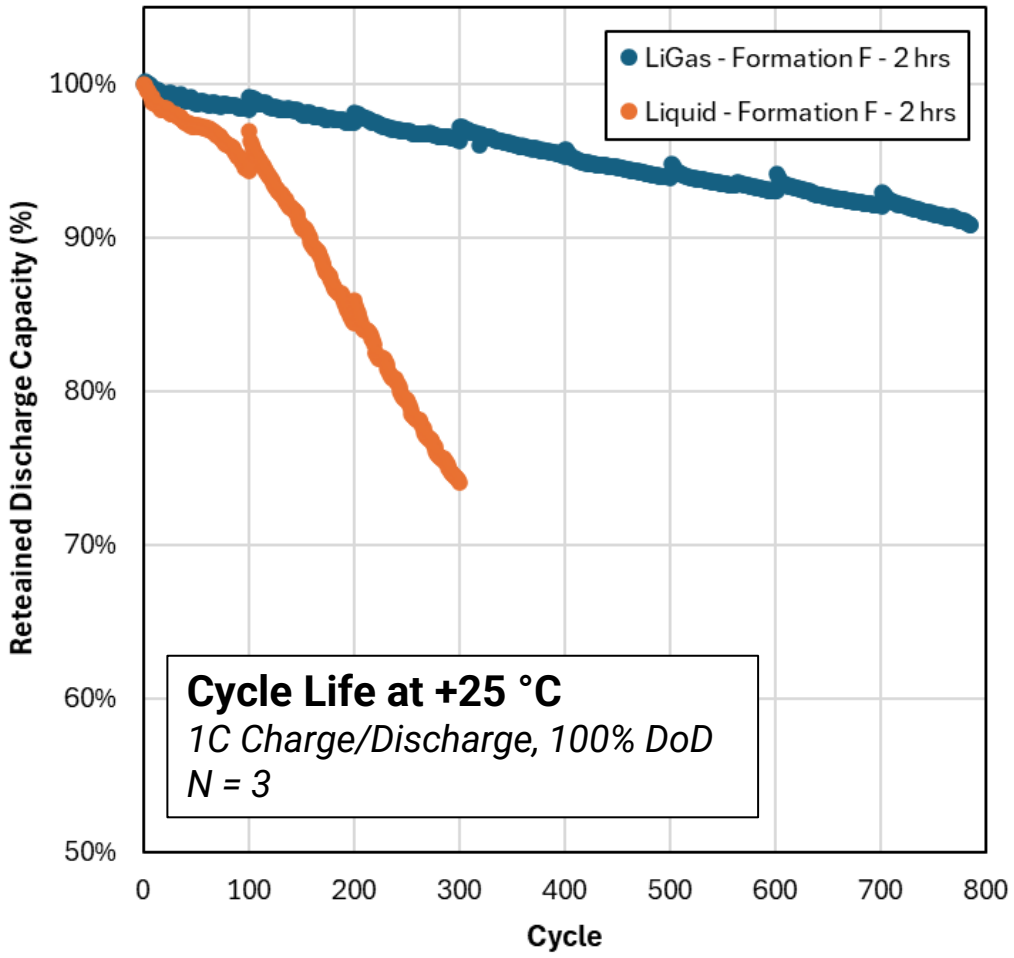


2.7 Ah 18650, Graphite / NMC811 (3.35 mAh/cm²)

LiGas cell formation

LiGas enables 2-hour formation without affecting the cycle performance.

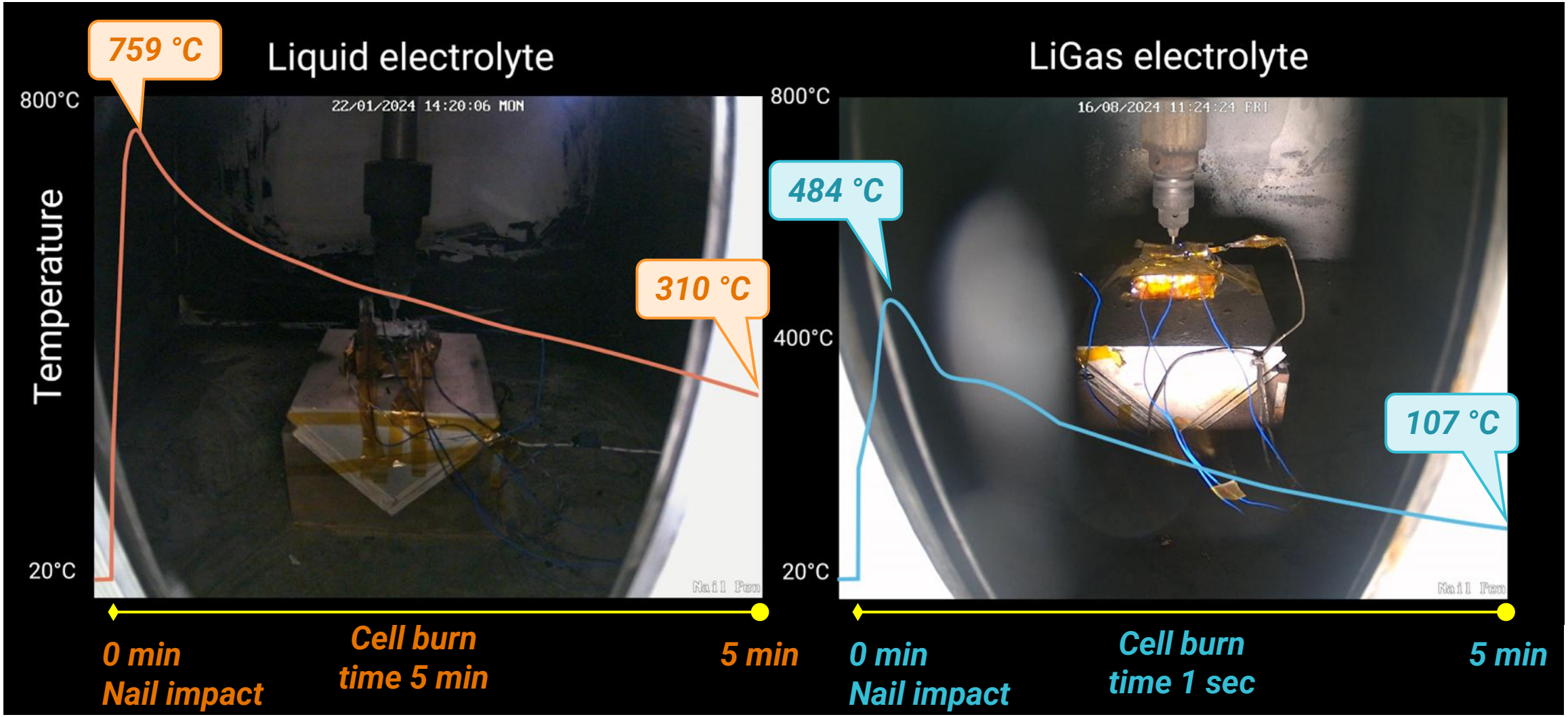




2.7 Ah 18650, Graphite / NMC811 (3.35 mAh/cm^2)

Nail Penetration (SAE J2452): No explosion or side wall rupture.

LiGas has lower peak temp, shorter burn time, faster cooling. Reduced risk for thermal propagation.



Identical Jelly Rolls: 2.7 Ah 18650, Graphite / NMC811 (3.35 mAh/cm²)

No thermal propagation

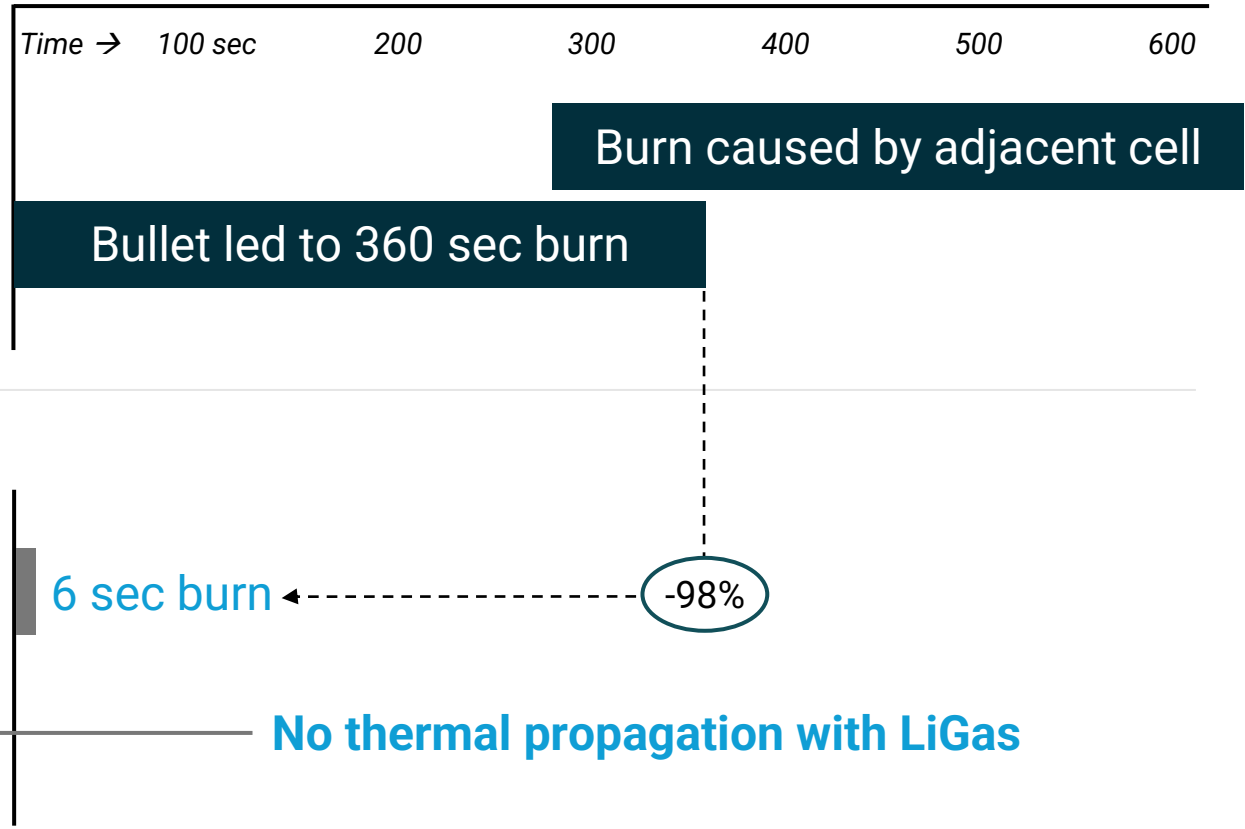
2023 safety test: no thermal propagation, even under direct ballistic impact

Electrolyte type

Liquid electrolyte

South 8 LiGas

Ballistic test results



Summary

- **LiGas properties:** LiGas has high electrochemical stability (>5V), low viscosity (1/3), and high ionic conductivity over a wide temperature range.
- **Low temperature performance:** Discharge performance at temperatures down to -60°C has been greatly improved and the cells also demonstrated 1/3C charge/discharge cycle at -20°C.
- **Stabilization of Si cells:** Compared to conventional electrolytes, the capacity retention is better during fast charging cycle at 3.2C and during 60°C holding tests.
- **The LNMO cathode:** LiGas exhibited stable cycle performance in the high voltage region (4.85V).
- **Cost:** The time required for the injection and formation processes has been significantly reduced. Formation can now be completed in as little as two hours.
- **Safety:** By releasing LiGas outside the system, Li-ion carriers and combustion materials are significantly reduced, suppressing the propagation of thermal runaway between cells.

Thank You

SOUTH 8™

www.south8.com