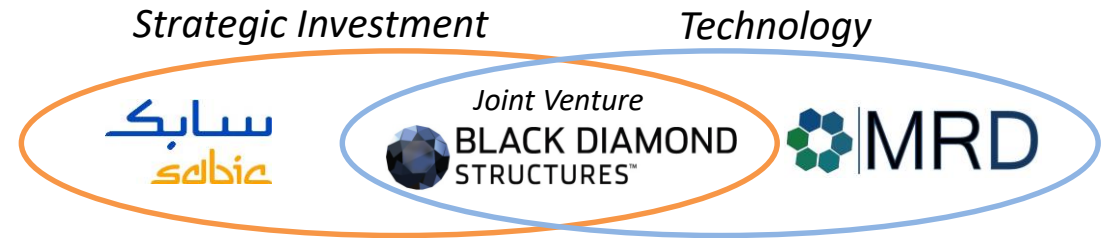


**BLACK DIAMOND
STRUCTURES™**

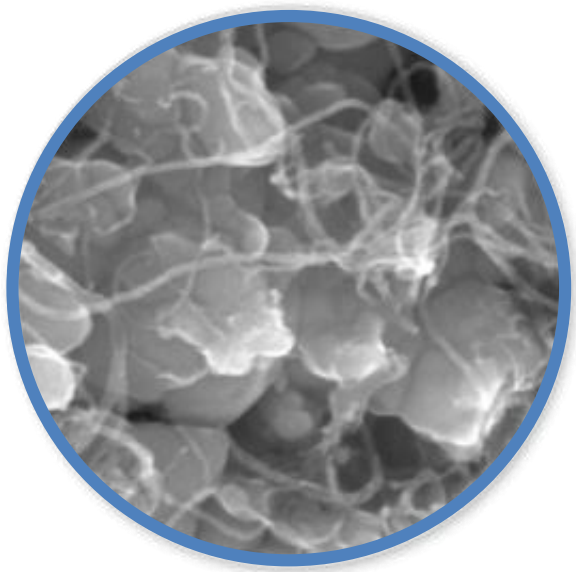
MOLECULAR REBAR® Nano-Solutions for Silicon-based Anodes

Who We Are

- **Black Diamond Structures** is a developer, manufacturer, and marketer of innovative nanomaterial products and solutions based on revolutionary **MOLECULAR REBAR** technology
- Formed as a Joint Venture between SABIC and Molecular Rebar Design, LLC
- A worldwide footprint for sales and support
- US-based manufacturing facility
 - Fully operation since 2014
 - Recently increased production from 1M liters/year to 3.3M liters/year
 - Gained full ISO9001 certification in 2017



Our Focus on Energy Storage



Lead Acid Batteries

- Commercial Sales and Customer Development
- Active with >150 customers globally
- Qualified in range of OEM applications, inc. automotive



Lithium Ion Batteries

- Product Development and Customer Trials
- Working w/ materials suppliers, cell makers, OEMs
- Building portfolio of solutions to enable lower cost/kwh

MOLECULAR REBAR Products For Pb-Acid Batteries

Enhances Consistency of Performance

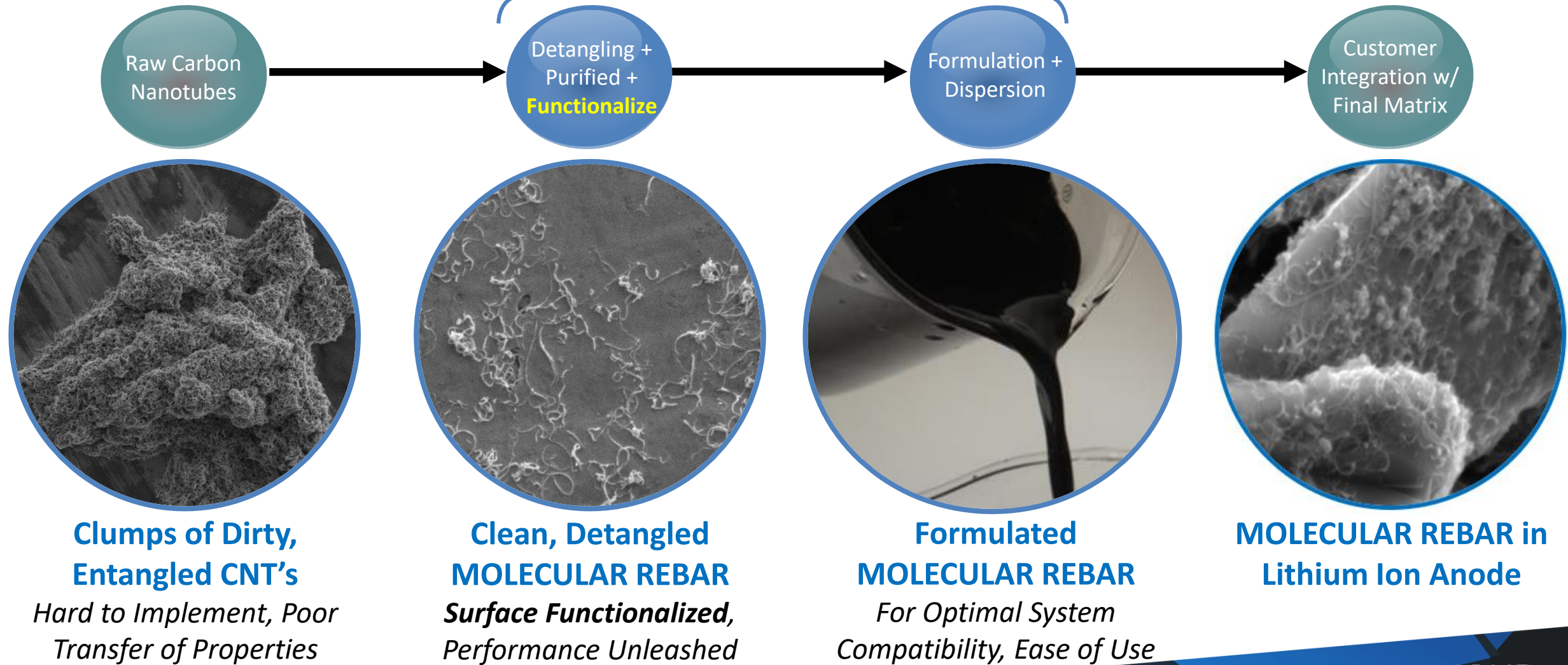
- Improves Charge Acceptance >15%*
- Increases Cycle Life 25-300%*
- Enables Partial State of Charge Operations
- Reduces Irreversible Sulfation
- Enhanced Plate Durability
- Improves Thermal Operational Ranges
- Simple Integration Into Existing Processes



*Dependent on battery and test protocol

MOLECULAR REBAR Base Technology

Key Competitive Advantage



MOLECULAR REBAR Solutions for LIB

Graphite
Anode

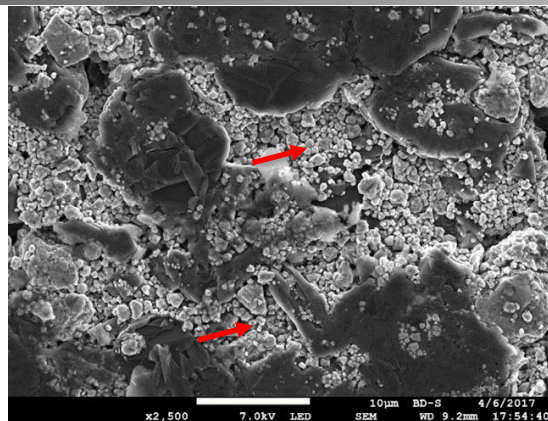
Silicon based
Anodes

Cathodes and
LTO Anode

MOLECULAR REBAR solutions enable
high energy Lithium Batteries by
improving the cycle life of high-capacity
Silicon-based anodes

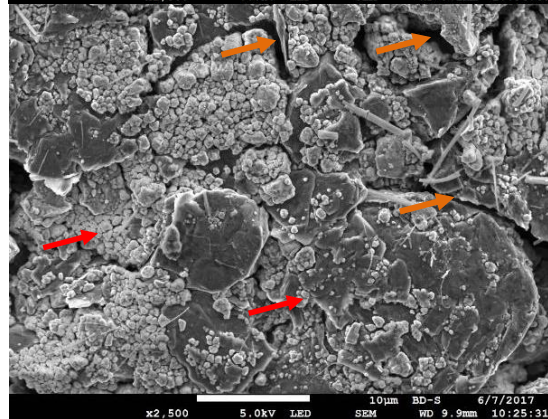
Silicon Anode Challenges and Solutions

Fresh Electrode



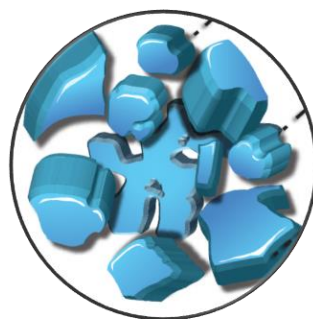
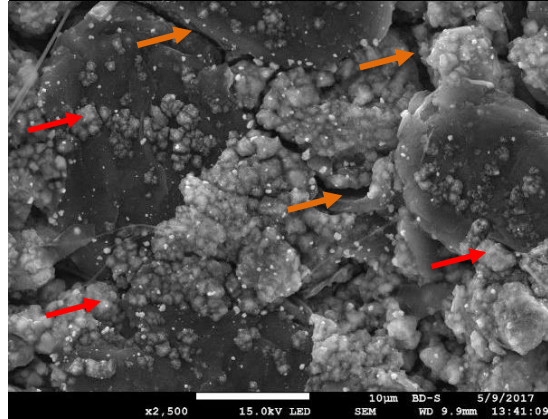
System = crack free
Si = small, tight (↑)

During Formation



System = cracking (↑)
Si = SEI, swelling (↑)

After Cycling



System = cracked (↑)
Si = swollen, puffy (↑)

- **Silicon Challenges**

- Expansion/contraction stresses electrode
- Capacity/Lithium loss

- **Typical Silicon Solutions**

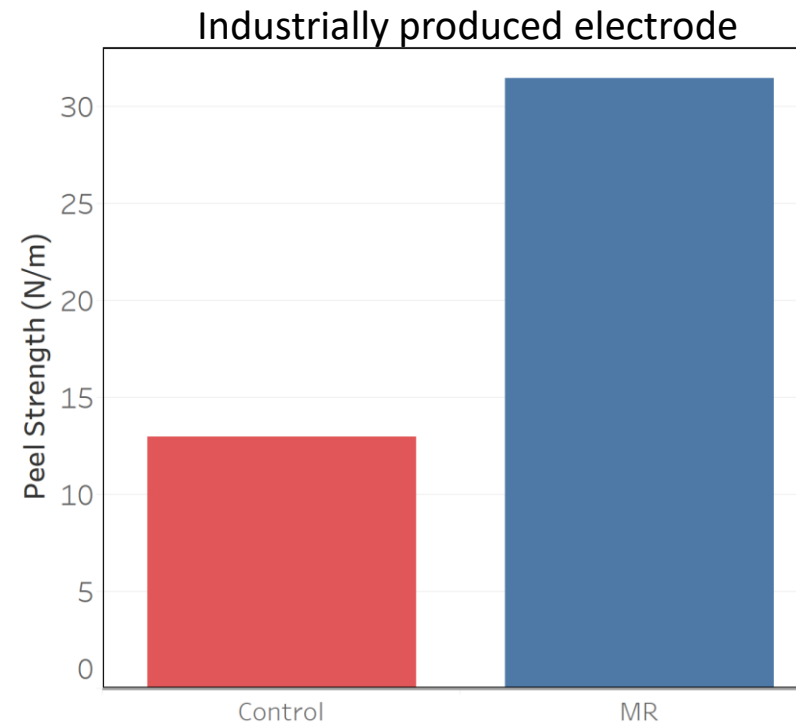
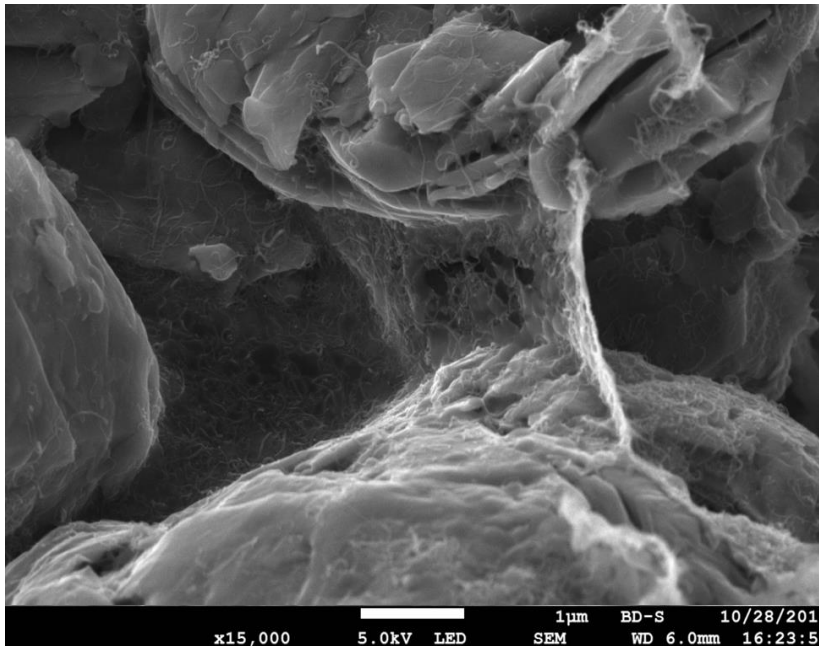
- Improved Si materials*
- Tougher binders*
- Performance Enhancers*
- New electrolyte
- Process control

- **Molecular Rebar Products are Complimentary**

- Provide benefits on top of existing solutions
- * = Synergizes with...

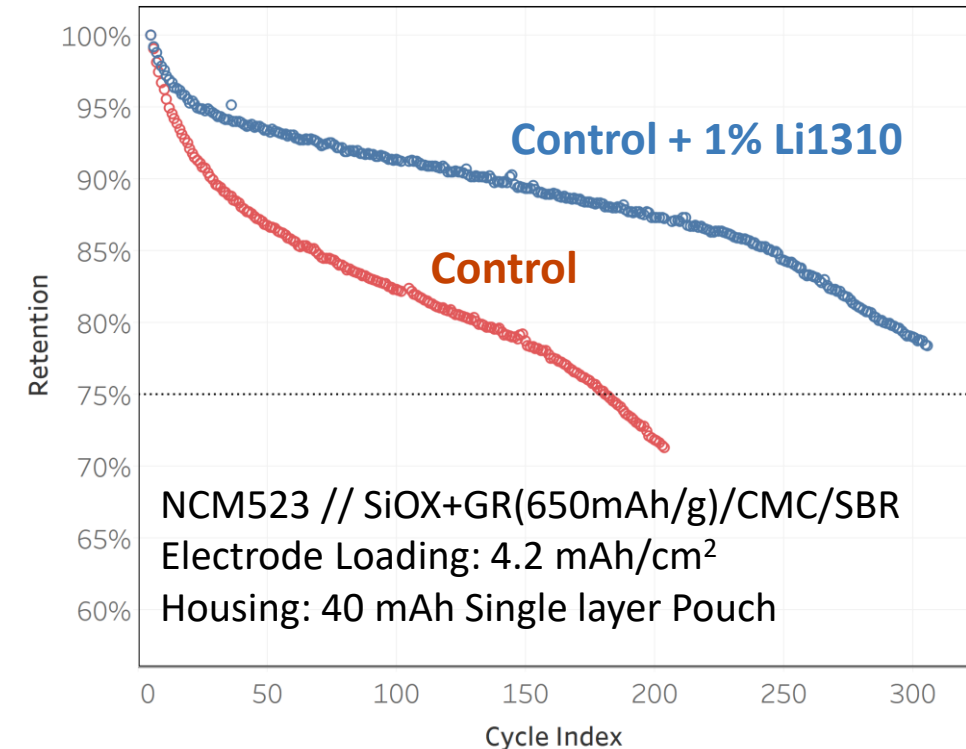
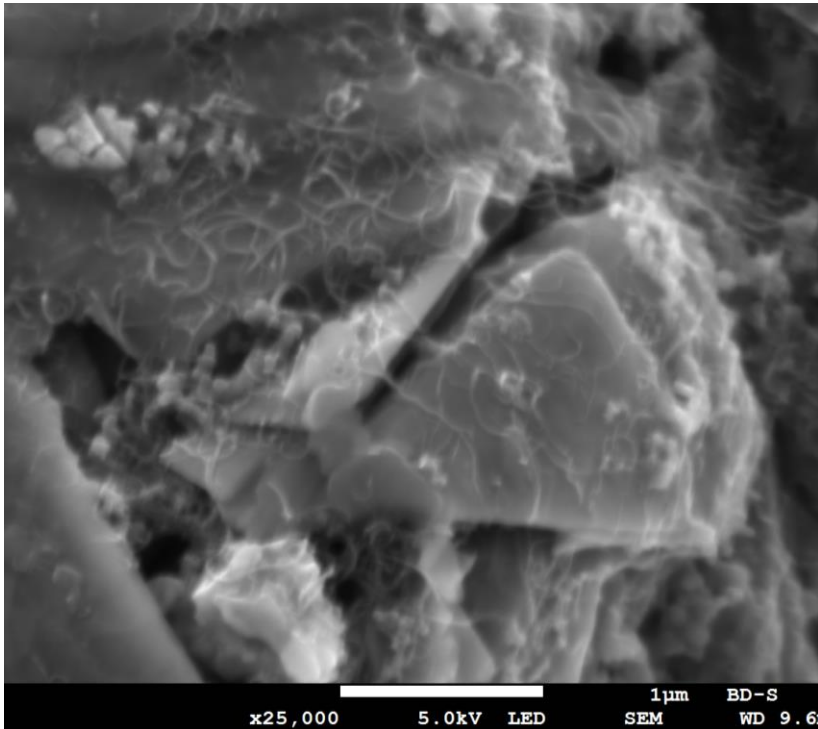
Li1300x Enhance Strength

- Interparticle integrity is the key to address the Silicon challenge
- MOLECULAR REBAR solutions increase peel-strength/mechanical-properties
- Mechanical strength gained by increasing particle-particle connectivity and reinforcing binder



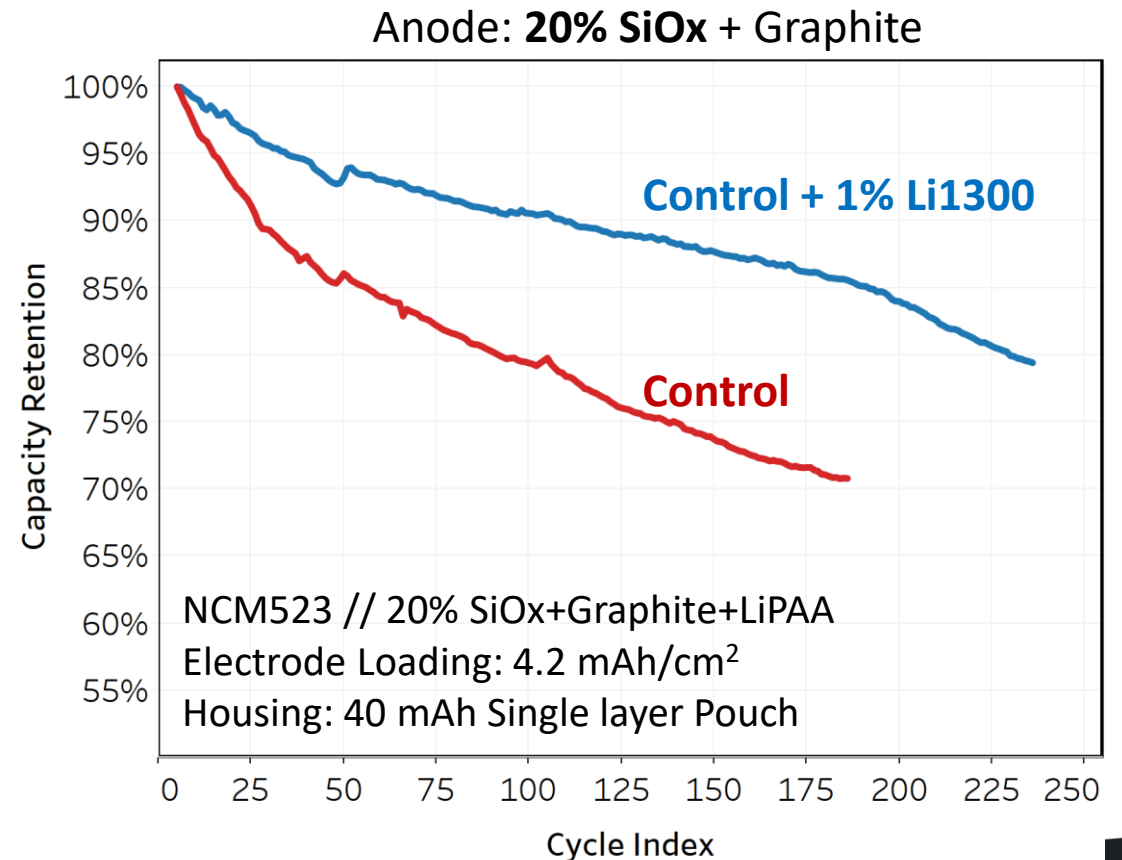
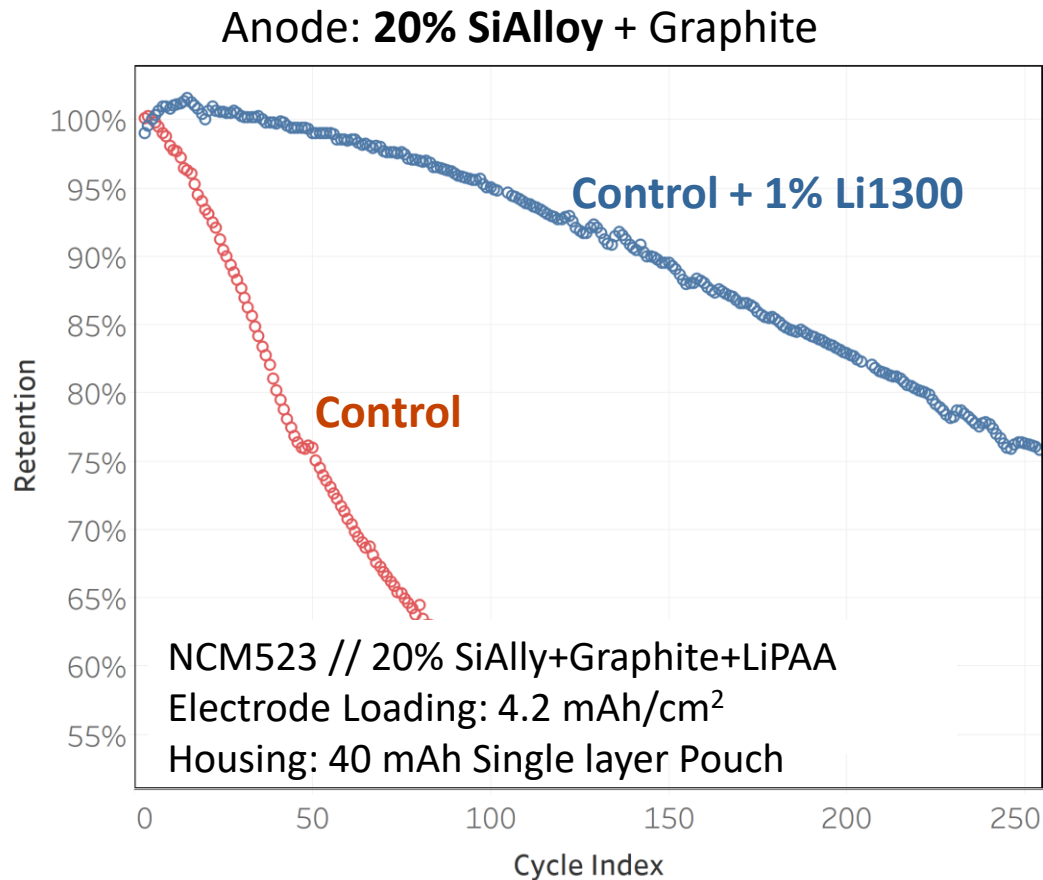
Li1300x Enhances Cycle Life

- Demonstrated ~300 cycles with very high capacity (650 mAh/g) anode
 - Functionalization enhances the cycle life due to strong interaction with active materials and binder systems
- MOLECULAR REBAR technology helps
 - Maintain good contact between particles
 - Toughen binder

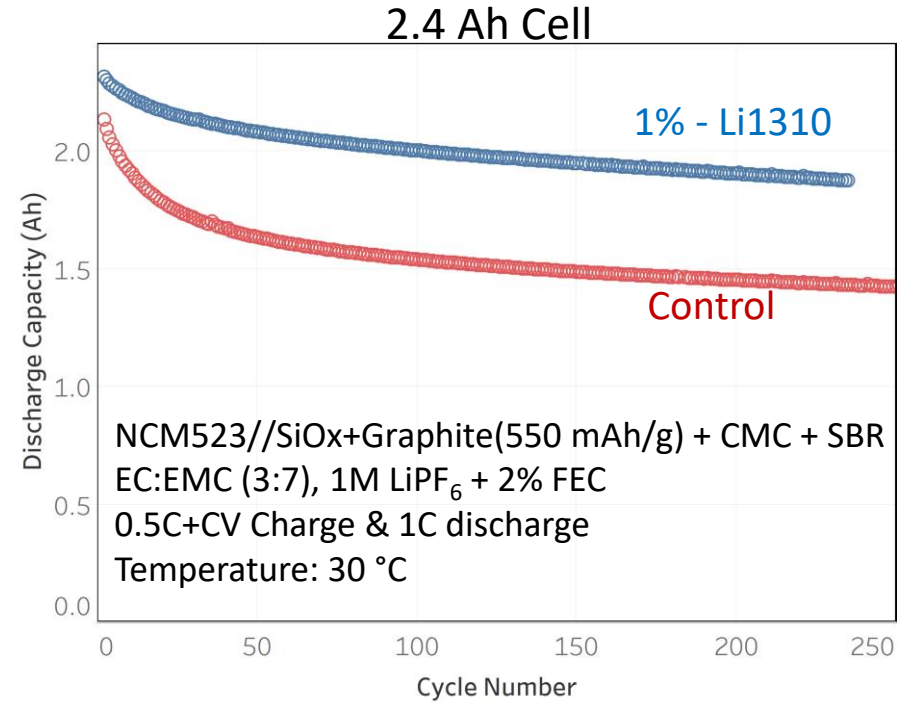
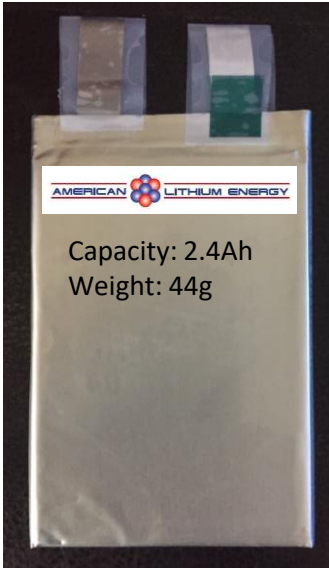
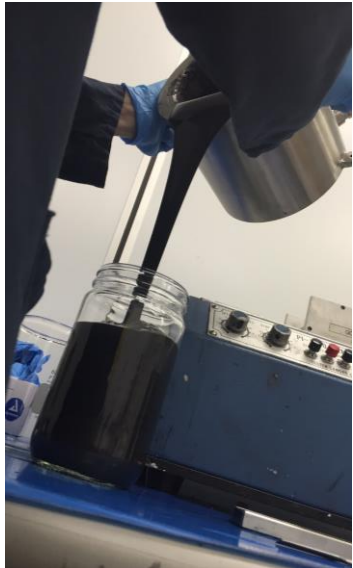


Improves Leading Types of Si-based Anodes

- Technology is designed for:
 - Different type of Si-based anodes: Silicon Oxide, Silicon Alloy alternatives
 - Different types of Binders: CMC/SBR, LiPAA

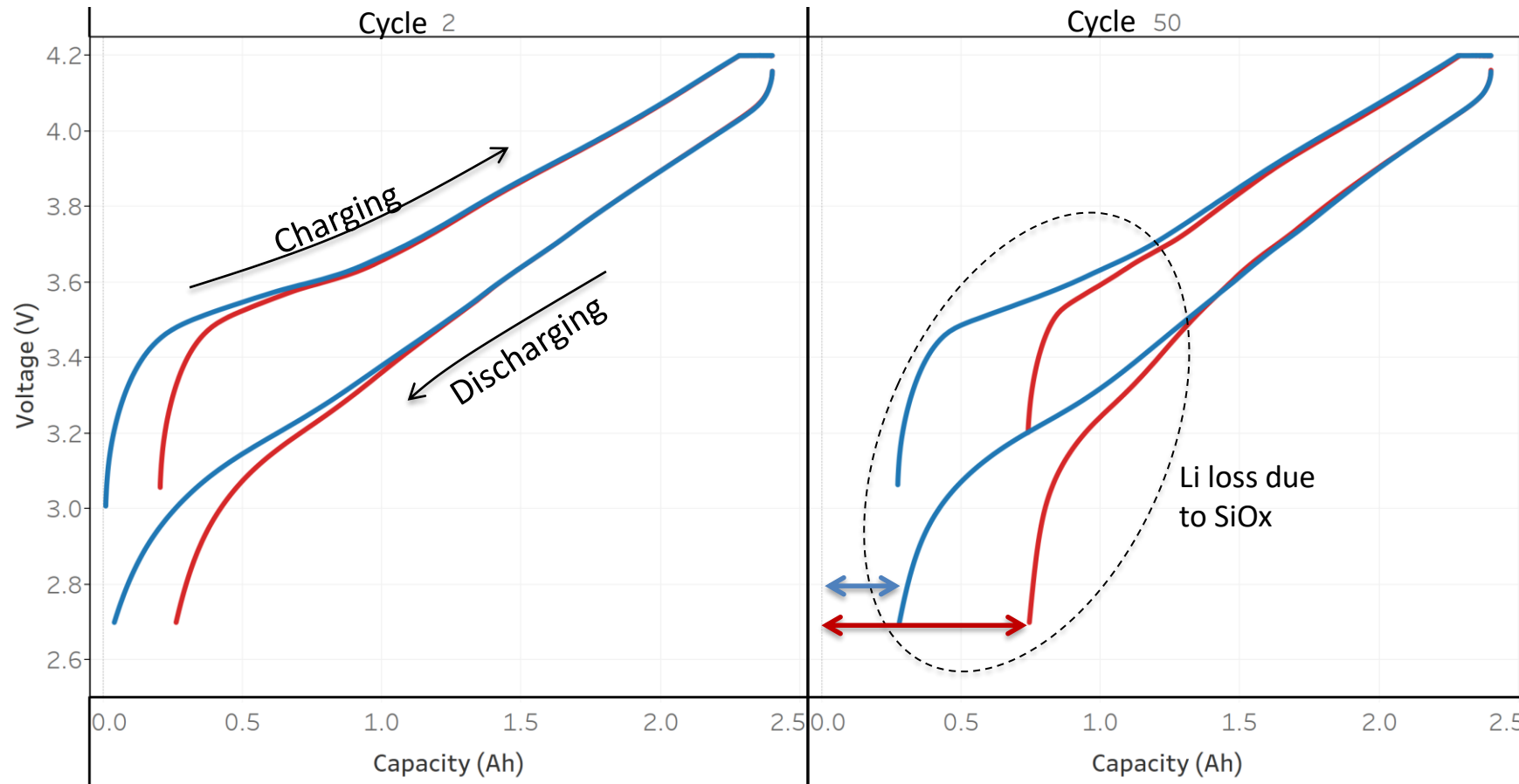


Testing in Large Format Cells



- **Easy to implement**
 - Processability of MR has been evaluated in large scale mixers
 - No major change in mixing conditions
 - Easily fits in to existing manufacturing method
- **Consistent improvement even in large format cells**
 - Achieved over 225 cycles with 80% capacity retention

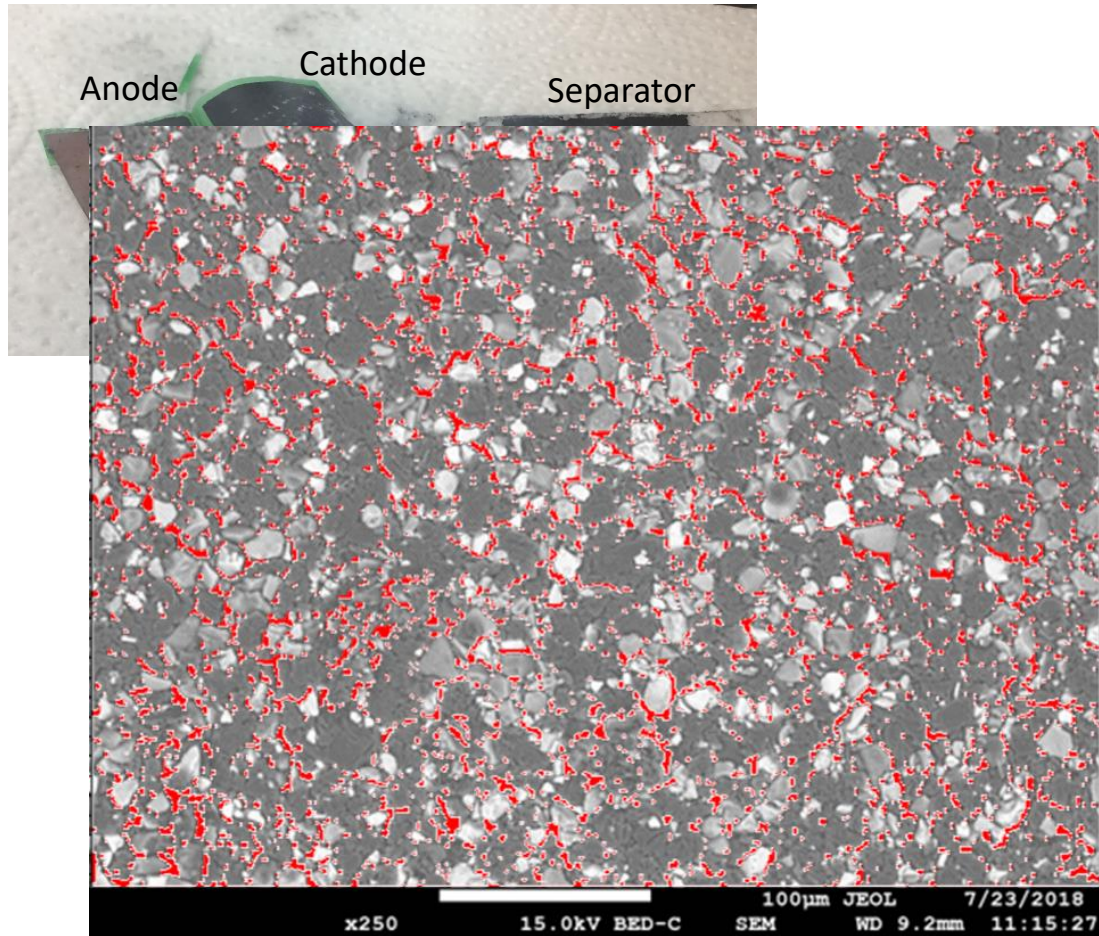
Li1300x Reduces Irreversible Li-Loss



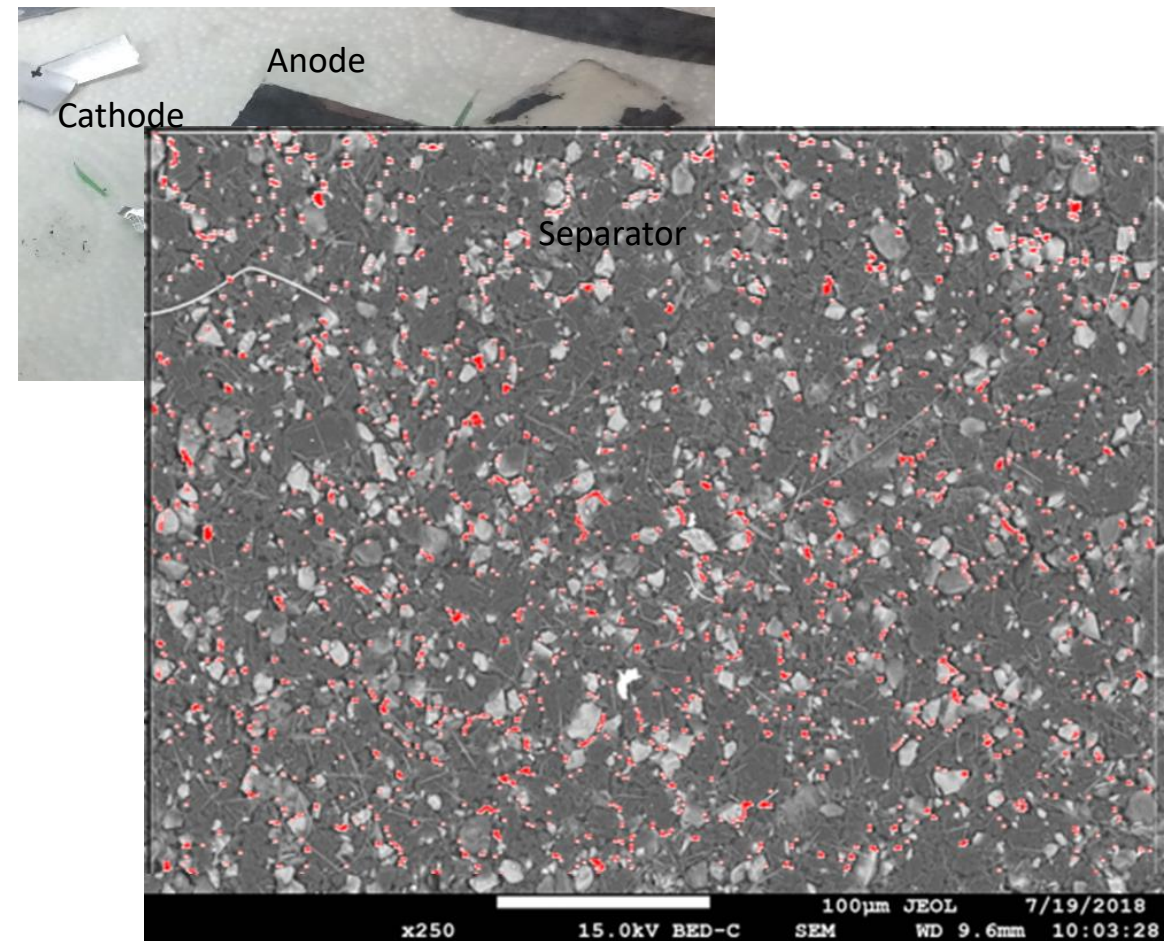
- In 50 cycles, most of the capacity due to SiOx is lost
- MR containing cells retains capacity contributions from SiOx

Improved Strength and Electrical Contact with Li1300x

Control

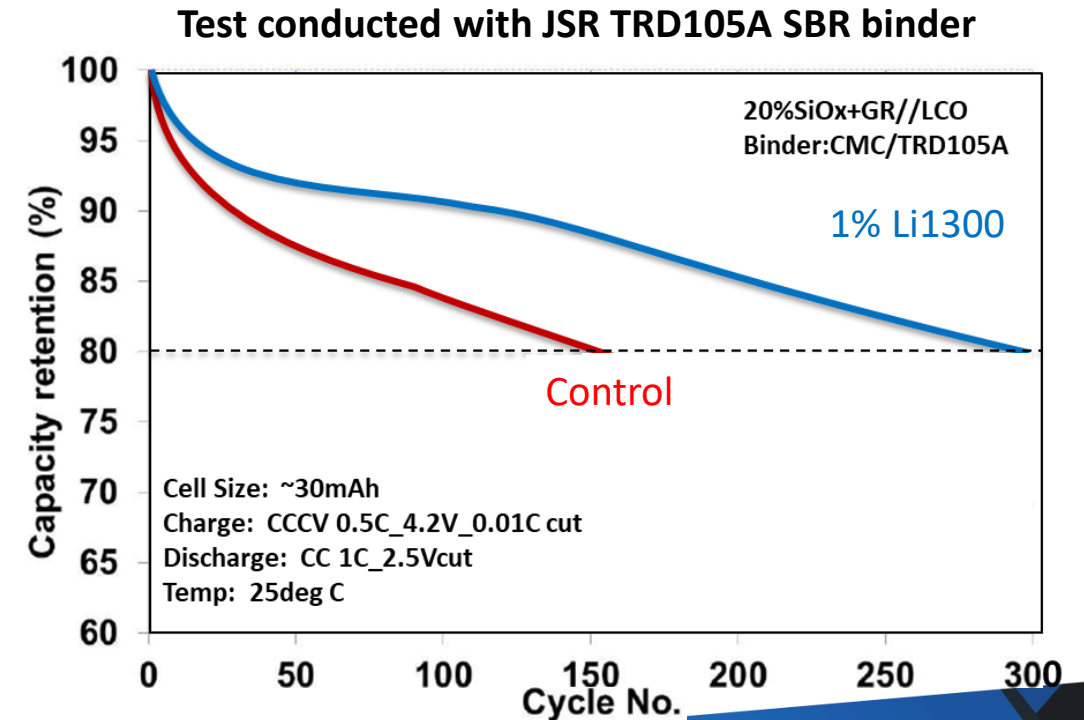
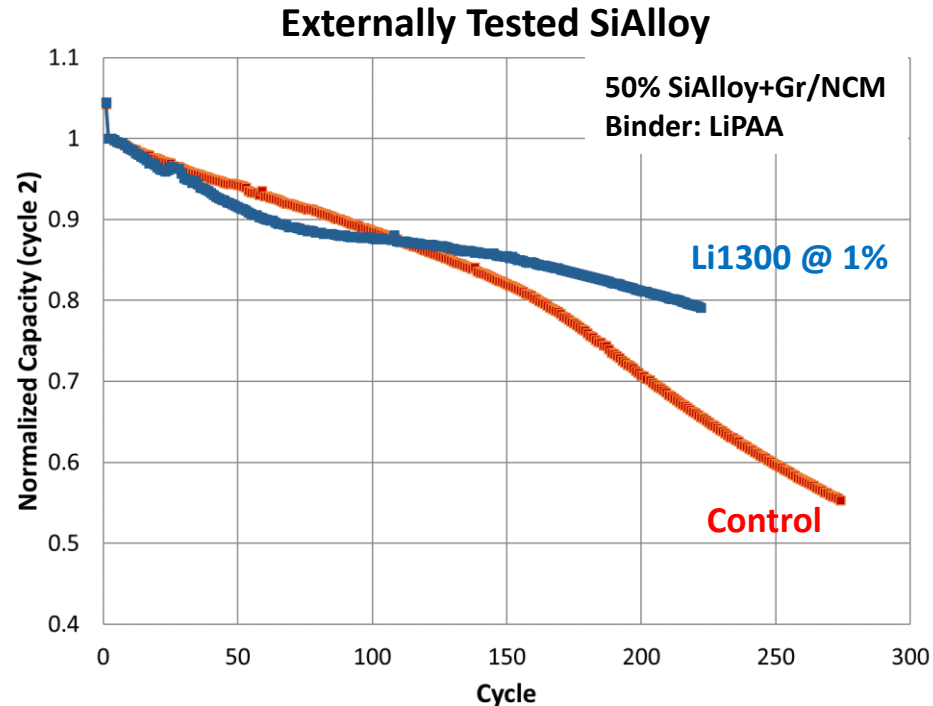


Control + 1% Li1300N



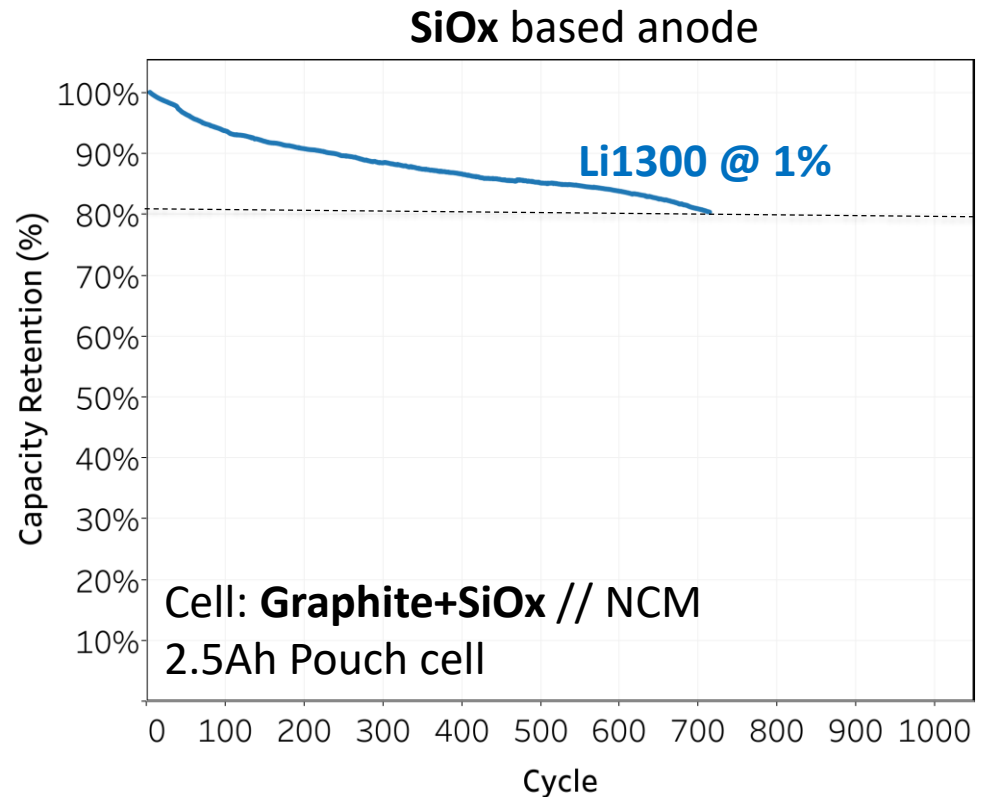
External Validation Mirrors Internal Testing

- Dozens of manufacturers and material suppliers are evaluating our products to find benefits in their system
 - Internal data matches external trial data (SiOx and SiAl)
- Early external trials with Silicon Alloy or Silicon Oxide show benefit in multiple cells types/builds
 - 20-100% improvement in cycle life
 - Further improvements expected with optimization



Validation by Cell Manufacturers

- Excellent performance: >700 cycle at 45°C during 100% DoD and 1C Cycling



Summary

- **Features of MOLECULAR REBAR Technology**
 - Enables the use of high silicon percentages to enhance energy density
 - Easy to implement in lab or pilot-scale with existing equipment and formulations
 - Enhances cycle life 10-100% in certain systems
 - Enhances mechanical strength

“Use of MOLECULAR REBAR enabled production of our high-capacity, silicon-based anodes!”
– Battery Manufacturer

Thanks For Your Attention

Visit Us Online: www.blackdiamond-structures.com



Contact Us:

Dr. Vinay Bhat – Director of Li-Ion Technology

vbhat@bd-structures.com

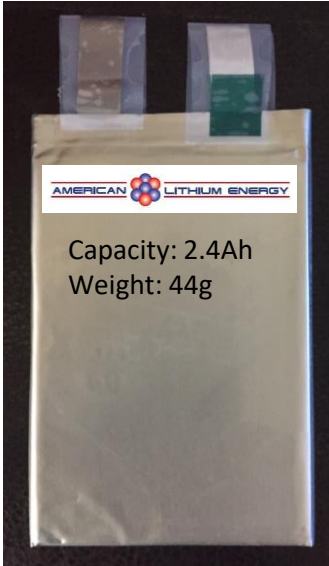
Tim Knaus – Vice-President, Global Sales

tknaus@bd-structures.com

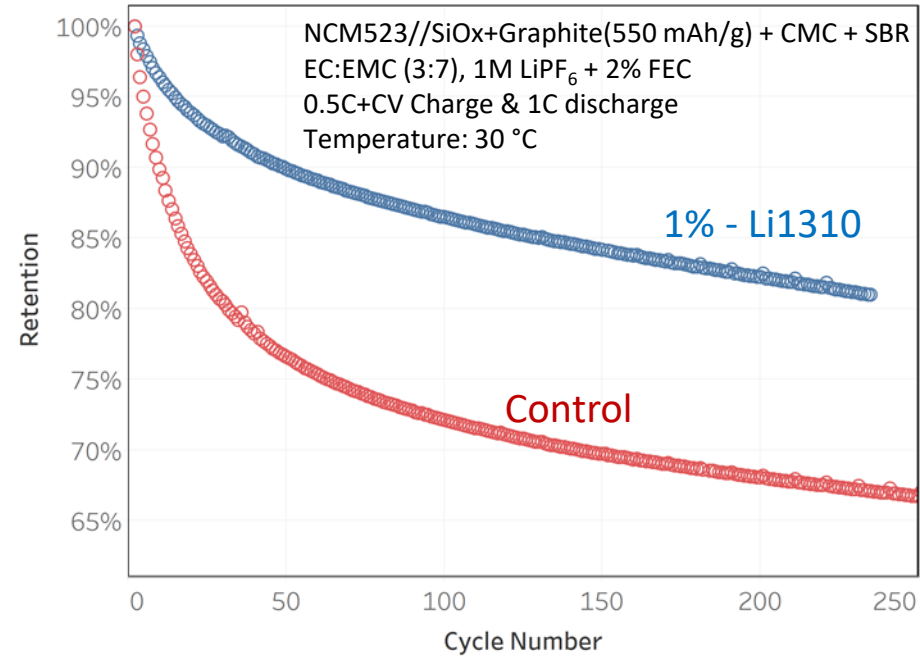
Dru Kefalos – Chief Marketing Officer

dkefalos@bd-structures.com

Testing in Large Format Cells



2.4 Ah Cell



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