

SPECIALITY CARBON BLACKS

# HIGH PERFORMANCE MATERIALS

FOR ADVANCED LEAD BATTERIES



**CABOT** 



## Introduction

Cabot Corporation is a global performance materials company and we strive to be our customers' commercial partner of choice. We have been a leading manufacturer of carbon black and other specialty chemicals for more than 140 years, and our global reach enables us to partner closely with customers to meet the highest standards for innovation performance, quality and service. We are a key player in the provision of high performance materials and technology to many sectors of the energy industry.

### Delivering battery performance through particle science expertise

As demand grows for advanced lead batteries in the automotive, industrial and grid storage applications, battery manufacturers are looking for performance materials companies like Cabot to enable the next generation of lead batteries.

We bring unparalleled scale and technological depth when assisting our customers with a broad range of carbon and other particulate materials, such as metal oxides and composites. Our capabilities span the entire range of carbon particle sizes, morphologies and surface properties desired by battery manufacturers and include the ability to control key properties independently, allowing our products to provide the specific functional properties valued in the customer's application.

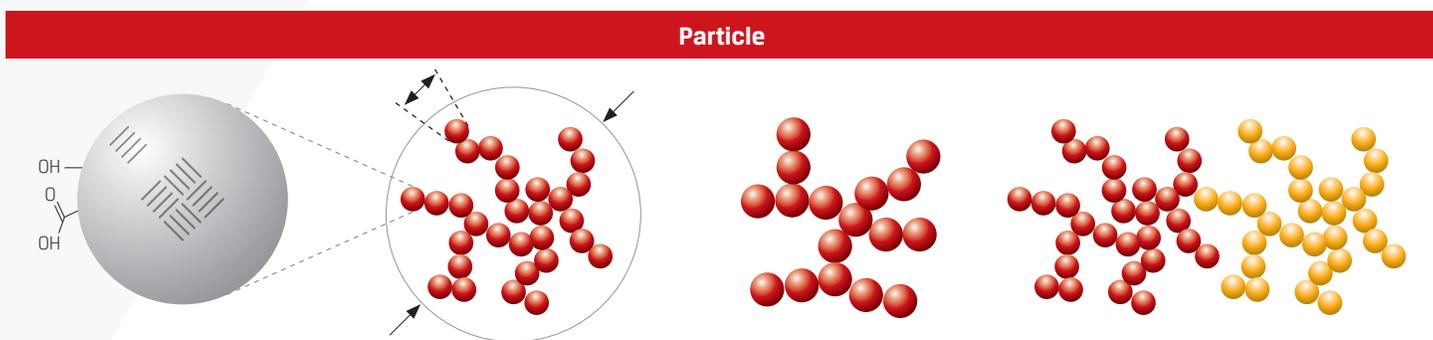


Figure 1: Our precisely engineered specialty carbon additives offer a broad range of particle sizes, morphologies and surface properties that deliver specific functionalities.

Property	Function	Attribute
<b>Conductivity</b>	Electrical conductivity, ionic conductivity, thermal conductivity, charge storage, contact resistance, insulating	<b>Particle size</b>
<b>Rheological</b>	Dispersion, paste viscosity and solid loading, binder interaction, electrolyte storage capacity, thickening efficiency	<b>Aggregate size</b>
<b>Mechanical</b>	Electrode density, flexibility, compressibility, adhesion, hardness, stiffness, separator stability and porosity	<b>Pore structure</b>
<b>Surface properties</b>	Moisture adsorption, adhesion, oxidation stability, inertness, electrolyte stability, electrolyte storage capacity	<b>Surface chemistry</b>
		<b>Surface graphitization</b>

## Lead batteries

Lead batteries are the most mature and recyclable battery technology and remain the most widely used batteries in a variety of energy storage applications. Approximately 96% of all consumer and commercial vehicles use lead batteries to provide basic start-lighting-ignition (SLI) functionality. Electric scooters, popular in China, are powered mostly by lead batteries. Fork lifts, telecom towers and variety of backup and power storage applications use lead batteries as the most convenient and affordable battery solution. New applications, such as micro-hybrid cars and storage for renewables are placing strong demand for improved cycleability and charge acceptance. These existing and emerging applications are pushing lead battery manufacturers to deliver advanced products with increasing levels of performance and durability, while at the same time reducing total system cost. Engineers and designers of advanced lead batteries can use carbon additives to improve durability and performance of batteries for micro hybrid electric vehicles, electric scooters (e-bikes), fork lifts, telecom back-up and grid level electricity storage.

Our PBX® carbon additives are best suited for the lead batteries industry and are ideal for use in automotive, e-bike, energy storage, stationary and industrial applications. Our PBX additives have unique properties that can enable:

- ◆ Higher dynamic charge acceptance (DCA)
- ◆ Increased cycle life at partial state-of-charge conditions
- ◆ Good dispersibility and ease of use in paste preparation
- ◆ Improved manufacturing and battery uniformity

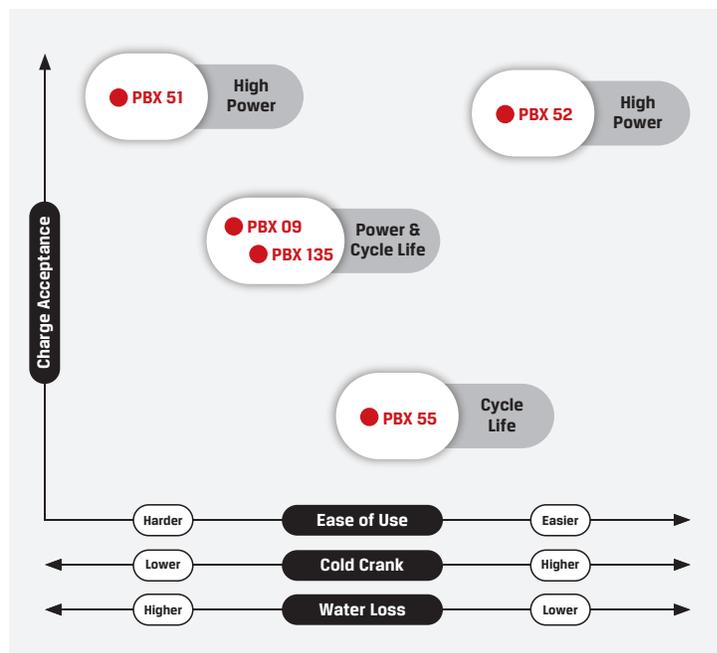
### Our additives for advanced lead batteries

#### Performance in lead batteries

- ◆ Carbon additives can increase negative electrodes' active surface area and rechargeability at low state of charge
- ◆ For valve regulated lead acid (VRLA) applications that require extreme charge acceptance, consider PBX 51 and PBX 52 carbon additives
- ◆ For balance between charge acceptance, cycle life and secondary properties consider PBX 09 carbon additive for VRLA batteries and PBX 135 and PBX 55 carbon additives for flooded batteries

#### Ease of use and formulation benefits

- ◆ We offer products and formulation expertise that can address some of the trade-offs among performance, ease of processing, overcharge water loss and other requirements
- ◆ PBX 52 carbon additive is delivered in pre-wetted form which facilitates incorporation into the paste and eliminates dust during processing, while still flowing like a dry powder.
- ◆ We also continue to supply the lead battery industry with highly conductive carbon blacks, including VULCAN® XC72 and VULCAN XC72R specialty carbon blacks.



- ◆ We also offer PBX 4, PBX 7 and PBX 7R carbon additives that can replace conventional carbon blacks and acetylene blacks used to provide basic functionality in lead batteries

## Micro-hybrid cars

### Emerging micro-hybrid car market for lead batteries

- ◆ Micro-hybrid cars featuring Start-Stop functionality can achieve:
  - ◆ 5%-15% fuel savings
  - ◆ Meet more stringent CO<sub>2</sub> emission requirements

In 2018, about 30 million micro-hybrid vehicles were powered by advanced lead batteries, and this number is expected to grow to 40 million vehicles in 2022. As shown in figure 2, by 2025 market share of start-stop vehicles powered by lead batteries will grow to more than 50%.

Both VRLA and enhanced flooded batteries (EFB) are successfully used in the micro-hybrid car application.

### Requirements for batteries used in micro-hybrid cars:

- ◆ High charge acceptance
- ◆ Increased cycle life at partial state-of-charge
- ◆ Good low temperature performance
- ◆ Cost efficient solution

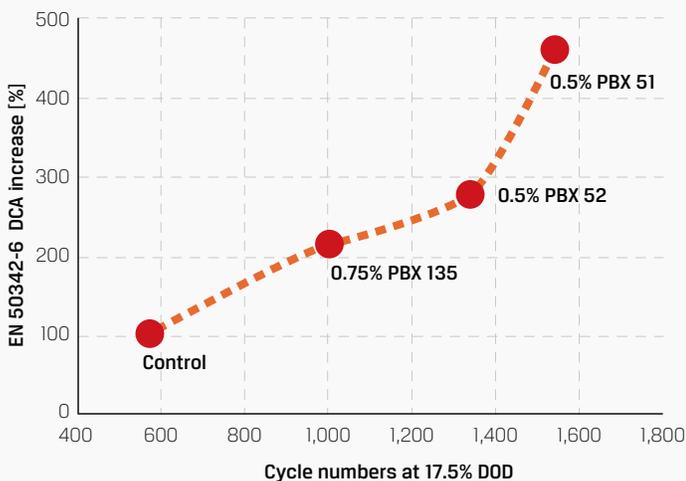
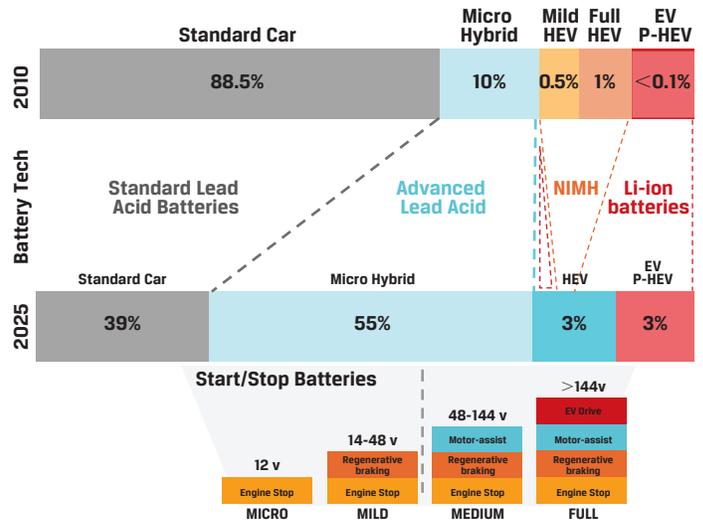


Figure 3: DCA and cycle life with our PBX performance additives vs. control electrode.



Adapted from *Avicenne Energy Market Report for Rechargeable Batteries 2018*

Figure 2: Growth in market adoption of Start-Stop cars

### Benefits of PBX® carbon additives:

- ◆ Easy to incorporate into negative paste formulation
- ◆ More than 3x improvements in charge acceptance and cycle life with low loading
- ◆ Require less water to be added to the paste
- ◆ Provide higher paste density
- ◆ Good integrity of negative electrodes

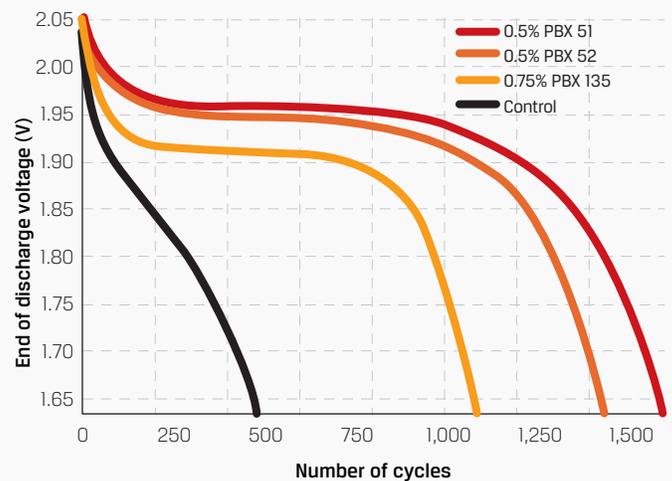
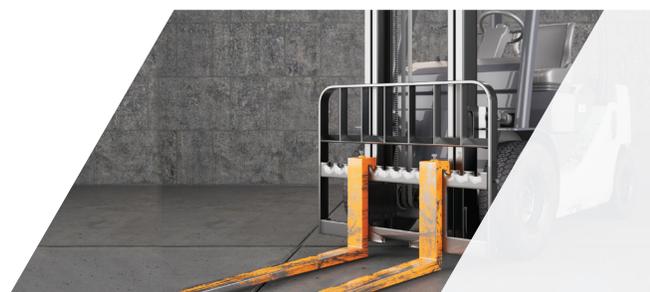


Figure 4: In continuous cycling tests at 17.5% depth of discharge, even at low loadings of 0.5-0.75%, PBX carbon additives significantly improve cycle life.

## Telecom, energy storage and fork lifts

### Stationary and industrial applications

Engineers and designers of advanced lead batteries for telecom, backup and grid level electricity storage and fork lifts can also use carbon additives to improve the durability, performance and manufacturing cost of their batteries. New requirements for telecom batteries used in unreliable grid areas are creating demand for improved stability and cycle life. The expanded use of renewable energy sources such as solar and wind are also increasing demand for improved lead acid battery systems with better cycle life and uniformity. Additionally, the growing market for battery-powered fork lifts can also benefit from improved lead battery technology.



### Requirements for stationary and fork lift batteries:

- ◆ Increased cycle life for cycling and backup operation
- ◆ Deep discharge
- ◆ Good battery string uniformity
- ◆ Cost efficient solution

### Our PBX® products for superior performance

Our PBX carbon additives enable lead battery manufacturers to extract the highest performance out of each active material, extending cycle life and charge acceptance of lead batteries. PBX additives cover a broad range of carbon properties and can be used in a variety of applications and operating modes. For further information to help you select the best product for your specific lead battery application, please contact your Cabot representative.

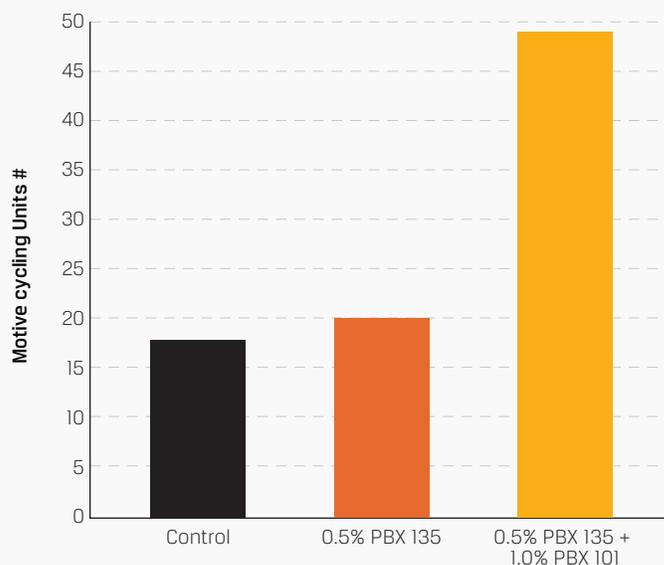
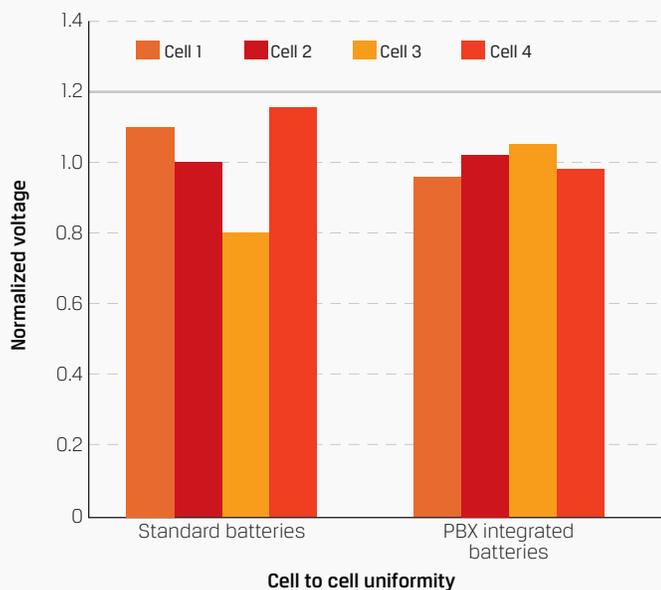


Figure 5: PBX products can improve uniformity in a string of battery cells

Figure 6: Deep discharge cycling of flooded batteries

## E-bikes and electric vehicles

### E-bike and electric vehicle (EV) applications of lead batteries

Lead batteries are widely used in e-bike applications in China and other regions. However, recent government regulations now limit the permitted weight of e-bikes and correspondingly the weight of their battery, which favors use of competitive lithium-ion battery solutions. As a result, there is an increased demand for lead batteries with reduced weight, and correspondingly higher lead utilization and improved cycle life for e-bikes throughout Asia.

#### Requirements for e-bike and EV batteries:

- ◆ Increased lead utilization and reduced weight
- ◆ Increased cycle life especially under deep discharge
- ◆ Good low temperature performance
- ◆ Cost efficient solution

### Our PBX® products for superior performance

Our PBX carbon additives enable manufacturing improvements by reducing variability between battery cells used to make e-bike or EV battery packs. PBX carbon additives can also improve cycle life by reducing negative plate sulfation and providing new formulation options for improvements to low temperature performance.

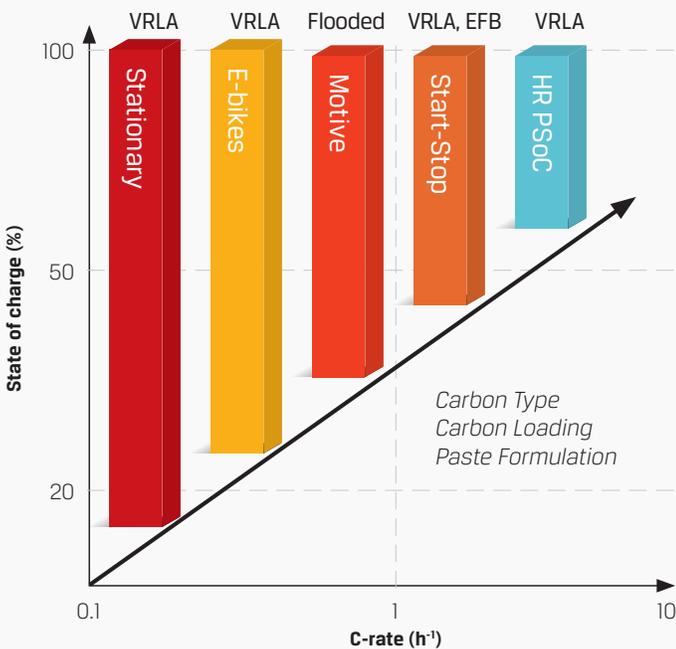


Figure 7: Different applications require different carbon additives

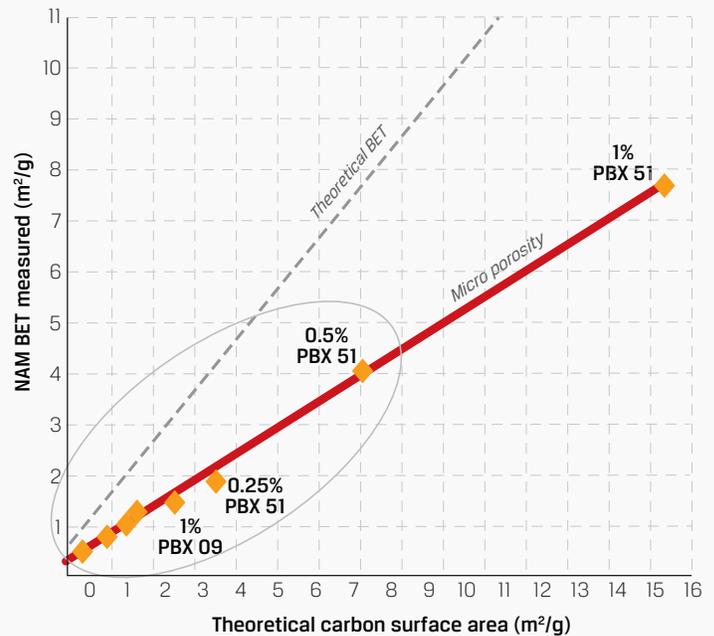


Figure 8: Effect of Cabot carbon additives on the negative electrode surface area

In addition to their structure and morphology, our PBX® products feature surface properties, ranging from highly hydrophilic to highly hydrophobic (as shown in figure 9). Surface properties of carbon additives can affect dispersibility and performance under various test conditions. While PBX additives are suitable for use with a variety of paste mixing processes used by battery manufacturers – dry addition, wet dispersion or pre-wet – the method for incorporation of some PBX additives into the negative paste mix can significantly impact the degree of improvement. We can further assist battery manufacturers with the suggested carbon mixing procedure for each PBX product to maximize performance benefits.



Figure 9: PBX carbon additives have surface properties ranging from hydrophilic to highly hydrophobic.

PBX PERFORMANCE ADDITIVES TYPICAL PROPERTIES					
	PBX 51	PBX 52	PBX 09	PBX 135	PBX 55
<b>BET [m<sup>2</sup>/g]</b>	1300 - 1550	950 - 1150	210 - 260	120 - 180	45 - 60
<b>OAN [ml/100g]</b>	140 - 200	130 - 160	100 - 130	150 - 180	120 - 150
<b>Fe [ppm]</b>	<50	<35	<20	<20	<20
<b>Applications</b>	Start-Stop, e-bike, lead EV	Start-Stop, lead EV	Telecom, ESS, UPS	Start-Stop EFB	SLI, EFB
<b>Typical loading</b>	0.25 - 0.5%	0.25 - 0.5% [dry carbon basis]	0.5-1%	0.5-1%	0.25-0.5%

The data in the table above are typical test values intended as guidance only and are not product specifications. Product specifications are available upon request from your Cabot representative.

In addition to PBX high performance additives, we also offer specialty carbon grades that can replace conventional carbon blacks and acetylene blacks for a wide range of performance needs including:

- ♦ Highly conductive carbon blacks, such as VULCAN® XC72 and VULCAN XC72R specialty carbon blacks for improved cycleability
- ♦ PBX 4, PBX 7 and PBX 7R carbon additives for improved basic functionality in lead acid batteries

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## Our commitment to energy

The world depends upon energy to drive industry, support commerce and care for communities. The world's energy consumption continues to increase, despite planned energy saving initiatives. Satisfying this demand while also striving for a sustainable environment will require not only reliable and safe energy production and distribution from today's technology, but novel solutions to enhance our power generation, storage, transmission and consumption into tomorrow's world.

We are committed to supporting that goal, and we maintain development programs with industry bodies, institutes and universities across the world. We will continue to use our expertise in small particle science to deliver solutions that meet the energy needs of today and the challenges of tomorrow.

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