

MOLECULAR REBAR[®] Nano-Solutions for Silicon-based Anodes

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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



Easy to Implement at Scale

- No need for additional mixing equipment
 - Slurry processing can be completed with existing tools
- No significant change to formulation protocols
 - Material is added alongside aqueous component
- Compatible with multiple binder systems
 - Examples: CMC/SBR, LiPAA, etc
- Viscosity within pumping and filtering tolerances

Introducing MOLECULAR REBAR Solutions for LIB

MOLECULAR REBAR Solutions for Graphite

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MOLECULAR REBAR Solutions for Silicon

MOLECULAR REBAR Solutions for Cathodes, 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

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...

MOLECULAR REBAR Solutions Enhance Strength

- Adhesion and Cohesion are key to combating the Silicon challenge
- MOLECULAR REBAR solutions increase mechanical properties by 30-40%
- Mechanical strength gained by increasing particle-particle connectivity and reinforcing binder

MOLECULAR REBAR Enhances Cycle Life

- Functionalization enhances the interaction with active materials and binder systems
- MOLECULAR REBAR technology helps
 - Maintain good contact between particles
 - Toughen binder

BLACK DIAMOND STRUCTURES[™]

MOLECULAR REBAR Reduces Impedance Growth

- Large addition of Carbon Black reduces initial impedance, but does not prevent impedance growth
- MR addition improves Coulombic efficiency and reduces impedance growth

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

Anode: 20% SiAlloy + Graphite

STRUCTURES"

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

Externally Tested SiAlloy

Validation by Cell Manufacturers

• Excellent performance: <a>>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
- Application Engineers available to confirm system compatibility, mixing protocols, and offer product suggestion for best results

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

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