LaB_6 & CeBix™ Cathodes

Overview:

LaB_6 and CeBix™ (CeB_6) cathodes are ideal for many small spot size applications such as SEM, TEM, surface analysis and metrology, and for high current applications such as microwave tubes, lithography, electron-beam welders, x-ray sources and free electron lasers.

Applied Physics Technologies has decades of experience in research, development, and manufacturing of LaB_6 and CeBix™ cathodes. We can provide the cathodes you need for replacement, OEM, and custom applications.

Creating Your Next Generation Products

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Our Specialties:

CeBix™ Cathodes
APTech Exclusive Product;
Direct Replacement for LaB_6

R&D Partnering
End-Users, OEMs, Government

LaB_6 Cathodes
Full Line Offered

Field Emitters
Electrochemically Etched, Several Materials

Rebuilding Services
Restoring LaB_6, CeB_6, Carbide, and Tungsten Emitters

Refractory Metals
Tungsten, Molybdenum, & Many More

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Lanthanum hexaborides (LaB_6) & Cerium Hexaborides (CeB_6) CeBix™ Cathodes

The unique properties of hexaborides crystals provide stable electron – emitting media with work functions near 2.5eV. The low work function yields higher currents at lower cathode temperatures than tungsten, which mean greater brightness, or current at the beam focus, and longer cathode life. Typically, these cathodes exhibit 10 times the brightness and more than 10 times the service life of tungsten cathodes. In electron microscope applications, these characteristics translate to more beam current in a smaller spot at the sample, improved resolution, and less frequent cathode replacement.

For applications with large beam spot sizes, where large total current and current density are required, large, flat crystal surfaces of LaB_6 or CeBix™ can be the cathodes of choice. This regime is unsuitable for point sources such as field emitters, which are unable to provide sufficient total current, and has been thought of as the realm of the dispenser cathode. However, LaB_6 and CeBix™ may be more suitable, being particularly robust and resistant to chemical poisoning.

They have modest vacuum requirements and long shelf life, and need only be brought up to operating temperature to provide emission, eliminating the activation procedure required of dispenser cathodes. They can provide long-term, stable operation at current densities up to 50 A/cm², and may be fabricated in a variety of shapes and with many different heating and mounting configurations. LaB_6 and CeBix™ are the materials of choice for high current cathodes in a variety of advanced and custom applications.

Performance & Lifetime

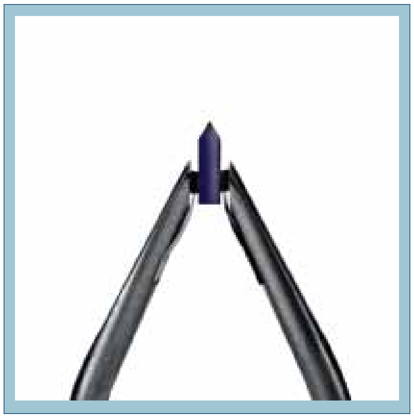
The performance and lifetime of the hexaboride cathode are determined by several factors: vacuum level cathode temperature, impurity level, crystal orientation, tip shape, and mount design.

Vacuum requirements are more stringent for hexaborides emitters than for tungsten in order to minimize carbon contamination. In laboratory tests, CeBix™ has proven to be more resistant to the negative impact of carbon contamination than LaB_6, which gives it an edge in potential cathode lifetime.

Excessive operating temperatures accelerate evaporation, thus decreasing the life of the cathode. Care must be taken to properly optimize cathode temperatures to obtain the required emission without overheating the crystal. CeBix™ has another advantage over LaB_6 relating to lifetime: its evaporation rate at normal operating temperatures near 1800 K is lower than that of LaB_6. So long as care is taken to operate the cathode below 1850 K, CeBix™ should maintain an optimum tip shape longer, and therefore last longer.

	CeB_6 <100>	LaB_6 <100>	Tungsten Filament
Brightness (A/cm^2-sr)	10^7	10^7	10^6
Short-term Beam Stability (% RMS)	<1	<1	<1
Typical Service Life (hr)	1500+	1000+	100
Operating Vacuum (torr)	10^7	10^7	10^6
Effective Work Function (eV)	~2.65	~2.70	4.5
Evaporation Rate (g/cm^2-sec) @ 1800 K	1.7×10^{-9}	2.3×10^{-9}	N/A

The Crystal



crystal impurities:

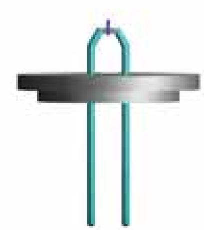
Impurities in the crystal will reduce both brightness and lifetime of the emitter because impurities increase both work function and volatility. We grow and fabricate our own high quality, single-crystal materials using a well-defined process called “Inert Gas Arc Float Zone Refining.” An electric arc melts a pressed-power stick of LaB_6 or CeBix™ in a controlled atmosphere of inert gas, allowing the liquid-phase zone to freeze onto a selected-orientation seed crystal as the arc is moved along the stick. The finished crystal assumes the desired orientation of the seed with less than 30 parts per million by weight metal impurities. Correct melt zone temperature and process speed minimize excessive boron evaporation to achieve the optimum ratio of metal to boron atoms in the grown crystal.

crystal Orientation:

Crystal orientation can be selected to match the cathode design or application. For electron microscopy, the <100> orientation is most desirable due to its brightness and crystal plane symmetry about the optical axis. As the cathode ages, the plane symmetry ensures an even evaporation rate relative to the axis, maintaining a centered, flat emitting surface. Also, the emission patterns from the symmetric crystal planes will remain consistent as they become more exposed by evaporation, contributing to a brighter beam spot.

Cathode Tip Design

The design of the cathode tip is critical for maximum lifetime and optimum performance. Tip design must also match the specific application’s requirements for beam current, spot size, and brightness. For electron microscopy, a conical tip with a flat emitting surface at the apex has proven to be the optimum design.



With the flat-tipped cone design, changes in both cone angle and flat diameter affect emission characteristics. In general, the small cone angle (60°) result in higher brightness, but at a larger angle (90°) provides longer life and easier alignment. Small flat diameters also result in higher brightness plus a smaller source size, but larger flats provide longer lifetimes and more beam current.

These trends allow us to tailor our cathodes to the requirements of practically all thermionic cathode applications. For examples, SEM and most transmission electron microscope (TEM) applications are best served by 90° cone angle and 16 µm flat tip. This combination provides high brightness, a moderate source size, and very good lifetime. High resolution TEMs require a 60° cone and a 5 µm flat tip for very high brightness and a small source size.

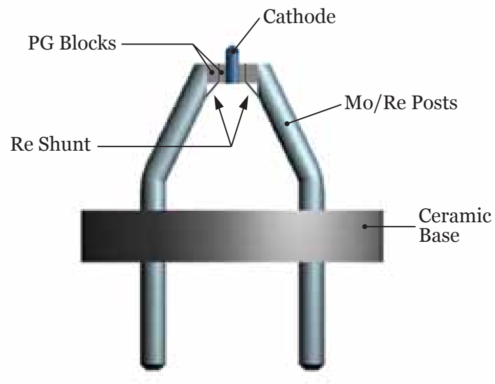
In applications requiring high total current in a large beam spot, a <310> oriented crystal in a “top hat” configuration may be preferred, providing a slightly lower work function and large emitting surface. We excel at developing specialized cathodes for custom application and research purposes. Contact us for your custom cathode needs.

The cathode's mount design has a significant impact on performance. The design must be simple, durable and precise. It must resist any movements of the crystal, despite the high operating temperatures, yet be easy to install and align. We feel we employ the best mount design in the industry, the Mini Vogel Mount.

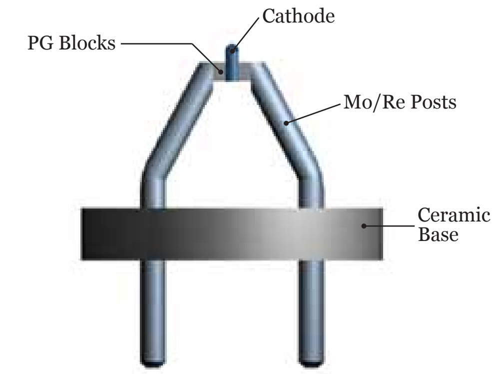
In 1988, FEI of Hillsboro, Oregon introduced the Mini Vogel Mount (MVM) to provide the benefits of the original Vogel mount in a smaller, simpler, and more elegant design. Twin posts are rigidly fixed in a thick ceramic base, and bent towards the center in an inverted 'V'. The posts are made of a molybdenum-rhenium alloy that maintains a high modulus of elasticity even at high temperatures. The posts are spread slightly during assembly to allow placement of small pyrolytic graphite blocks between the crystal and posts. The blocks act as resistive heaters, and help thermally isolate the hot crystal from the highly conductive posts. When the compressive force of the posts is released, the crystal is held with strength and precision. The clamping force of the posts will remain near 5,000 psi for the life of the cathode.

The structure of the MVM is amazingly robust, sustaining reasonable impact without deviating from structural specifications. Because the graphite pads shield evaporation of the crystal in the direction of the clamping force, the emitter crystal can be fully utilized without degradation of the mount. Structural failure of the MVM is not a concern when the cathode is operated within the correct temperature and pressure range. Typically, the beam stability of the Mini Vogel Mount cathode exceeds the specification of the system in which it runs.

The use of rhenium shunt in conjunction with the MVM was inherited from FEI. Since may SEM's and their electronics were designed around a tungsten hairpin filament, the resistance change with temperature of the PG used in the MVM is sometimes problematic. The resistance of the 0.001" thick shunt enables the cathode to better match the temperature and resistance curve of a tungsten filament. In the shunted version, the current bypasses the outer PG block by taking the path of least resistance through the shunt. All of the heating is generated by the inner block. The design takes advantage of the anisotropic properties of PG by orienting the poor thermal conduction plane in the direction between the shunt and the Mo/Re post.



Shunted
(SMVM)



Non-Shunted
(MVM)

Applied Physics Technologies is involved with the production and development of electron emitting materials and electron sources. Custom design and fabrication capabilities augment our standard catalog items to meet our customers' needs. Partnering is available for your more challenging product requirements, particularly for key component realization. Applied Physics Technologies maintains an active role in fundamental electron emission research and publication, striving to bring the newest ideas from the laboratory to the marketplace. Please visit our website: **www.a-p-tech.com** or call us at **503.434.5550** for more information.

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