Low-cost, High Energy Si/Graphene Anodes for Li-ion Batteries

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Presenter: Rob Privette

Project ID: ES237

XG sciences
THE MATERIAL DIFFERENCE

XG Sciences, Inc.

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Overview

Timeline

- Project start date: Nov. 15, 2012
- Project end date: Dec. 22, 2015
- Percent complete: 51%

Budget

- Total project funding
  - DOE share $1,147, 684
  - Contractor share $123,042
- Funding received in FY14
  - $499,990
- Funding for FY15
  - $499,909

Barriers

- Barriers addressed
  - Specific Energy
  - Life
  - Cost

Partners

- XG Sciences - Project lead
- A123 System
- Georgia Institute of Technology
- Collaborators
  - Argonne National Laboratory
  - Ashland Specialty Ingredients
  - Daikin America
  - Lawrence Berkeley National Laboratory
  - Sandia National Laboratory

Relevance

Overall Objectives:

- Demonstrate XG SiG™ Si-graphene nano composite next generation Li-ion anode:
  - 600 mAh/g (Specific Energy Barrier),
  - 85% 1st cycle efficiency and
  - 1000 cycles with 75% capacity retention (Life Barrier)
- Stabilize and optimize the XG SiG™ anode pilot production (Cost Barrier)
- Develop a scalable dispersion and coating process with desired electrode properties
- Validate the XG SiG™ technology in commercial grade 2 Ah prototype Li-ion cells

Current Term Objectives:

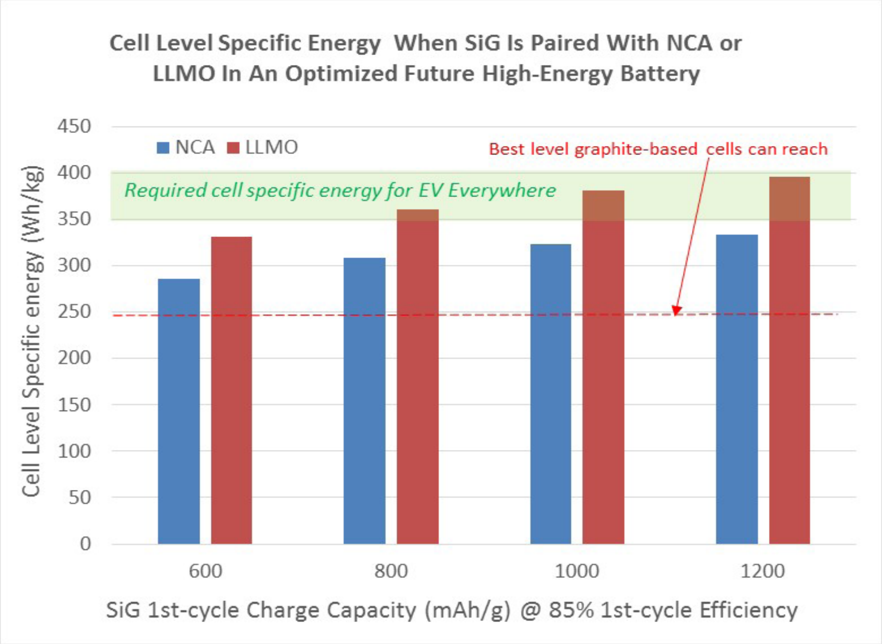
- Demonstrate XG SiG™ anode performance:
  - 600mAh/g (Specific Energy Barrier),
  - 85% 1st cycle efficiency, and
  - 500 cycles with 70% retention (Life Barrier)
- Define XG SiG™ manufacturing product and process variable limits
- Demonstrate 2-3 L XG SiG™ slurry preparation and coating
- Demonstrate XG SiG™ performance in 2Ah cells

Impact on Barriers

EV Everywhere program defines a cell specific energy target of greater than 350 Wh/kg with 1000 cycles

Project Objective #1: Improve XG SiG™ anode performance

a. 600 mAh/g (Energy Barrier),
b. 85% 1st cycle efficiency, and
c. 1000 cycles with 75% capacity retention (Life Barrier)



Impact on Barriers

EV Everywhere targets cutting battery costs to $125/kWh

- This has been one of the biggest challenges for Si-based anodes due to poor scalability and prohibitive process cost.
- XGS' XG SiG™ manufacturing process specifically addresses the cost issue in three ways:
  - Use of a low cost Si precursor,
  - Incorporating XG SiG™ formation into an existing manufacturing process,
  - Automation and modular design of the production system making the XG SiG™ process less labor intensive
- Cost models show that XG SiG™ can achieve a competitive price as compared with graphite which is required for the commercial acceptance for PHEVs and EVs.

Milestones

Tasks	2014				2015			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Improve EC performance of XG SiG™				MS1			MS2	
2. Optimize pilot production							MS3	
3. Characterize materials/electrodes/cells								
4. Optimize dispersion				MS4				
5. Optimize electrolyte/additives						MS5		
6. Design/build 2Ah prototype cells				MS6			MS7	

MS 1: Demonstrate XG SiG™ silicon anode material in full cells:
600mAh/g, 85% 1st cycle efficiency, 500 cycles with 70% retention
MS 2: Demonstrate 600mAh/g, 85% 1st cycle efficiency, 1000 cycles with 70% retention
MS 3: Demonstrate XG SiG™ manufacturing process readiness
MS 4: Demonstrate electrode coating ready for prototype cell builds 2~3 L slurry preparation
MS 5: Select final electrolyte / additive
MS 6 & 7: Demonstrate XG SiG™ performance in 2Ah cells

Status of Current Term Milestones

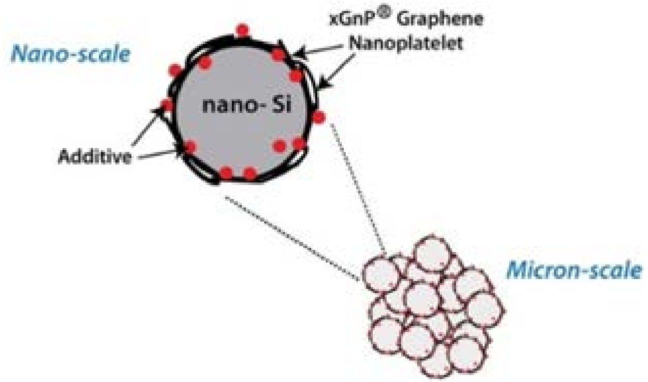
Milestone ID	Description	Status
1	**Demonstrate 600mAh/g, 85% FCE, 500 cycles with 70% retention**	Demonstrated XG SiG™ material 600 mAh/g, 85% FCE and 70% capacity retention at 500 cycles targets in small format cells
3	**Demonstrate XG SiG™ manufacturing product and process variable limits**	XG SiG™ manufacturing product and process variable limits were defined and implemented resulting in improved material quality
4	**Demonstrate 2-3 L XG SiG™ slurry preparation and coating**	Electrode coating of XG SiG™ material was successfully demonstrated by A123 using their commercial coater (>6 L) and Argonne National Lab.
6	**Demonstrate XG** SiG™ **performance in 2Ah cells**	2 Ah pouch and cylindrical cells were produced and performance demonstrated. Performance gaps were defined that are being addressed in year 2.

Approach to Performance Improvement

Milestone: 600mAh/g, 85% FCE, 70% capacity @ 500 cycles

Status: Demonstrated XG SiG™ material 600 mAh/g, 85% FCE and 70% capacity retention at 500 cycles targets in small format cells

- Employ material modification to target more stable SEI layer
  - Si precursor
  - Composite formulation
  - Composite manufacturing process



- Reduced Si fracture
- Reduced Li^+ reaction
- Optimized graphene nanoplatelet support

Approach to Manufacturing Process Improvement

Milestone: Define XG SiG™ manufacturing product & process limits

Status: XG SiG™ manufacturing product and process variable limits have been defined and implemented resulting in improved quality

- Define Measurement Capability
- Define XG SiG™ Product Specifications
  - Relate key performance to manufacturing metrics
- Develop Manufacturing Process Control
  - Define material – process parameter sensitivity
- Define Manufacturing Process Capability
  - Optimize process targeting manufacturing metrics

Approach to Dispersion and Coating Improvement

Milestone: Demonstrate XG SiG™ slurry preparation and coating

Status: Electrode coating was successfully demonstrated by A123 using their commercial coater (>6 L) and at Argonne National Lab

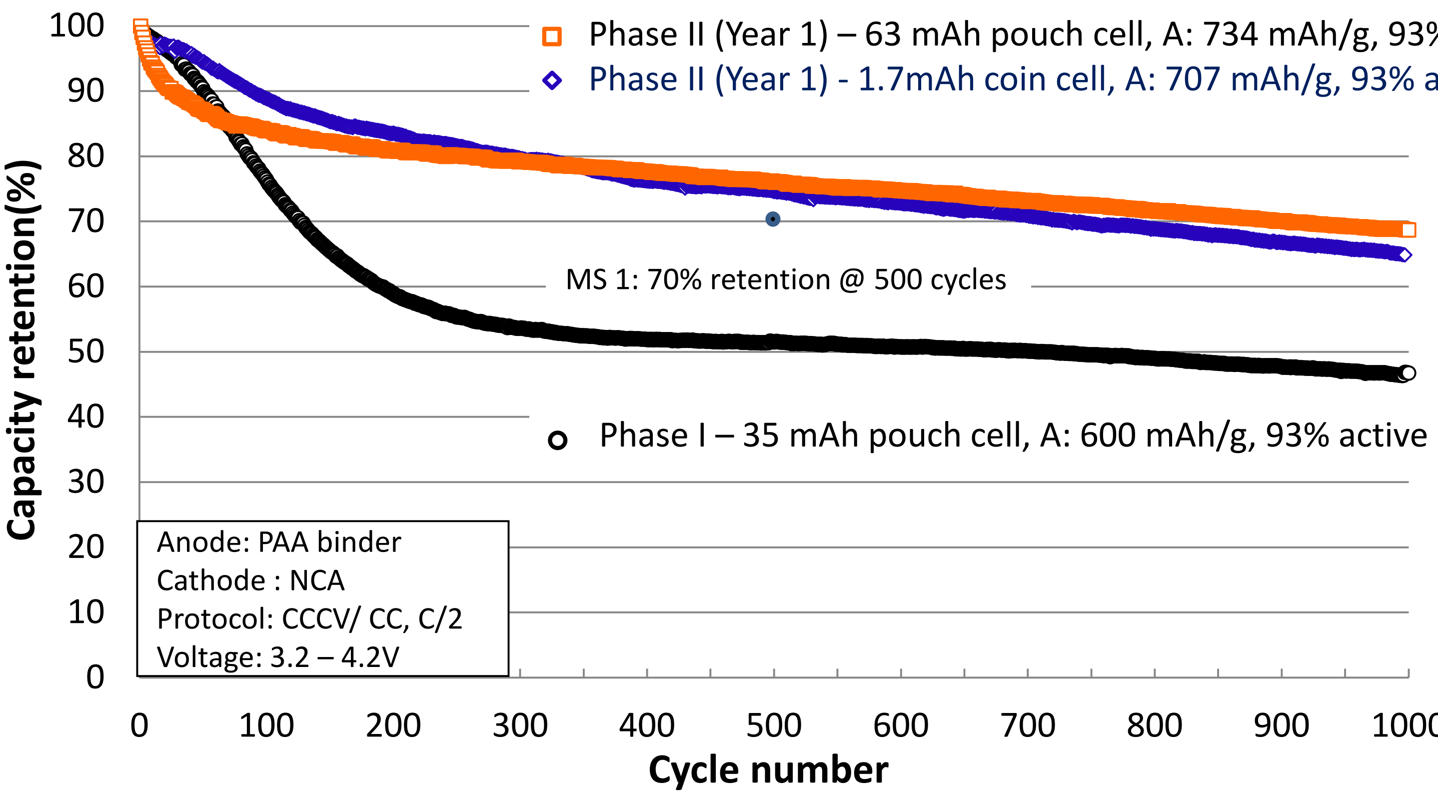
- Identify:
  - Industrial mixer types,
  - Preferred solvents,
  - Material and slurry limitations (e.g. particle size, viscosity, etc.)

  used by XG Sciences customers
- Characterize slurry shear conditions in successful XG SiG™ laboratory dispersion and coating (magnetic stirrer)
- Scale-up slurry conditions to customer equipment preferences
- Transfer dispersion recommendations to customer

Technical Progress

XG SiG™ met MS 1 target in 63 mAh pouch cells

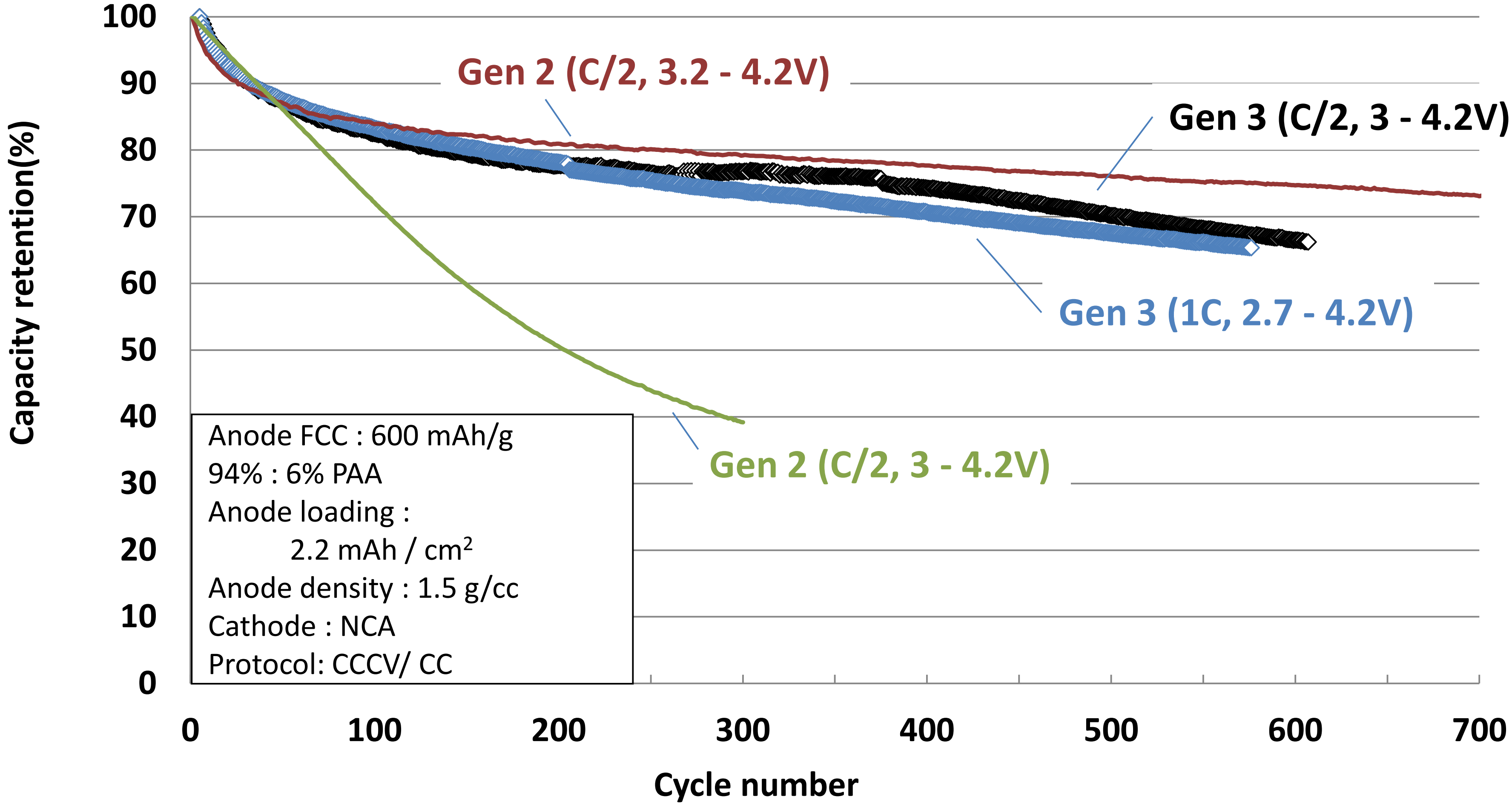
Improvement tied to: (a) modified Si precursor, (b) optimized formulation, and (c) manufacturing process modifications



Technical Progress

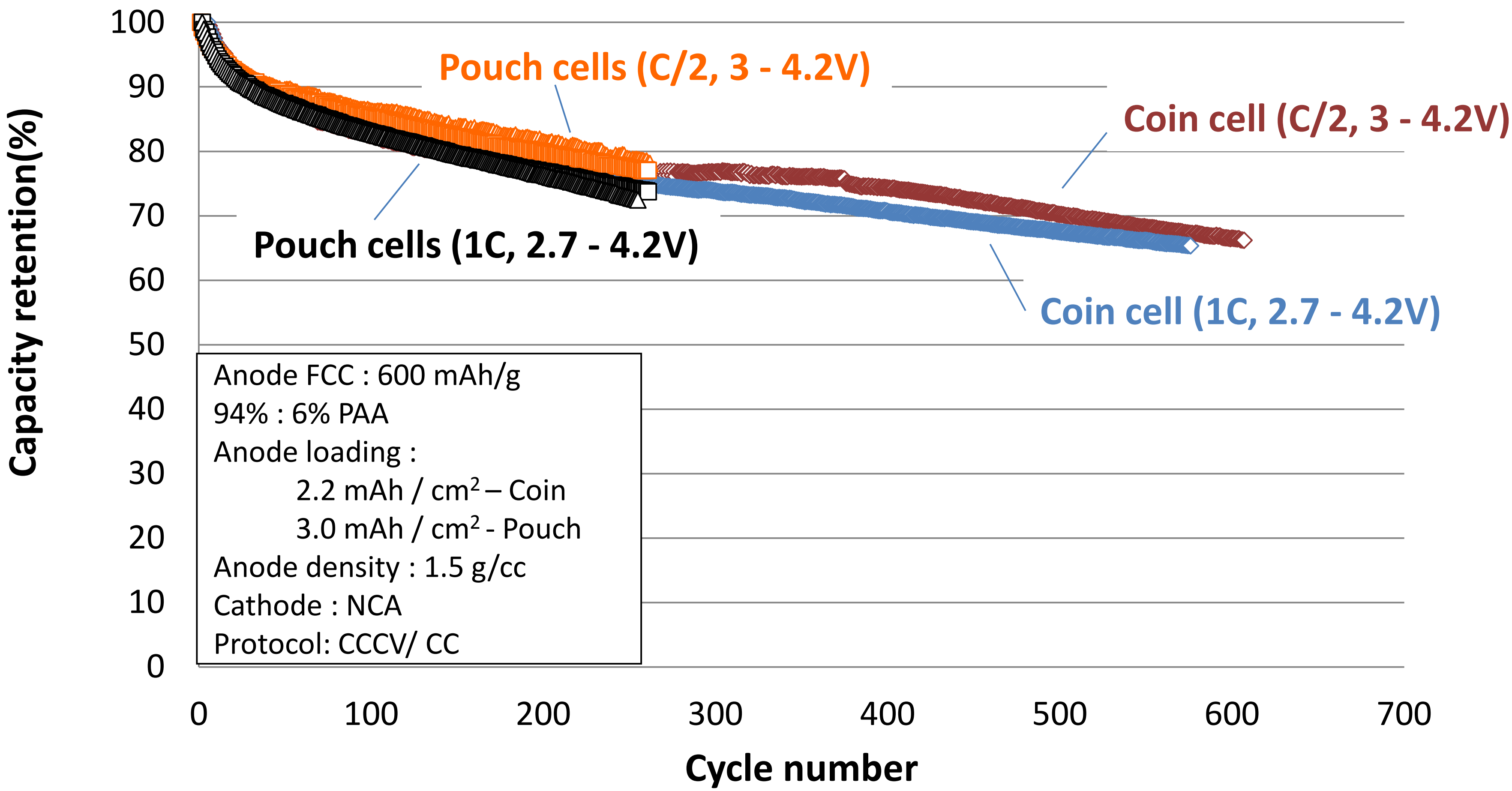
New Gen 3 Silicon anode stable over wide operating voltage

Improvement tied to improved formulation



Technical Progress

Pouch cell demonstration with new Gen 3 Silicon anode

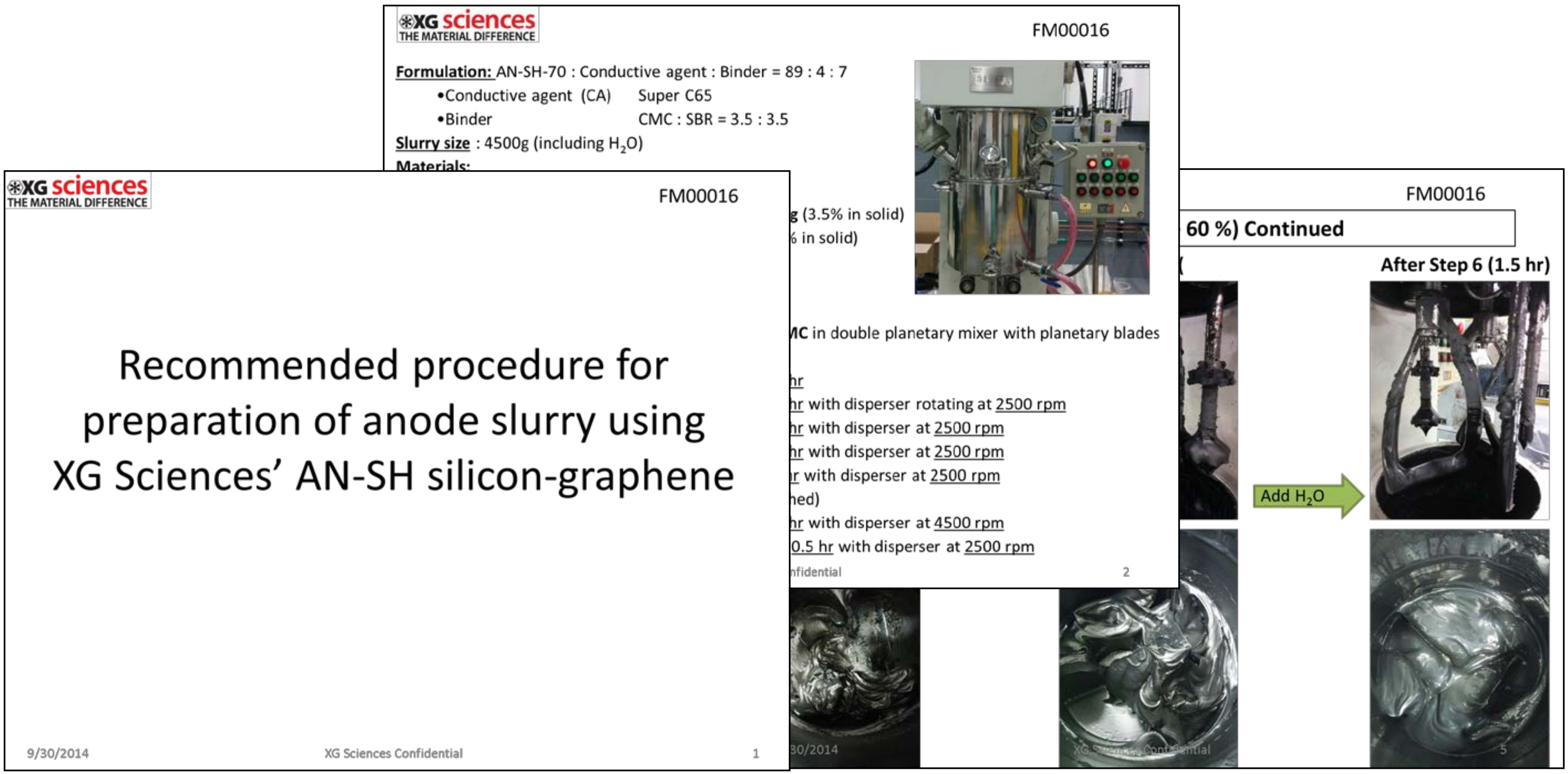


Technical Progress

Industrial-type mixer used to develop slurry protocol in support of electrode coating readiness demonstration (MS 4)

Technical Progress

Slurry protocol successfully transferred to A123 Systems in support of electrode coating readiness demonstration (MS 4)



Technical Progress

Slurry coat ability demonstrated on pilot-scale equipment in support of electrode coating readiness demonstration (MS 4)

XGS benchtop coating trial

50 μm Coating

75 μm Coating

Coating on Cu compressed to 1.8 g/cc

Machine coating trial at ANL

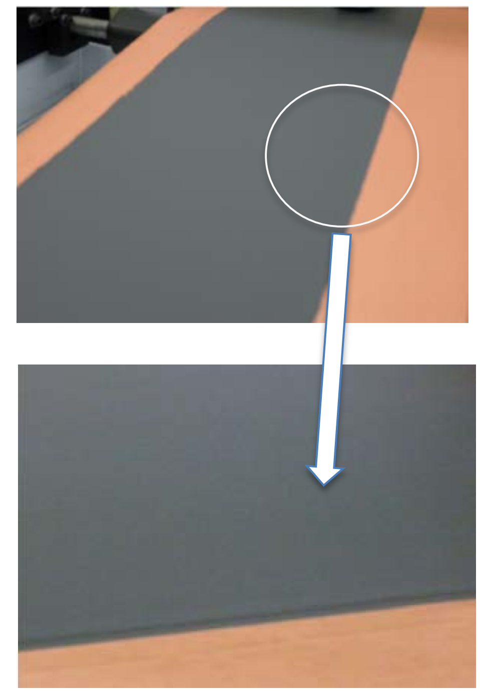
5 mAh/cm^2 and 7.2 mAh/cm^2

No cracks were observed

Technical Progress

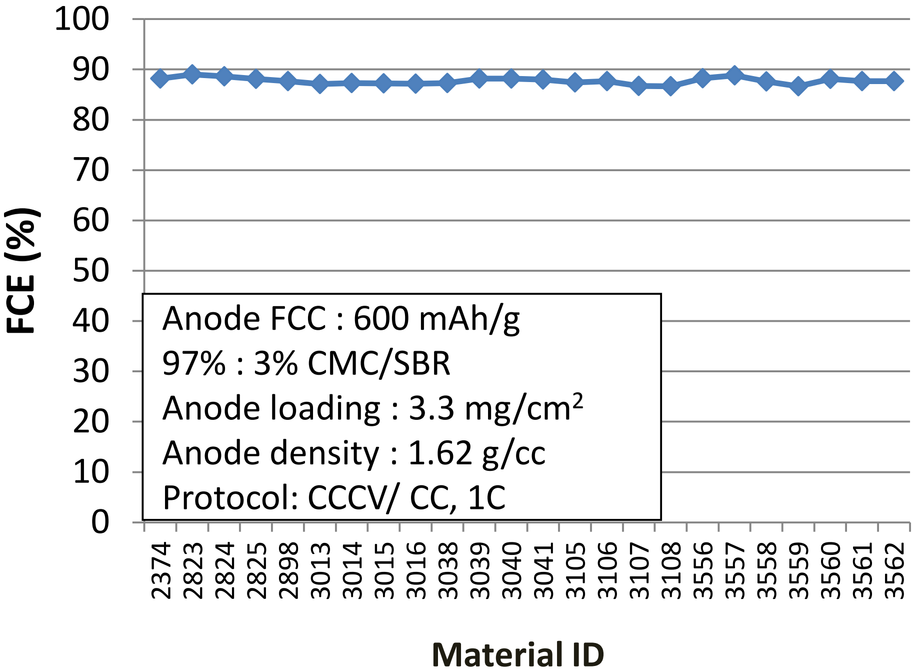
Met MS 4 with successful coating demonstrated on commercial machine

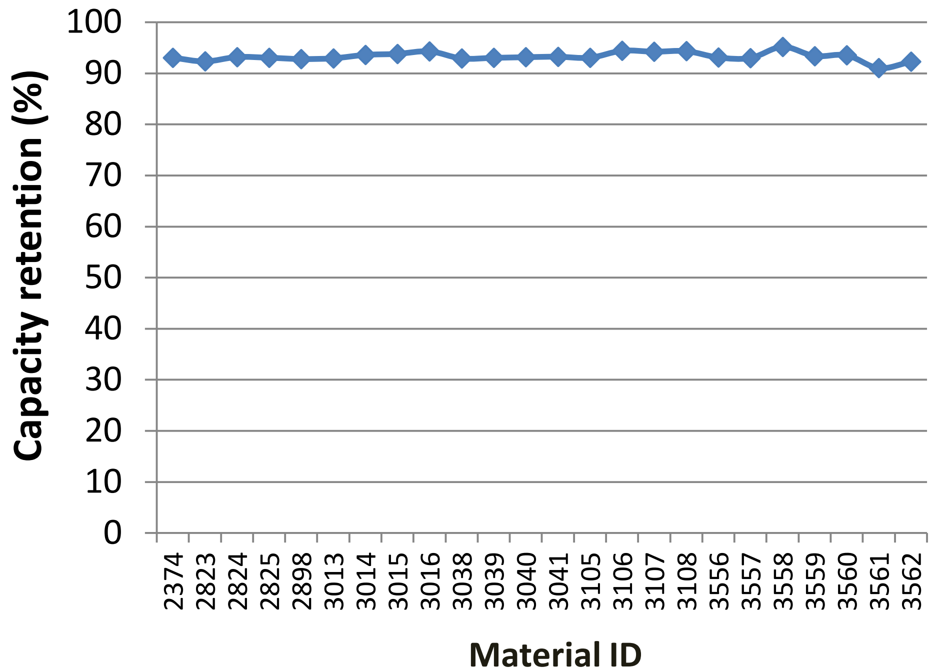
- Aqueous slurry made with polyacrylic acid binder
- Double-sided coating
- Coat weight 4.0 mg/cm^2 per side
- High quality coating confirmed
- XG SiG anode exhibited much better internal resistance than typical graphite anode



Technical Progress

Production material shows good consistency in
1st Cycle Efficiency and capacity retention
in support of MS 3 - Manufacturing process readiness





Reviewer Comments, Collaboration & Remaining Challenges

- Project was not reviewed last year

- Collaborations and Coordination
    - XG Sciences – Prime
    - A123 Systems – Subcontractor
    - Georgia Institute of Technology – Subcontractor
    - Argonne National Laboratory (A. Jansen)
    - Ashland Specialty Chemicals
    - Daikin America
    - Lawrence Berkeley National Laboratory (G. Liu)
    - Sandia National Laboratory (C. Orendorff)

- Remaining Challenges
    - Further improve capacity retention to meet 75% capacity at 1000 cycles
    - Maintain manufacturing process control with new material formulations
    - Maintain dispersibility and coatability new potential new formulations

Proposed Future Work

Barrier	Proposed work	Objective (MS)
Specific Energy, Life	• Silicon composite material modification including - Si precursor physical characteristics - Additives/ coatings to reduce electrolyte reactions • Graphene conductive additive - Modified functionalization • Binder and electrolyte - Continue supplier collaboration with focus on improved cycling stability, gas generation, reduced inactive material	Demonstrate: 600 mAh/g, 85% FCE, 70% Cap retention @1000 cycles (MS2)
Cost	• Translate future material developments to plant production	Demonstrate: Manufacturing readiness (MS3)
Specific Energy, Life	• Transfer future non-active materials (composite, conductive additive, binder, etc.) to A123 mixing and coating equipment	Demonstrate: Electrode coating ready for prototype cell builds (MS 4)
Specific Energy, Life	• Design, fabricate, assemble and demonstrate cells	Demonstrate 2Ah cells (MS 7)

Summary

- XG Sciences is on target
  - Goals met for Si anode performance based on full cell cycling in small format cells.
- All material developments
  - Transferred to high capacity plant production, material at numerous cell customers.
- Slurry and coating developments
  - Transferred to A123 Systems and numerous other cell manufacturers.

2014 Technical targets	2014 Technical results
Demonstrate 600mAh/g, 85% FCE, 500 cycles with 70% retention	Demonstrated 600 mAh/g, 85% FCE and 70% capacity retention at 500 cycles targets in small format cells
Demonstrate XG SiG™ manufacturing product and process variable limits	XG SiG™ manufacturing product and process variable limits were defined and implemented resulting in improved material quality
Demonstrate 2-3 L XG SiG™ slurry preparation and coating	Electrode coating of XG SiG™ material was successfully demonstrated by A123 using their commercial coater (>6 L) and Argonne National Lab.
Demonstrate XG SiG™ **performance in 2Ah cells**	2 Ah pouch and cylindrical cells were produced and performance demonstrated. Performance gaps were defined that are being addressed in year 2.