HIGH PERFORMANCE MATERIALS
FOR ADVANCED LEAD ACID BATTERIES
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 135 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 acid 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 acid 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.

**Introduction**

<table>
<thead>
<tr>
<th>Property</th>
<th>Function</th>
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</thead>
<tbody>
<tr>
<td>Conductivity</td>
<td>Electrical conductivity, ionic conductivity, thermal conductivity, charge storage, contact resistance, insulating</td>
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<tr>
<td>Rheological</td>
<td>Dispersion, paste viscosity and solid loading, binder interaction, electrolyte storage capacity, thickening efficiency</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Electrode density, flexibility, compressibility, adhesion, hardness, stiffness, separator stability and porosity</td>
</tr>
<tr>
<td>Surface properties</td>
<td>Moisture adsorption, adhesion, oxidation stability, inertness, electrolyte stability, electrolyte storage capacity</td>
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**Attribute**

- Particle size
- Aggregate size
- Pore structure
- Surface chemistry
- Surface graphitization

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

Lead-acid batteries are the most mature and recyclable battery technology and remain the most widely used batteries in a variety of energy storage applications. Currently more than 98% of all consumer and commercial vehicles use lead acid batteries to provide basic start-lighting-ignition (SLI) functionality. Electric scooters, popular in China, are powered mostly by lead acid batteries. Fork lifts, telecom towers and variety of backup and power storage applications use lead acid 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 acid 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-acid 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 acid 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 acid batteries

Performance in lead acid 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 carbon additive
- For balance between charge acceptance, cycle life and secondary properties consider PBX 09 and PBX 300G carbon additives 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
- We also continue to supply the lead acid 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 current conventional carbon blacks and acetylene blacks used to provide basic functionality in lead acid batteries.
Micro-hybrid car

Emerging micro-hybrid car market for lead acid batteries

Micro-hybrid cars featuring Start-Stop functionality can achieve:
- 5%-15% fuel savings
- Meet more stringent CO$_2$ emission requirements

In 2016, 20 million micro-hybrid vehicles were powered by advanced lead acid batteries, and this number is expected to grow to 35 million vehicles in 2020. As shown in figure 2, by 2020 market share of start-stop vehicles will grow to > 65%.

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

Benefits of PBX$^\text{®}$ carbon additives:
- Easy to incorporate into negative paste formulation
- Nearly double dynamic charge acceptance (DCA) and improve cycle life multiple times with low loading (0.25%-1.0%). See figures 3 & 4
- Require less water to be added to the paste
- Provide higher paste density
- Good integrity of negative electrodes

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

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

Figure 4: PBX 135 carbon additive is designed for use in extended flooded batteries where prevention of acid stratification is the primary objective. In continuous cycling tests at 17.5% depth of discharge, even at low loadings of 0.5-1% PBX 135 carbon additive significantly improves cycle life.
Telecom, energy storage and fork lifts

Stationary and industrial applications

Engineers and designers of advanced lead acid 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 acid 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 acid battery manufacturers to extract the highest performance out of each active material, extending cycle life and charge acceptance of lead acid 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 acid 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 acid batteries

Lead acid batteries are widely used in e-bike applications in China and other regions. The market demand for e-bikes in China is more than $30M per year and is continuing to grow. As a result, there is increased demand for improved cycle life and overall performance of lead acid batteries to enable the expansion of e-bike applications and extend the use of lead acid batteries for pure EV vehicles throughout Asia.

Requirements for e-bike and EV batteries:

- 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. For further information to help you select the best product for your specific lead acid battery application, please contact your Cabot representative.
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 hydrophillic to highly hydrophobic.

<table>
<thead>
<tr>
<th>PBX PERFORMANCE ADDITIVES TYPICAL PROPERTIES</th>
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<tr>
<td></td>
</tr>
<tr>
<td>BET [m²/g]</td>
</tr>
<tr>
<td>OAN [ml/100g]</td>
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<tr>
<td>Fe [ppm]</td>
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<tr>
<td>Applications</td>
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<tr>
<td>Typical loading</td>
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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
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.