High Energy Density, Long Cycle Life Lithium-Sulfur Batteries for Space Applications

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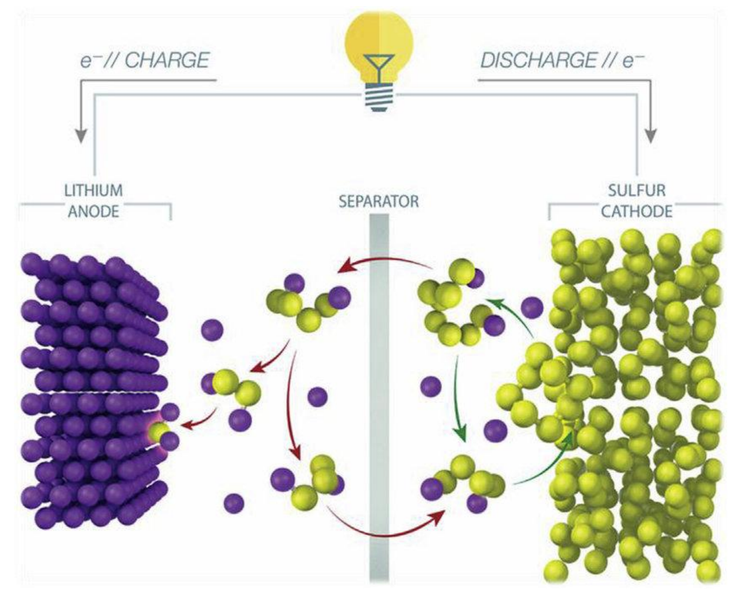
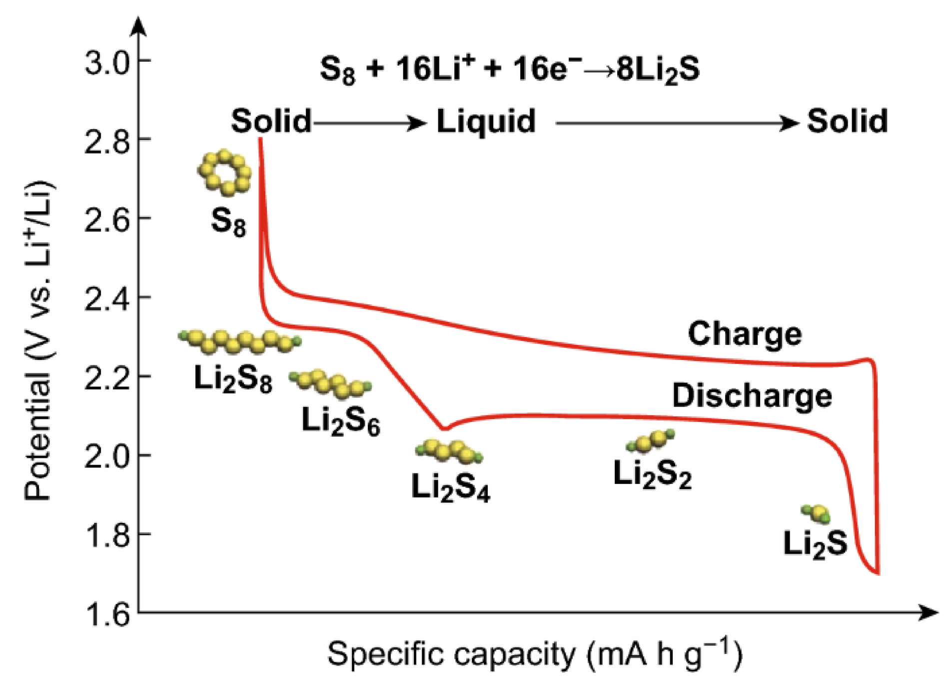
The Lithium-Sulfur Battery



lithium metal anode

sulfur (composite) cathode

$S_8 \rightarrow Li_2S$



Charge-discharge curve

Advantages

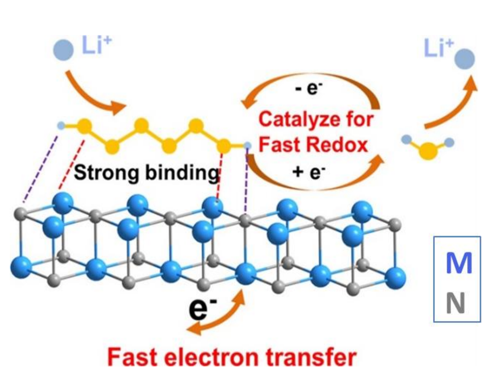
- High theoretical specific energy
  - lithium specific capacity of 3861 mAh/g
  - sulfur specific capacity of 1672 mAh/g
  - theoretical 2500 Wh/kg (only active Li and S_8)
  - theoretical ~500 Wh/kg (full cell)
- Sulfur is abundant and very inexpensive (no nickel or cobalt required)

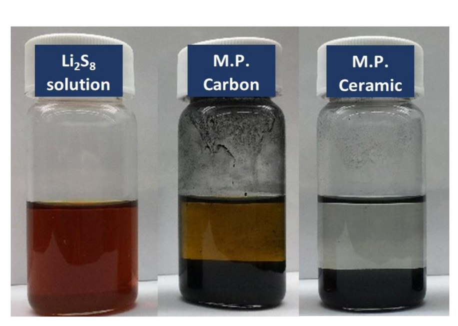
Challenges

- Very low electrical conductivity of S_8 and Li_2S
- 80% volume increase in conversion of S_8 to Li_2S
- Challenging to utilize >~60% of S_8 in cathode
- Li_2S_n soluble in the electrolyte: redox shuttle to anode reduces coulombic efficiency, forms Li_2S on the anode
- Cycling of lithium metal anode leads to dendrites (which can short the cell) and dead lithium

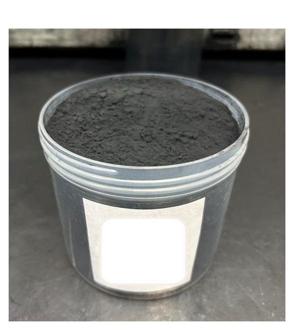
Navitas Sulfur Cathode

An electrically conducting metal nitride is a component of the sulfur cathode composite; it adsorbs lithium polysulfides more strongly than carbon does

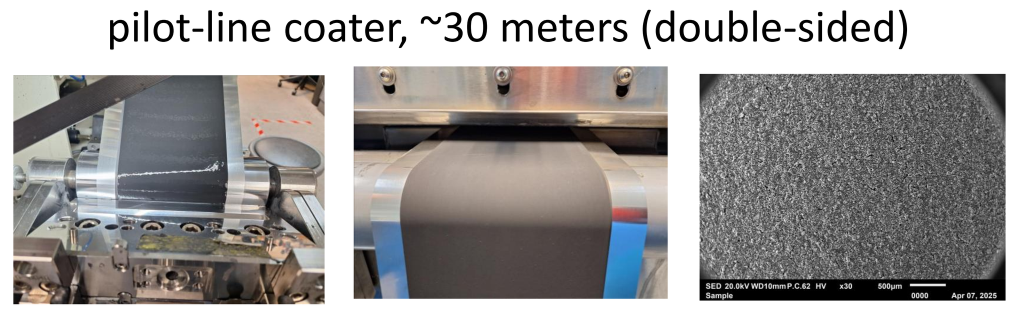




Composite cathode active material is made by melt-infusion of sulfur in 600 g batches



A slurry of active material, conductive carbon, and our proprietary aqueous binder is coated on our pilot-line coater, ~30 meters (double-sided)



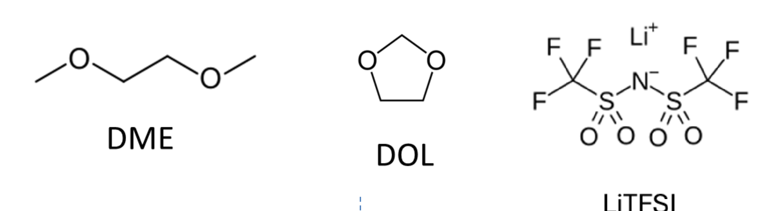
3.5 - 4.0 mg S_8 cm^{-2} coating is uniform and crack-free

Alternatively, a dry-process cathode can be made with PTFE binder in a twin-screw extruder (TSE)

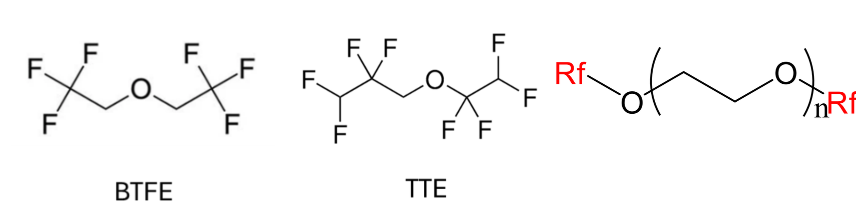
flakes from TSE → ground/powdered flakes → laminated onto Al current collector

Electrolyte

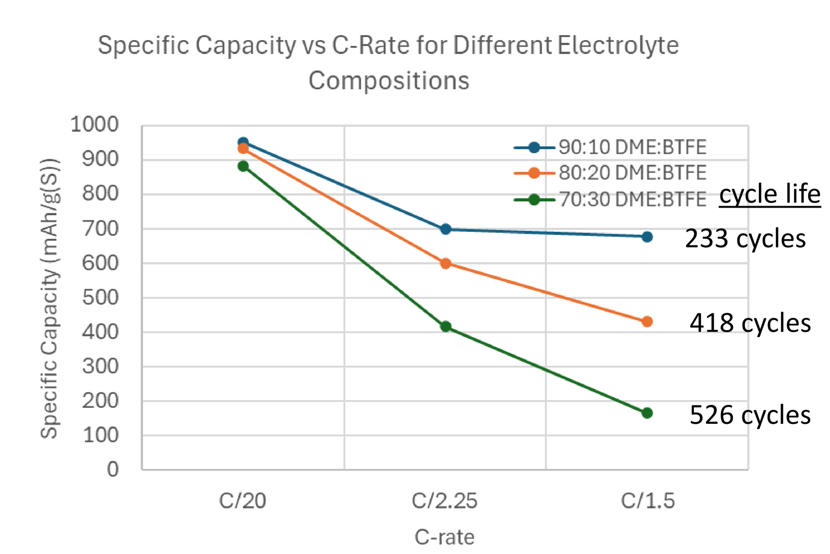
A typical electrolyte is 1.0 M LiTFSI in 1:1 DME:DOL with 0.3-0.5 M $LiNO_3$



Added fluorinated ethers and glymes reduce the solubility of lithium polysulfides in the electrolyte



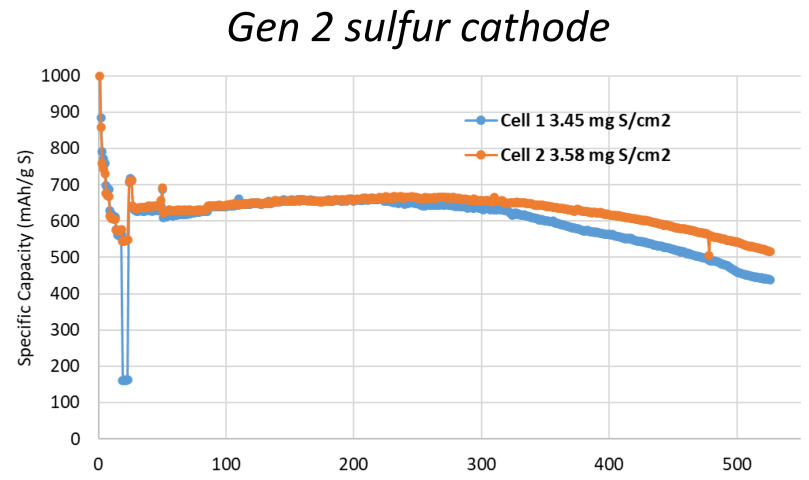
more fluorinated solvent → lower lithium polysulfide solubility → worse rate capability but longer cycle life



Coin Cells

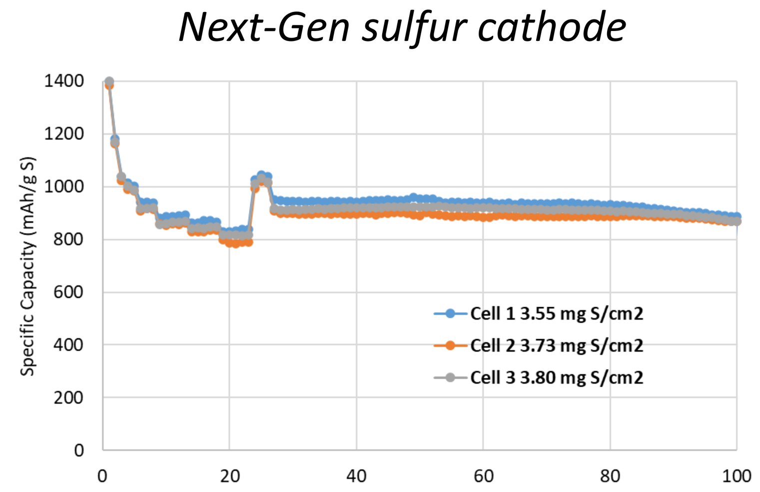
cycling protocol: C/20 (x2), C/10 (x3), C/5 (x3), C/2.25 (x5), C/1.5 (x5), 1C (x5), C/10 (x3), C/3 (x500); 1.6-2.6 V
E/S = 10 µL/mg S

Gen 2 sulfur cathode



- good rate capability through 1C
- stable cycling for > 500 cycles
- good specific capacity of 650 mAh/g (S) at C/3

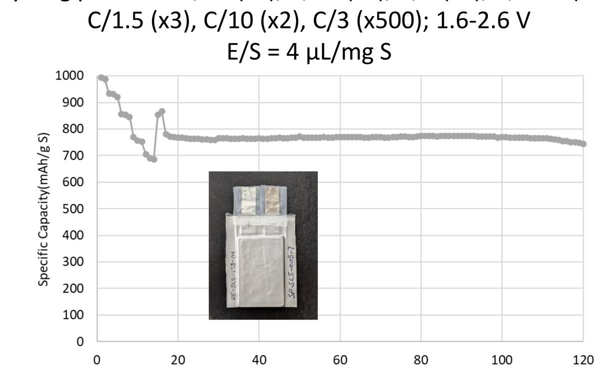
Next-Gen sulfur cathode



- excellent rate capability through 1C
- outstanding specific capacity of 950 mAh/g (S) at C/3
- cycle life needs improvement

Multi-layer Pouch Cells

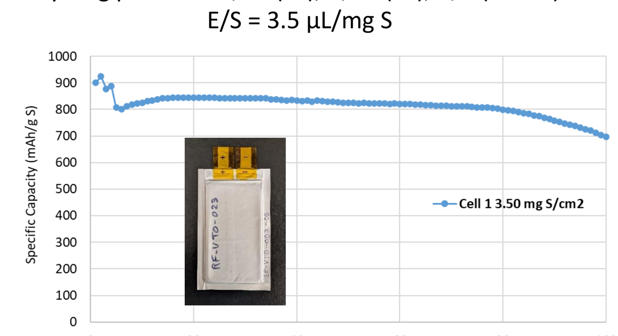
cycling protocol: C/20 (x2), C/10 (x3), C/5 (x3), C/2.25 (x3), C/1.5 (x3), C/10 (x2), C/3 (x500); 1.6-2.6 V
E/S = 4 µL/mg S



RF SLS 178

- cell capacity ~ 0.5 Ah
- stable cycling >120 cycles
- specific capacity of 775 mAh/g (S) at C/3

cycling protocol: C/20 (x2), C/10 (x2), C/5 (x1000)
E/S = 3.5 µL/mg S



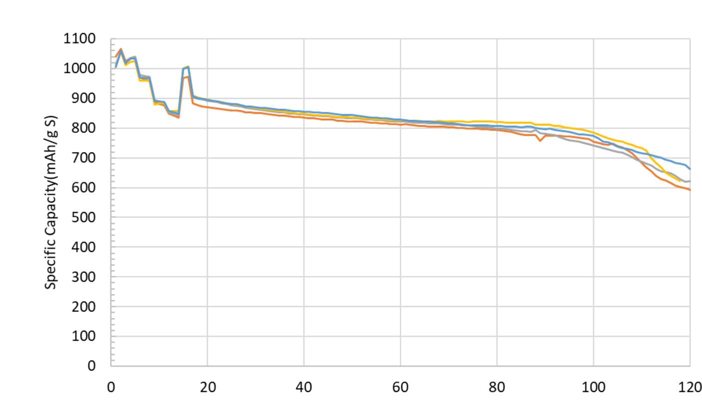
RF VTO 027

- cell capacity ~ 3.0 Ah
- stable cycling >100 cycles
- specific capacity of 830 mAh/g (S) at C/5

18650 Cylindrical Cells

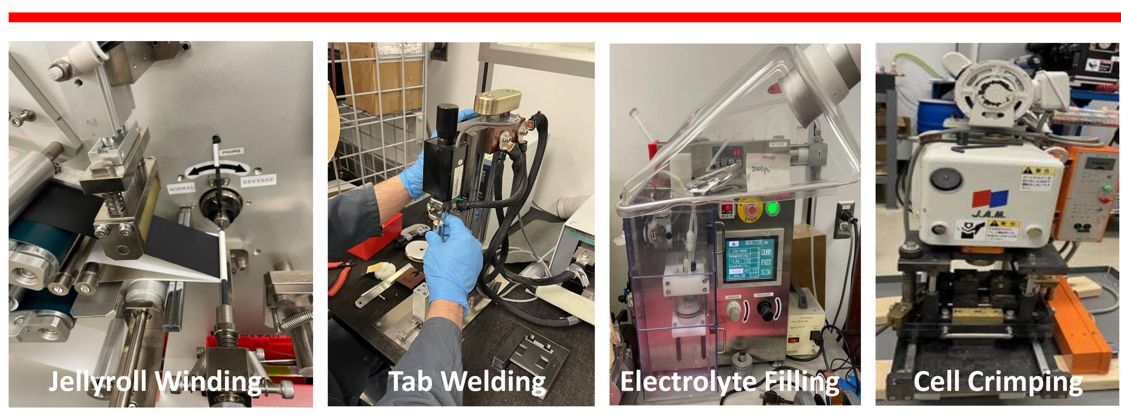
cycling protocol: C/20 (x2), C/10 (x3), C/5 (x3), C/2.25 (x3), C/1.5 (x3), C/10 (x3), C/3 (x500); 1.6-2.6 V
E/S = 2.8 µL/mg S

filled cell before and after crimping



- cell capacity 2.2 Ah
- stable cycling to >120 cycles
- specific capacity of 900 mAh/g (S) at C/3

Navitas Capabilities in Electrode Coating and Cell Building and Testing



18650 Cylindrical Cell Assembly Line

Pouch Cell Assembly

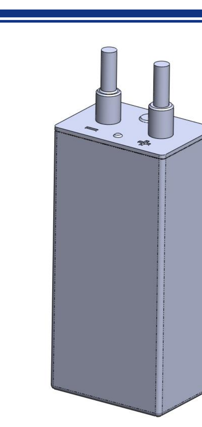
Automated Round Cell Assembly Line

5781173 Prismatic Space Cell

Coming Soon

57 × 81 × 173 mm cell body

standardized form factor for satellites



Acknowledgements

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