Development of High Energy Density Li-Sulfur Cells

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Overview

Timeline

12.5% completed

Start: Sep. 30, 2011

End: Jan. 15, 2015

Barriers Addressed

- Power and energy density
- Cycle and calendar life
- Abuse tolerance

Budget

- DOE $ 5M
- Cost Share: $2.29M
- FY 2012: $1.626M (DOE)

Partners

- Johnson Controls
- EC Power
- Argonne National Lab
- Idaho National Lab

Objectives

Develop a **full lithium-sulfur battery system** with high energy density and efficiency, good cycle life and safe operation.

Project scope

Design of full Lithium-Sulfur cell:

- Cathode: Nanocomposite Sulfur – high energy / power
- Advanced Lithium anode – stable
- Electrolyte – nonflammable, stable
- Optimized cell design

Performance targets

4Ah cells

600 Wh/L (cell level)

Cycle life 500+ cycles

Excellent safety characteristics

Milestones

Phase I: Advanced material development and characterization (10/2011-01/2013)

- Evaluate baseline cells
- Develop and optimize cathode, anode, and electrolyte
- Thermal and failure mechanism studies

Phase II: Material scale up and 1Ah pouch cell development (01/2013-01/2014)

- Cathode and anode scale-up, continued improvement, and 1 Ah pouch cell design and testing
- Continued investigation of electrolytes and failure mechanisms

Phase III: Large format 4 Ah prismatic cell design (01/2014-01/2015)

- Continued scale-up, failure mechanism analysis, and 4 Ah prismatic cell design and testing
- Cell modeling and optimization

Approach

Anode	Investigating / optimizing composite Li-based anodes Exploring polymer electrolyte coatings
Cathode	Investigating nanocomposites Pursuing methods for increased sulfur loading
Electrolyte	Scanning electrolytes and additives Assessing and developing novel solvents Optimizing electrolytes for poly-sulfide dissolution
Cell design	Optimizing cells design for chemistry requirements Conducting modeling and experimental testing

Approach - Cathode

- Generate new, well-structured carbon frameworks to improve volumetric energy density
- Optimize framework pore geometry and investigate new framework materials and structures to maximize sulfur loading and thus energy density
- Make intelligent use of additives to prevent polysulfide dissolution and improve cycling and overall performance
- Materials process optimization to identify best production condition.

Approach - Anode

- Design composite lithium-based anode to suppress dendrite growth, promote stable SEI formation, improve anode stability
- Develop effective anode coating to prevent dendrite growth and lithium polysulfide deposition

Approach - Electrolyte

- Develop ionic liquid electrolytes and electrolyte additives to improve performance and safety
- Develop new electrolyte systems to improve safety, rate capability, and anode SEI formation, and decrease polysulfide dissolution
- Investigate the mechanism of polysulfide dissolution to provide complementary insight

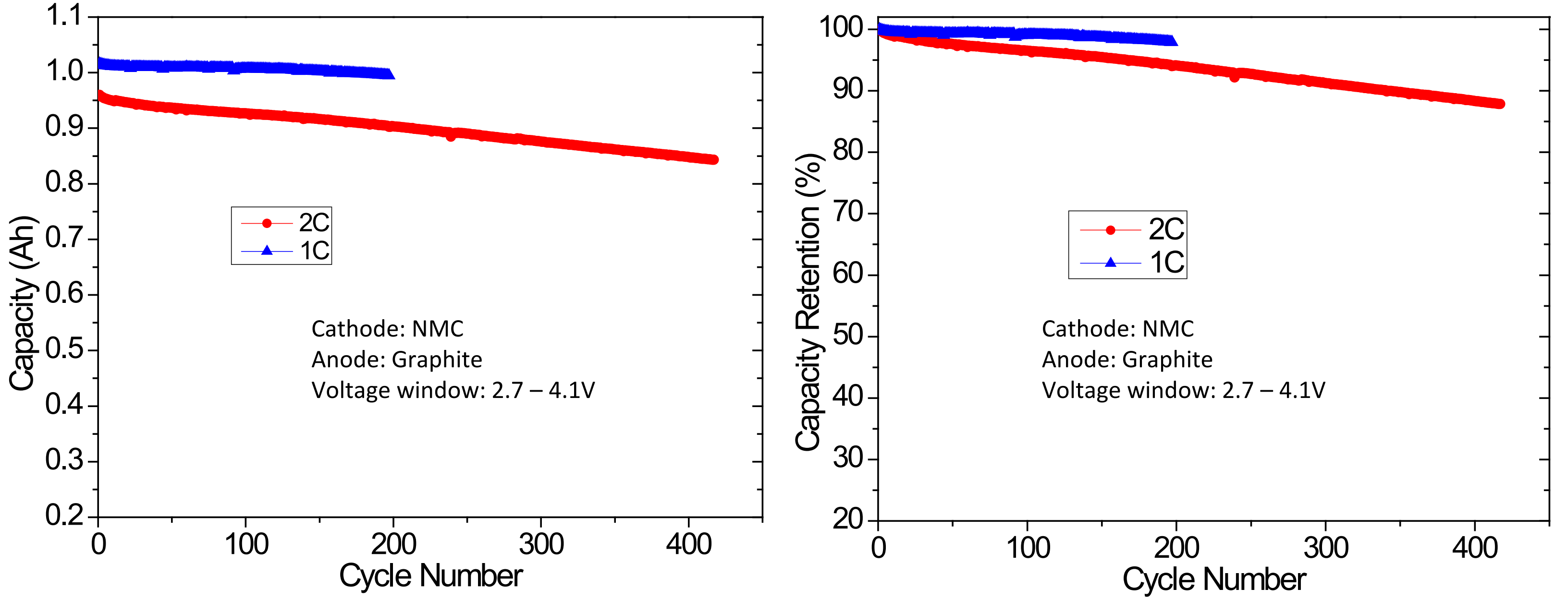
APPROACH – CELL DESIGN

- Optimize prismatic full cell parameters – electrode size, electrode matching, number of electrodes in stack, etc
- Synergistically leverage cell modeling and experimental testing to iteratively improve design

Technical Accomplishment and Progress

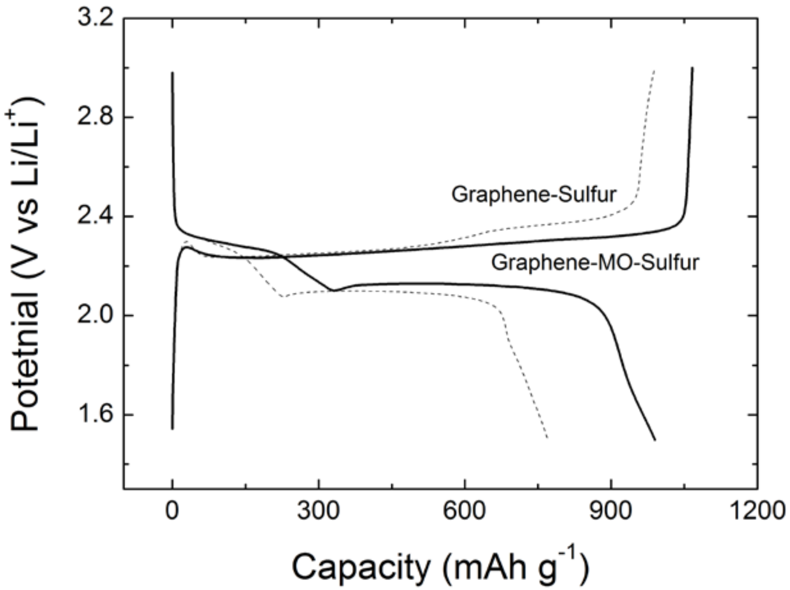
- Developed 1 Ah NCM-based baseline cells
- Developed metal oxide adsorbent and verify its effect to improve capacity and efficiency in graphene-metal oxide-sulfur nanocomposite cathodes.
- Developed carbon-sulfur composite cathode with high sulfur loading.
- Electrolyte additive development and testing

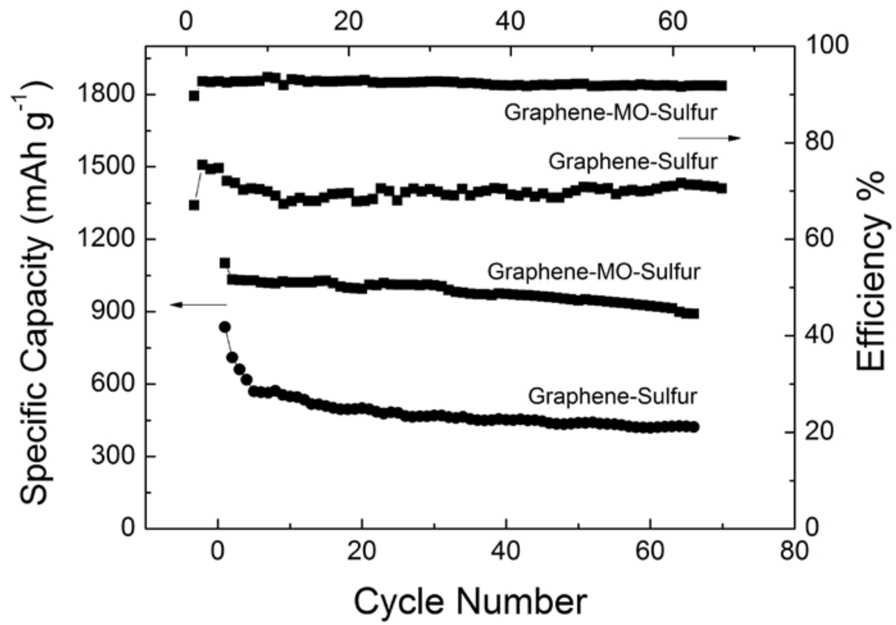
1 Ah Baseline Cells Cycling Update



- 1C cycling: 88% capacity retention in 418 cycles
- 2C cycling: 98% capacity retention in 197 cycles

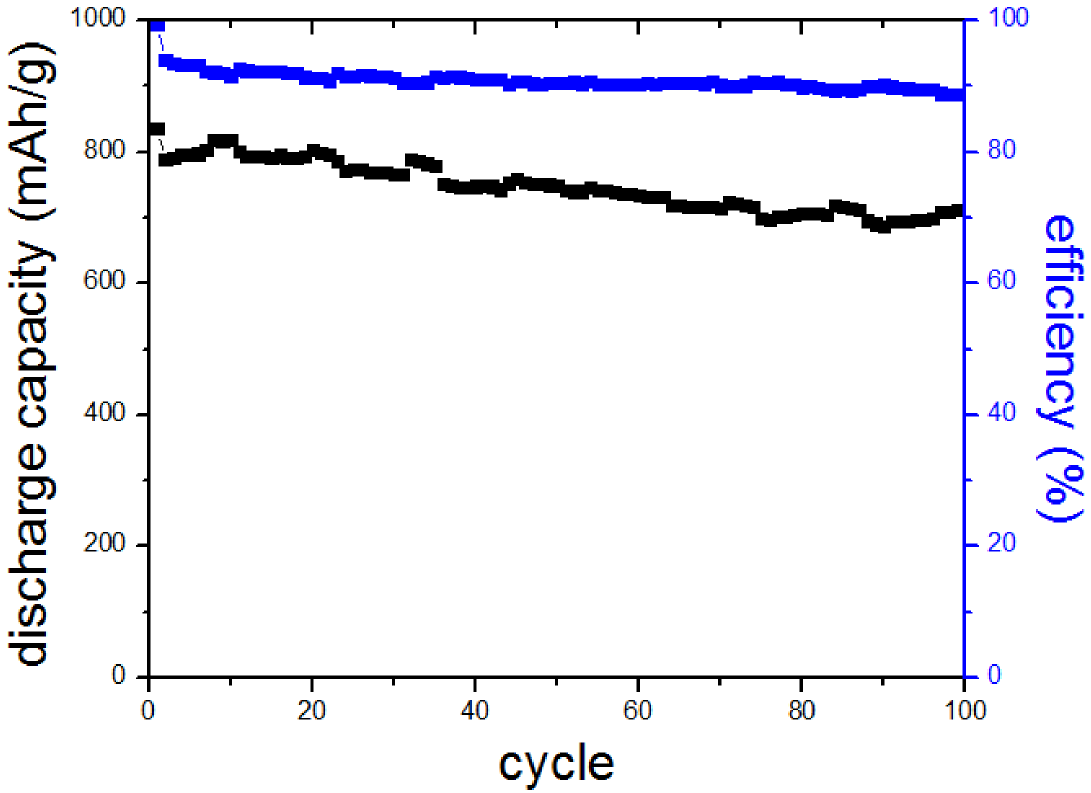
GRAPHENE-METAL OXIDE-SULFUR CATHODES





- **Graphene-metal oxide-sulfur composite** with 1st-cycle capacity ~1100 mAh/g, 92% efficiency, and capacity retention of 86% after 50 cycles.
- Metal oxides show adsorbing effect to soluble polysulfides.

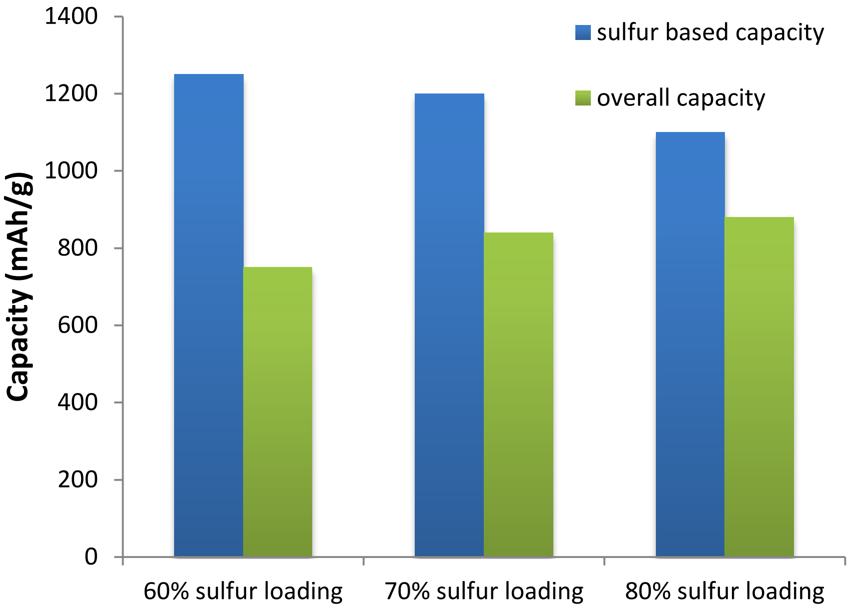
Sulfur-Carbon Nanocomposite Cathodes



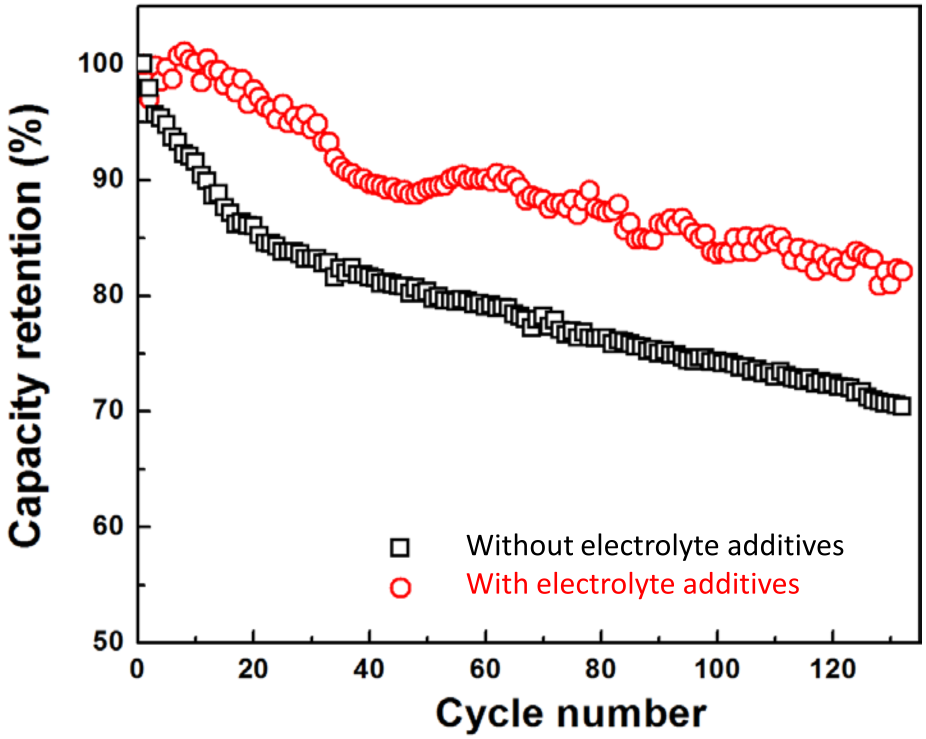
- **Nanocomposite sulfur cathodes** with sulfur loading increased to **80 wt%** , 1st-cycle capacity ~1100 mAh/g, 90% efficiency, and capacity retention of 85% after 100 cycles at C/2.

Sulfur Loading Effects in Nanocomposite Cathodes

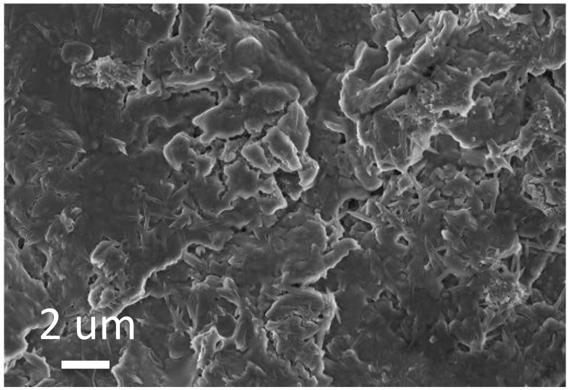
- Higher sulfur loading lowers initial specific capacity of sulfur .
- Overall initial capacity of nanocomposite sulfur cathodes still increases.



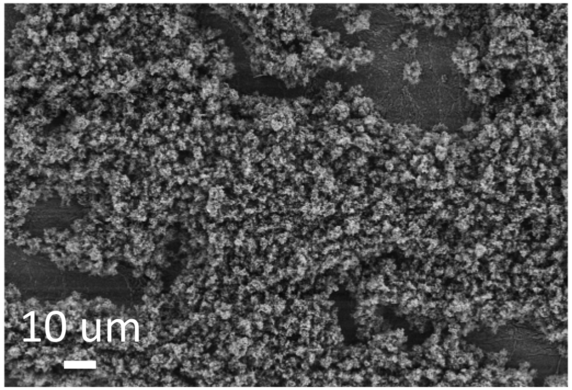
ELECTROLYTE ADDITIVES IMPROVE CYCLING PERFORMANCE



Surface morphology of Li metal after 100 cycles in Li-Sulfur Cells



With electrolyte additives



Without electrolyte additives

- Electrolyte additives improve capacity retention of Li-sulfur cells.
- Addition of electrolyte additive also mitigates the growth of mossy lithium or other deposits.

Future Work

- Further tune carbon framework properties (ex. pore size, morphology, etc)
- Investigate new cathode additive to decrease polysulfide migration.
- Investigate promising lithium-based anode systems to mitigate safety and stability issues of lithium metal anodes
- Investigate novel electrolyte systems and additives
- Optimize battery fabrication parameters

SUMMARY

- Designed graphene-sulfur composite cathode with metal oxide adsorbent
- Designed carbon-sulfur composite electrode with 80 wt% sulfur loading
- Investigated potential electrolyte additives and compositions
- Testing baseline 1 Ah cells