Lithium Sulfur Energy Storage Development for Space Applications

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Introduction

Objectives:

To transition lithium-sulfur battery from prototype large format pouch cells as developed under Navitas' Phase II SBIR's with NAVAIR and NASA to space-qualified cylindrical 18650 format, with adjustments in electrode and electrolyte design intended to increase energy density and cycle life. This is a multi-phase program, leading to development and qualification of 18650 format LSB cells that meet S-144 qualification and can deliver > 250 Wh/kg with a cycle life >1000.

Approaches:

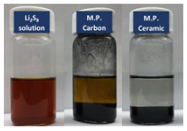
Address Material Limitations:

- ***Ceramic host*** active material that entraps polysulfides and ***improves cycle life***
- ***Ceramic-coated separator*** to constrict polysulfide movement ***for long cycle life (1000+)***
- ***Fluorinated glyme electrolyte*** to mitigate soluble polysulfide transportation and ***improve cell capacity***

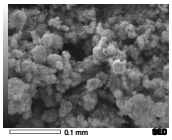
Address Process Challenges:

- Wet-slurry coating for high sulfur loading cathode (> 4.5 mg S/cm^2)
- Multifunctional coating on separator at a pilot scale
- Electrode design; Innovative electrolyte synthesis and E/S ratio

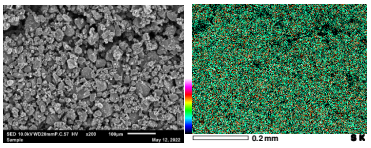
Sulfur Cathode with Navitas' Propriety Ceramics



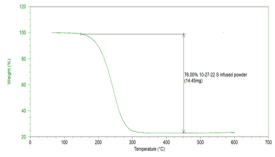
- Color of Li_2S_8 solution after contact with different cathode hosts overnight.



- Navitas' ceramic host has small particle sizes, < 20 nm.



- SEM and EDS images showed that sulfur infused composites have particle size less than 40 µm, and sulfur is uniformly distributed in Ceramic/Carbon hosts.



- The synthesized composites contain ~76% of sulfur from TGA analysis.

- High sulfur loading coating comes out of slot-die coater, which has three-zone drying ovens (heating pad, VFM, IR).

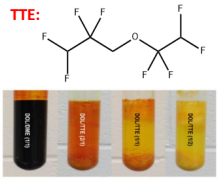
- A roll of double-side coated sulfur cathode with S loading ~ 4.6 mg/cm^2.

- Double-side coated sulfur cathode has a great adhesion and passes a Mandrel test.

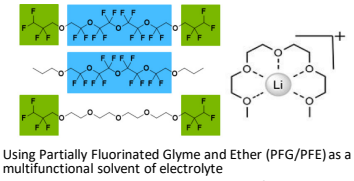
- Navitas's ceramic sulfur host has a strong polysulfide absorption ability
- The synthesized sulfur composites have a small average particle size, and sulfur (76wt%) was uniformly infused into the conductive sulfur host
- The high sulfur loading electrodes (> 4.6 mg S/cm2) are successfully coated with slot-die coater having three different drying zones
- The coated electrode were evaluated at coin cell and pouch cell levels with baseline electrolyte and uncoated separator.

Electrolyte Development

TTE:



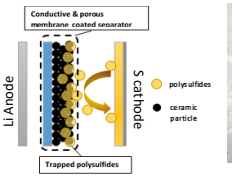
- Fluorinated ether (PFE), such as TTE, as a cosolvent suppresses polysulfide dissolution.

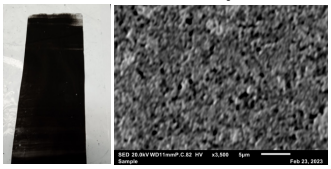


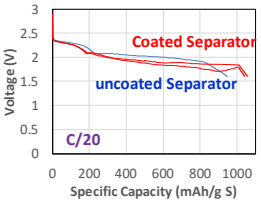
Using Partially Fluorinated Glyme and Ether (PFG/PFE) as a multifunctional solvent of electrolyte

- PFG has high ionic conductivity and non-flammability
- PFG retains the merits of PFE in suppressing polysulfide dissolution and promoting formation of LiF-rich SEI layer on electrode surfaces
- Oxygen numbers in PFG affect Li^+ solvation/desolvation.

Coated Separator

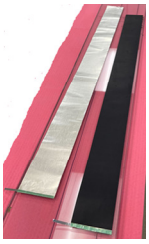






- SEM image showed ceramics and conductive carbon were uniformly coated onto separator
- The coating has a thickness of ~ 2 µm with a great physical and chemical adhesion when appropriate binder is used
- The coin cells with coated separator showed high sulfur specific capacity (~ 1050 mAh/g with baseline electrolyte at C/20 rate) due to the mitigation of polysulfide shuttling

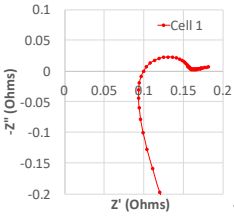
18650 Cylindrical Cell Assembly



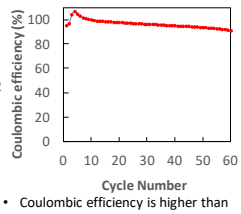
- Qualified Li/Cu/Li anode
- Double-side coated and calendered S electrode.

- Uncoated separator
- Coated separator will be applied in future 18650 cell builds.

- Navitas' first 18650 Li-S cylindrical cell
- Weight: 29.5 g
- OCV: 2.6 V.



- EIS of cylindrical cell
- Low R_s value: < 0.1 Ohm
- Low Charge Transfer R_c: < 0.075 Ohm.



- Coulombic efficiency is higher than 90% after 60 cycles
- Formation process needs to be optimized
- Discharged capacity and capacity retention needs to be improved; E/S ratio plays an important role.

Collaboration/Partnership

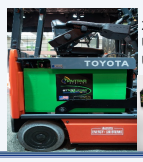
- **John Zhang (Argonne National Laboratory)**
  - Development of PFE/PFG electrolyte with different solvents, lithium salt
  - Investigation of E/S ratio on cell performance
  - Scale-up and Incorporation of PFE/PFG electrolyte into 18650 cylindrical cell
- **Kevin Sinclair (Lockheed Martin)**
  - Consulting service
  - Providing cell testing and feedback on prototype samples
  - 18650 cell evaluation to meet S-144 qualification
- **Tyson Craig and Wan Si Tang (Battery Innovation Centre)**
  - Initial assembly sequence and fixture settings for building Li-S 18650 cells
  - Optimization of jelly-roll design and 18650 cell assembly
- **Brad Reed**
  - Domain expert consulting service

Navitas Products

24V, 120Ah, Max 1100A, 1000 cycles

Heavy Duty Off-Road 6T Battery

CWB Battery (2.5 Ah)



24, 36, 48V, Up to 54kWh, Up to 1050Ah,

Forklift Batteries

Round Cells for Navy & LMS

Navitas and Partner Capabilities

Navitas' automated cell assembly line has an ultimate annual capacity of ~1M cells.

Jelly-Roll Winding | Can Grooving | Electrolyte Filling | Cylindrical Cell Crimping | Automated Cell Assembly Line in Dry Room at Navitas

Conclusions

- Ceramic in sulfur composite has a strong polysulfide absorption, and high sulfur loading cathode with great physical adhesion and electrochemical performance were successfully achieved.
- Partially Fluorinated Glyme improved Li-S performance due to low solubility of polysulfide in PFG and robust Li-F rich SEI layer formation.
- Multifunction coatings on separator face-to-cathode can mitigate polysulfide shuttling and electro-catalyze polysulfide to sulfur during charging process.
- 18650 cylindrical Li-S cells were successfully built, and its performance will be improved by combining cathode modification, PFG electrolyte, and multifunctional separator coating.

Future Work

- Formulation modification of sulfur composites and sulfur cathode
- Jelly-roll modification, such as dimension of electrodes and tab position
- Separator coating scale-up, electrolyte selection (solvent, concentration, additives, lithium salts), and Li anode protection to improve cell cycle life
- Improve 18650 cell performance and cycle life to meet S-144 qualification by combining cathode formulation modification, separator coating, innovative electrolyte, and Li anode protection.

Acknowledgements

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