

MOLECULAR REBAR[®]:

Discrete Carbon Nanotube additives for VRLA Motorcycle and e-Vehicle Applications

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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 discrete carbon nanotube (dCNT) technology, MOLECULAR REBAR[®]

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Global Adoption - MOLECULAR REBAR® Technology

• Global Adoption:

- Products Commercially Available and being *sold to* Lead Acid Battery Manufacturers across multiple end-use applications
- Working with >120 battery manufacturers worldwide, each at various stages of development and/or commercial sales.
- Recent approval for use in major Automotive OEM batteries. (SLI)
- Have proven that Molecular Rebar can help battery manufacturers meet new OEM requirements for "Advanced Automotive Battery" applications.
- Extremely large amount of data on full-scale production batteries.
- Participating in the CENELEC technical work group (Major Auto OEM's, large battery MFR's, limited supplier involvement).
- Approved to discuss three Mfr's publicly at this time (Eastman India, Pacific Battery Fiji, Tianjin Lantian Power Sources China)

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• Why the rapid adoption?

- Technology is innovative, cutting-edge, and *scientifically sound*
- Cost effective performance improvements over a wide variety of applications
- Low risk to use
- No (or very low) capital expenditure by manufacturer; very easy to use and implement
- Highly technical staff works hand in hand with your company during ramp up.
- World-class technical support from Black Diamond Structures[™]

About us : Products (by Application)

	Application	NAM Product	PAM Product	
Automotive	SLI & Heavy Truck – Conventional Flooded	Pb1100N	Pb1100P	
	Start/Stop – Enhanced Flooded	Pb1200N	Pb1200P	
	Advanced Auto - VRLA	Pb1300Nx	Pb1300Px	
	Motorcycle – VRLA	Pb1400N	Pb1400P	
Motive Power	eRickshaw - Flooded (Tubular)	Pb2100N		
	eRickshaw - Flooded (Flat Plate)	Pb2200N		
	eVehicles - VRLA	Pb2300N	Pb2300P	
	Lift Trucks – Flooded	Pb4100Nx	Pb4100Px	
Stationary	Inverter - Flooded	Pb3100N		
	Solar - Flooded	Pb3200N		
	Solar (PSOC)- VRLA	Pb3300N	Pb3300P	
	Advanced Renewables & Utilities - VRLA	Pb3400Nx	Pb3400Px	
	Telecom - VRLA	Pb3500Nx	Pb3500Px	

Commercial Product / Active Validation

About us: Product & Packaging

- Material is shipped as a black pourable liquid which is added directly to the paste mixer for both NEGATIVE & POSITIVE plates
- MOLECULAR REBAR[®] products are formulated for ease of use and incorporation
- Sold in 1,250L Totes, 200L Drums or 10L Jugs.
- 9 Month Shelf life
- A volume of pasting water is replaced with the MOLECULAR REBAR[®] liquid so total liquid volume remains the same



MOLECULAR REBAR® Technology



MOLECULAR REBAR® Benefits For Your Battery

- Enhances Consistency of Performance
- Improves Charge Acceptance >25%*
- Increases Cycle Life 25-300%*
- Enables Partial State of Charge Operations
- Reduces Irreversible Sulfation & Plate Growth
- Enhanced Plate Durability
- Improves Thermal Operational Ranges

• Simple Integration Into Existing Processes





7 *Dependent on battery and test protocol

Motorcycle VRLA Batteries: Pb1400 Series

- Products = Pb1410N & Pb1400P
- Key Features:
 - Used in Negative or Negative + Positive Electrodes
 - No change to existing paste process or recipe
 - Improved Consistency in Capacity + CCA Throughout Life
 - Extended Cycle Life / Reduced Warranty Failures
 - Increased Electrical Performance
 - Enhanced Plate Strength / Durability

Customer approved anonymous release 7Ah VRLA data included





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Pb1400 Series Products: Improved & Maintained Cold Cranking Amps

Molecular Rebar[®] provides higher CCA



Pb1400 increases CCA Duration

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- 50% increase with 10L of Pb1410N
- 100% increase with 20L of Pb1410N

Molecular Rebar® maintains higher CCA throughout life



1. Discharge for 2 hours @ 2.5X 10-hour rate (50% DOD)

2. Recharge @ 2.5X 10-hour rate with voltage limit of 14.4 V; 5 hours or minimum 108% charge return

-Repeat steps (1-2) 15X, Rest 24 hours, perform high-rate discharge at 40°C

-Repeat entire sequence for 6X, total of 90 cycles





- **Controls cannot recharge under standard JIS** charging protocol:
- MR enables the use of JIS charging in these batteries
- Combination of Pb1410N & Pb1400P provides ٠ a more significant shift in capacity retention than Pb1410N alone



0.1C, 14.8V 0.1C, 16V IIS 8-Control Pb1410N Pb1400P & Pb1410N Discharge Capacity (Ah) 6-5 -

C10 Capacity Cycling Under Various Charging Protocols

4 -

3-

Pb1400 Series Products: Improves Cycle Life (JIS C 8702)



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Molecular Rebar® extends cycle life by maintaining capacity



Pb1400 Series Products: Provides More Consistent Microstructure



SEM Imagery Post 50% DOD OEM Cycle Life Test



Control lacks uniformity and has significant crystal growth								
			1µm	LATPIOA- 8/9/2017				
x5,000	5.0kV	LED	SEM	WD 10.0mm 13:39:29				



Molecular Rebar[®] restricts growth and promotes uniformity

1µm	LATI	PIOC-	8/9	/2	01	7
EM	WD	10.0	mm 1.	4:	04	•

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5.0kV LED

x5,000

12

Pb1400 Series Motorcycle VRLA: Customer Testimonial #1

Customer produced 6Ah Motorcycle VRLA batteries using Pb1400 Series and found <u>2X Improvement in Cycle Life</u>

- Pb1400 enabled >10,000 ABNT/JIS Light Load cycles
 "MR has made our products the best in the market" Customer
- Commercially launched in several high-warranty return product lines using 10L Pb1410N & 34L Pb1400P
 - Added benefit: able to reduce formation time by 25%

 Optimizing Pb1400 Series loadings for implementation in all of their products to reduce warranty claims and formation time

Post ABNT 15941 (similar to JIS D5302 Light Load):

- CONTROL failed HRD check @ 5,600 cycles
- Pb1400 never failed and were stopped @10,600 cycles
- C₁₀ post cycling was 4Ah for CONTROL and 5Ah for Pb1400



- ✓ MR Plate has higher integrity, even after ~2X cycling
- Failure mode of CON: Positive Grid Corrosion



Pb1400 Series Products: Summary

- Products = Pb1410N & Pb1400P
- Key Features:
 - CCA enhanced initially and maintained throughout cycling
 - Pb1410N dose response: improvement with 20L > 10L
 - Better Charge Acceptance & Capacity Retention
 - Pb1400P with Pb1410N further enhances
 - Life Cycle is Significantly Increased
 - 50% DoD OEM Test
 - JIS C8702
 - JIS D5302 Light Load Test
 - MOLECULAR REBAR[®] can be optimized to meet your objectives





Pb2100, Pb2200 & Pb2300 Series for e-Vehicles



Deep Cycle Motive Products specially formulated for:

- Pb2100 Tubular Positive e-Rickshaw
- Pb2200 Flat Plate Positive e-Rickshaw
- Pb2300 VRLA for e-vehicle

Key Features:

- Reduced Recharge Times
- Sustained Capacity
- Assists in avoiding Deficit Charging & Sulfation



Pb2100 Series Tubular eRickshaw: Customer Testimonial #2

" Finally, we made a perfect e-rickshaw battery" – Customer

Customer Issue

- Tubular e-rickshaw batteries produced had chronic sulphation due to poor charge acceptance
- Field failures resulted in a 20% Warranty Return Rate
- Manufacturer had to stop producing e-rickshaw batteries

Pb2100N as the Solution

- Customer is now using 34L of Pb2100N to improve charge acceptance and suppress sulfation, providing consistent performance and dramatically extended life
- Customer has launched a new line of Premium High Warranty e-rickshaw batteries into the market
- Customer has also implemented Pb1100 Series for their Premium High Warranty Automotive – SLI Flooded batteries

Lab Testing: 50% Reduction in Recharge Time



Field Results: Check @ 4 Months

Bend Test

After Bend Test – MR Plate Showing High Integrity

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- Customer uses Pb1400 Series for VRLA Motorcycle, which enabled performance levels that allowed them to win new OEM business.
- Expanded same strategy with Pb2300 Series for Deep Cycle products
- Customer uses Pb2300 Series to create:
- New high performance products for applications where they could not previously participate
- Enhanced base performance in many of their standard products to increase market share in current business



Lab Results Deep Cycle 12V VRLA (75-100Ah) Wheelchair and e-Vehicle

- Reduced Recharge from 14hrs to 7-10hrs
- Increased 100% DoD Cycle Life by over 50%

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MOLECULAR REBAR: Performance-Enhancing Nanotubes

Customer Testimonial Summary

- Pb1400 Series: Motorcycle VRLA
 - Made products "best in market"
 - Dramatic reduction to warranty costs
 - Provided solution to win OEM business
- Pb2100 Series: Tubular Plate e-rickshaw
 - Enabled Performance for re-entry into the market
 - Created High Warranty Product
- Pb2300 Series: VRLA e-vehicle
 - Allowed entry into new application markets
 - Helped build better batteries to increase market share

General Product Summary

- MOLECULAR REBAR[®] in All Applications:
 - Improved Consistency in Performance Throughout Life
 - Extended Cycle Life / Reduced Warranty Failures
 - Increased Electrical Performance
 - Enhanced Plate Strength / Durability
- Pb1400 Series for Motorcycle VRLA
 - Improved & Sustained CCA Throughout Life
- Pb2100, 2200, 2300 Series for Deep Cycle Motive
 - Reduced Recharge Times
 - Sustained Capacity
 - Assists in avoiding Deficit Charging & Sulfation

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Our new ISO 9001:2015 Testing Facility!



Special Thanks to Our Partners:

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....Let's grow together



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To support our customers:

- 16ct 300A channels
- 48ct 100A channels
- 64ct 25A channels
- 1ct 1500A HRD unit

Thank you for your attention!

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