Protection of Li Anodes Using Dual Phase Electrolytes

Yuriy Mikhaylik
Sion Power Corporation
June 8, 2010

Project ID # ES012

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Overview

Timeline

- Project start date 10/1/2009
- Project end date   9/30/2012
- Percent complete 5 % (100% of Phase1)

Budget

- Total project funding
  - DOE share $832,215
  - Contractor share $1,996,639
- Funding received in FY09 $146,005
- Funding for FY10 $1,108,030

Barriers

Barriers addressed for EV application

- Specific Energy >250 Wh/kg
- Thermal stability, Safety
- Cycle Life

<u>Target of Phase 1 Applied Research</u>

Anode specific capacity exceeding 750 mAh/g over 50 full charge-discharge cycles in the laboratory scale Li-S cells.

Partners

BASF SE, Germany

- Development of Li-S battery materials

Project Objectives

- Develop a unique electrolyte providing two liquid phases having:
  - Good lithium ion conductivity.
  - Self-partitioning and immiscibility.
  - Optimum chemical stability for each phase’s respective negative and positive electrode.
  - Application to stabilize and protect lithium metal anodes.
- Demonstration of approach:
  - Lithium sulfur (Li-S) rechargeable battery:
    - Improve anode and cathode function.
    - Improve cycle life.
    - Increase thermal runaway temperature.

Project Milestones

- Success Criteria at Decision Points for 3 Phases of the Project:
  - Phase1 Criteria: Demonstration of anode unit specific capacity >750 mAh/g and > 50 charge/discharge cycles (03/31/2010).
  - Phase 2 Criteria: Demonstration of large format cells with high energy >250 Wh/kg and dual-phase electrolyte systems (07/31/2011).
  - Phase 3 Criteria: Large format cell manufacturing, test and evaluation. Demonstration of high energy, cycle life, and safety (thermal runaway temperature > 165^{o}C) (9/30/12).

Approach/Strategy

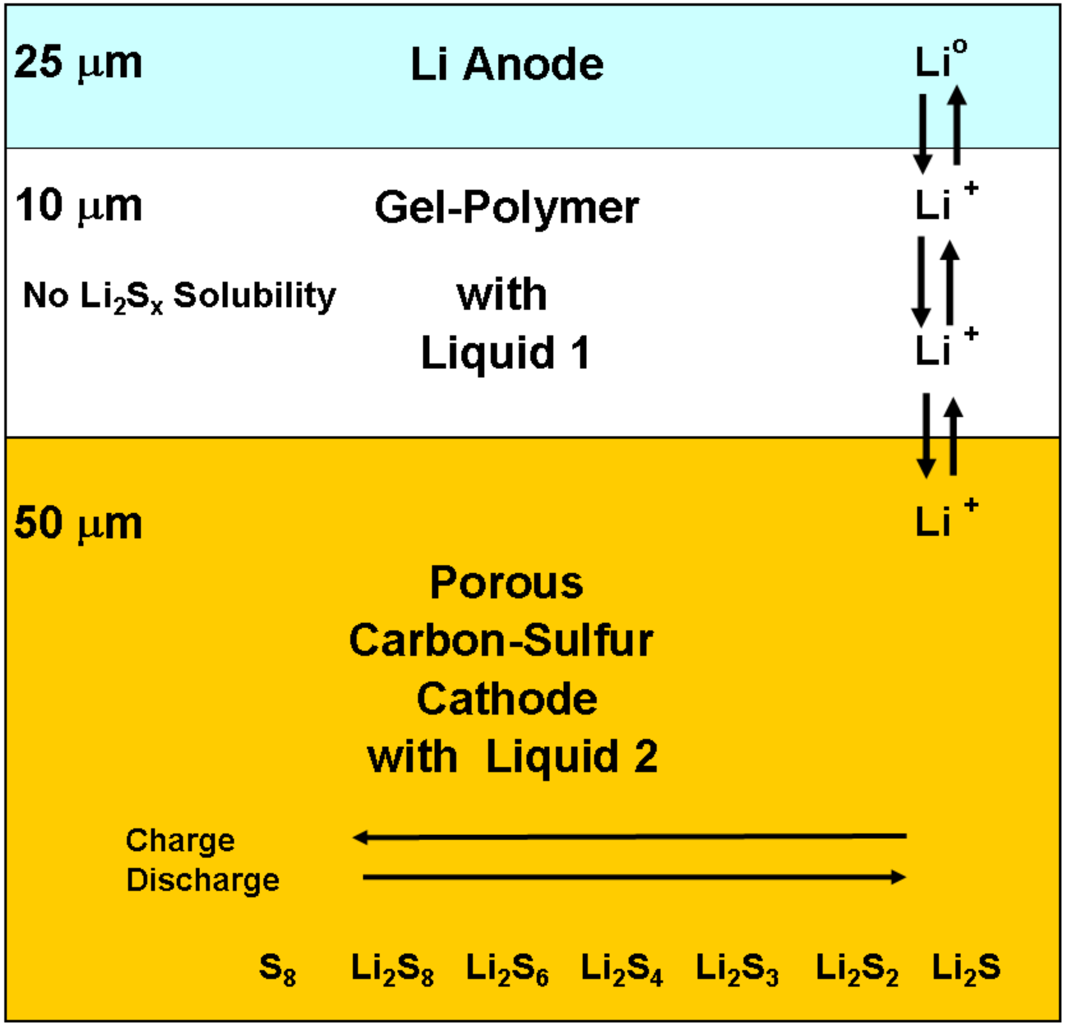
"Anode" Liquid 1:

- Immobilized within polymeric gel applied to anode.
- Stable with lithium preventing side reactions and dendrite growth.
- Immiscible with Phase 2 electrolyte and does not dissolve polysulfides.
- Polymeric gel can serve as coated separator.

"Cathode" Liquid 2:

- Tailored to improve high energy Sion Power sulfur cathode performance.
- Immiscible with Phase 1 electrolyte.
- High ion conductivity and lithium polysulfide solubility.

Dual Phase Electrolyte Li-S Battery

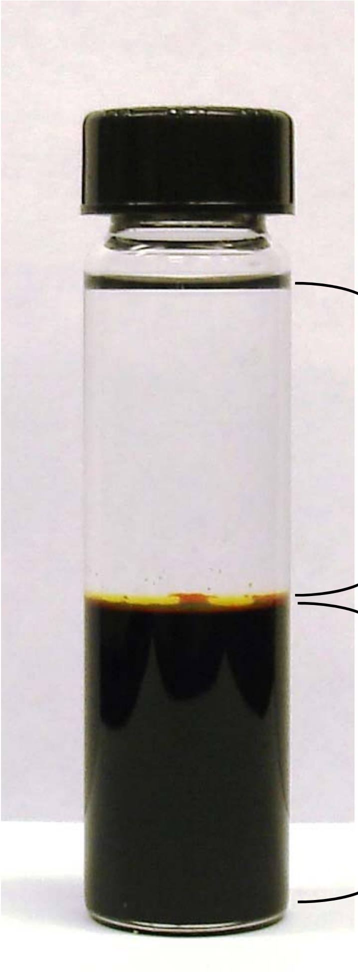


Approach/Strategy

SION POWER

Example of Dual Phase Electrolyte System

"Anode" and "Cathode" electrolytes are immiscible liquids and both have Li ion conductivity



"Anode" Electrolyte:

Solution of LiTFSI in Butyl Ether.

Electrolyte can be immobilized within polymeric gel applied to anode.

Li_2S_8 is insoluble in the Butyl Ether.

"Cathode" Electrolyte:

Solution of 30 w% Li_2S_8 in

1,2-Dimethoxyethane + LiTFSI

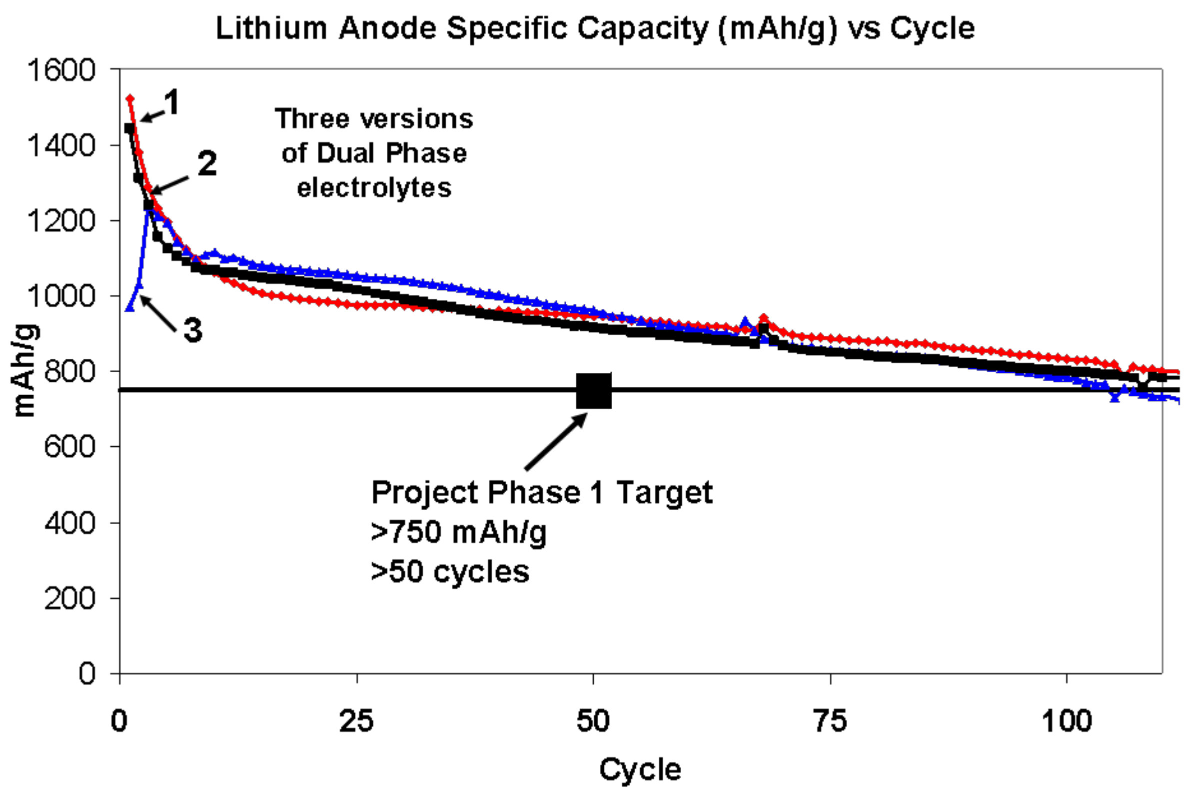
Technical Accomplishments and Progress

Significant Findings and Developments

- Twice longer cycle life vs. targeted.
- Elimination of thermal runaway with protection of Li anodes with Dual-Phase Electrolytes.
- Significant improvement of gel-polymer coating quality.

Technical Accomplishments and Progress

Twice longer cycle life of Li anode vs. targeted.

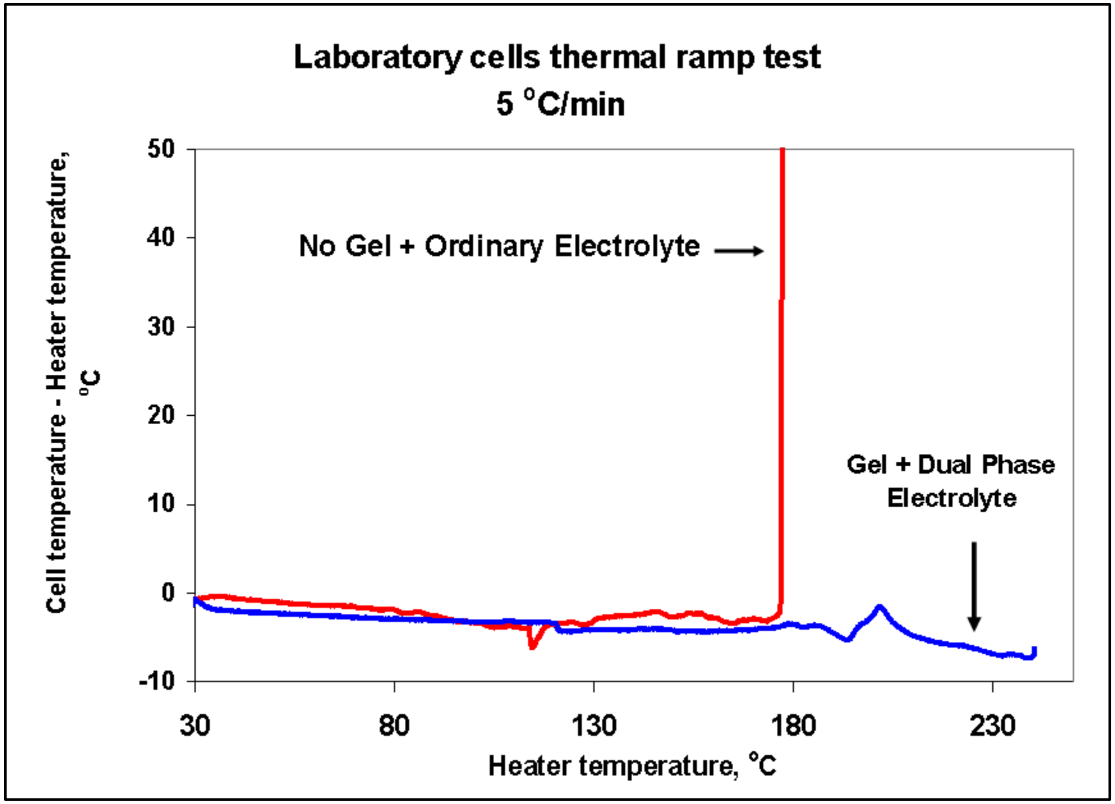


Success Criteria for Project Phase 1:

Demonstration of anode unit specific capacity >750 mAh/g and
> 50 charge/discharge cycles.

Technical Accomplishments and Progress

Elimination of thermal runaway with protection of Li anodes with Dual-Phase Electrolytes.



At temperatures above 181°C (Li melting point) molten metallic Li and molten Sulfur (mp ~120°C), separated only by a 10 μm gel-electrolyte membrane, showed no violent reaction

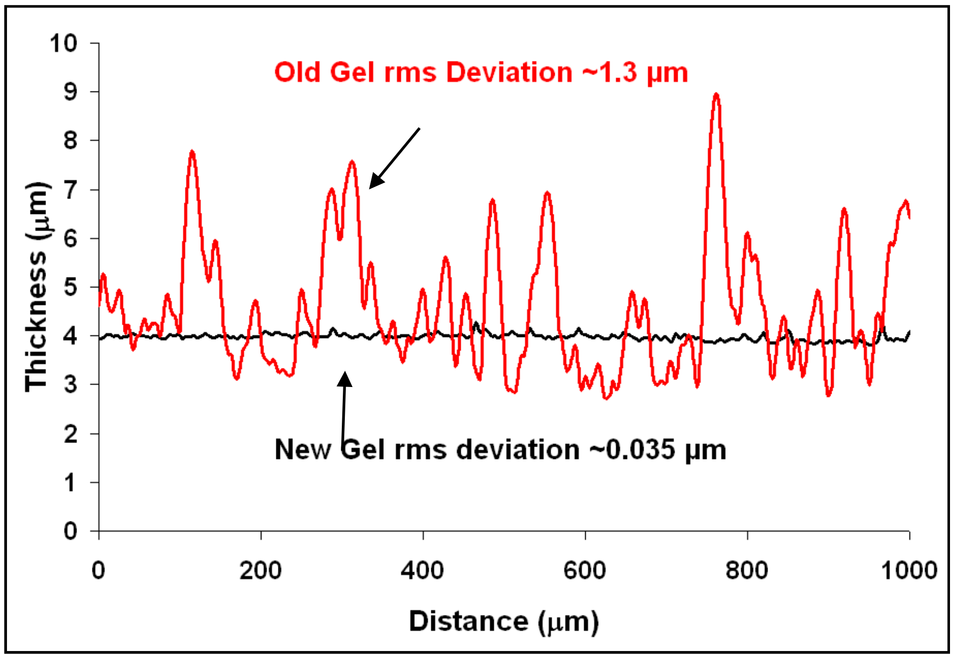
Note: increasing the runaway temperature to >165°C was Phase 3 Objective

Thermal ramp test results for fully charged 0.25 Ah Li-S cells.

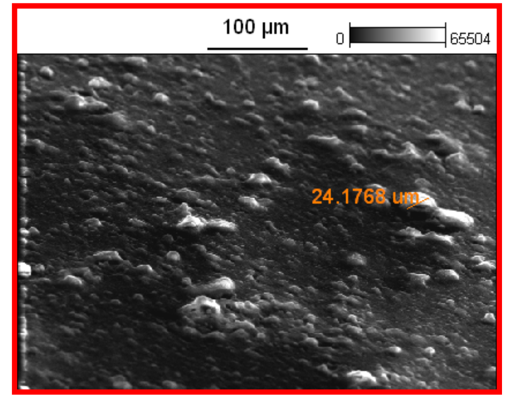
Technical Accomplishments and Progress

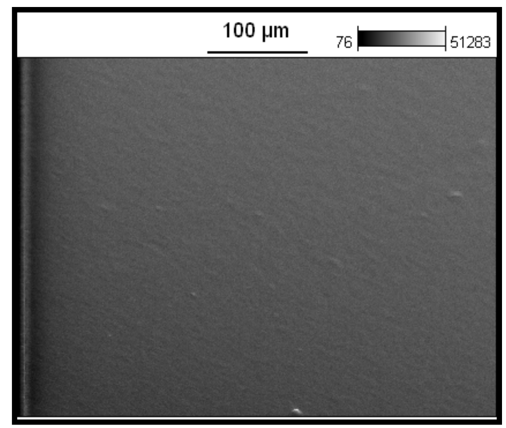
Significant improvement of gel-polymer coating quality.

Gel-polymer film thickness profile



Old Gel Layer





Improved Gel Layer

The improved smoothness was achieved through improved dispersion of nano-silica fillers.

Collaboration

Sion Power Corporation and BASF SE, Ludwigshafen, Germany, announced a Joint Development Agreement (JDA) to accelerate the commercialization of Sion Power's proprietary lithium-sulfur (Li-S) battery technology for the electric vehicle (EV) market and other high-energy applications.

The collaboration targets the development of battery materials to increase Li-S cycle life, energy density and safety to extend driving range of future EVs beyond 300 miles between charges.

- Relationship: Partner in JDA (not a sub-contractor).
- BASF collaborates with Sion Power outside the VT Program.
    - 14 BASF scientists report to Sion's Director of Materials Development and work full time on Li-S technology.

Proposed Future Work

Phase 2 Technology Development (04/01/10 - 07/31/11)

- Achieve and optimize cell hardware including the gel polymer and electrolyte features.
- Construct a model cell and evaluate performance based on USABC guidelines.
- Develop larger format prototype 2.5 Ah Li-S cells with the lithium anode stabilized by a dual phase electrolyte system, and demonstrate >350 Wh/kg specific energy and longer cycle life under USABC test conditions.

Summary

- We have accomplished and exceeded objectives for the Phase 1 project:
  - ➢ Twice longer vs. targeted cycle life demonstrated for Li anode unit with dual phase electrolyte.
  - ➢ Protection of Li anode with dual phase electrolyte eliminated thermal runaway in the laboratory 0.25 Ah rechargeable Li-S cells.
- Materials selected and coating techniques developed pave the way for Phase 2 targeting 2.5 Ah dual phase electrolyte protected cells with specific energy exceeding 350 Wh/kg
- Viability of dual phase electrolyte approach has been successfully demonstrated for the Li-S system and is applicable to other rechargeable systems.