Issues in Cathode Performance
Part 3--Cathode Emitter Material

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Part 1 of this article series (October 1994 issue) covered the performance features of various tip shapes and explained why the <100> crystal orientation is the industry standard. Part 2 (January/February 1995 issue) covered cathode mounting design and explained how the Mini Vogel Mount cathode design provides high-stability and long-lifetime performance.

LaB_6 and CeB_6 cathodes are used as high-brightness, high-stability, long-lifetime cathodes in a variety of electron beam applications. A high-brightness source provides small spot sizes for high resolution and improved analytical results from high beam currents.

High-brightness sources require emitting materials with low work function. Brightness (β) is defined by the beam current density per unit solid angle and is proportional to the work function as:

$$\beta \propto e^{(k\varphi)}$$

where φ is the work function and k is a constant.

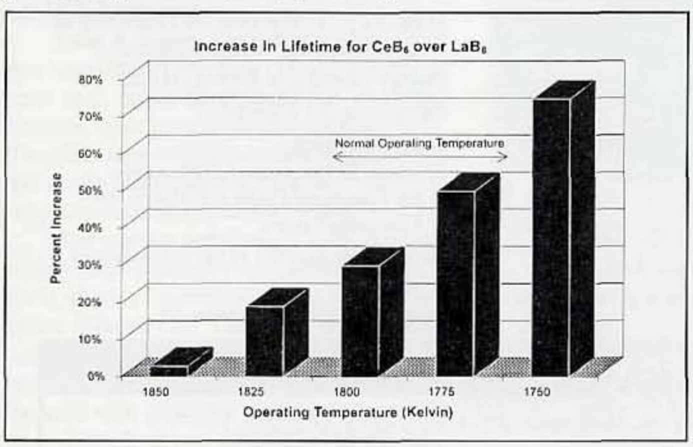
Long-lifetime sources require materials with low evaporation rates--the higher the evaporation rate of the material, the faster the emission surface erodes. For LaB_6, both the work function and evaporation rate are affected by the ratio of boron to lanthanum. Unfortunately, they do not reach their minimums at the same B/La ratio (see top right figure).

We have determined the best compromise between high brightness and long lifetime by calculating the figure of merit (FOM) for LaB_6, shown in the lower right figure. The FOM is calculated by dividing current density by the evaporation rate, where current density is inversely proportional to work function. The FOM increases as work function decreases (higher brightness) and as the evaporation rate decreases (longer lifetime). As you can see in the graph, the LaB_6 FOM has a distinguishable peak, and we process LaB_6 so that its final B/La ratio is at that peak.

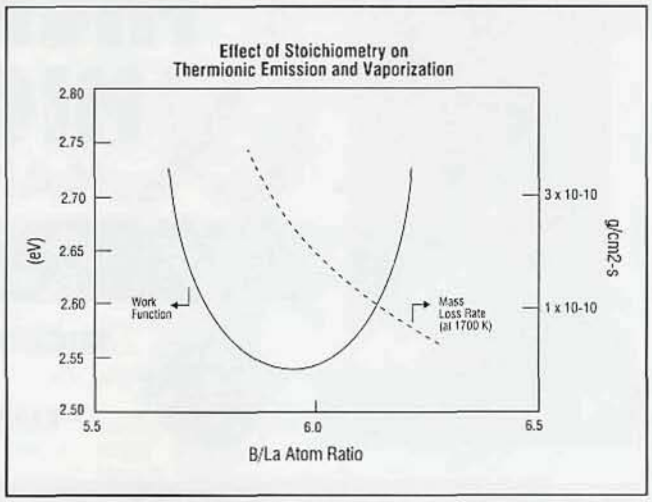
An Even Better Selection--CeB_6

A cathode is also available with a CeB_6 (cerium hexaboride) crystal instead of a LaB_6 crystal. CeB_6 has a lower evaporation rate and, consequently, a longer lifetime than LaB_6 --without sacrificing brightness. The graph below shows that CeB_6 can provide up to 50% longer lifetimes under normal operating conditions.

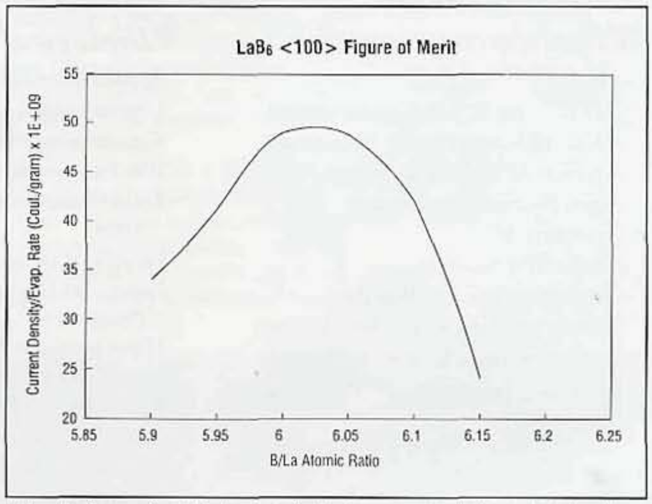
Impurities in the LaB_6 or CeB_6 crystal will reduce both brightness and lifetime of the emitter because impurities increase both work function and volatility. We grow and fabricate high-quality single-crystal materials using a well-defined process called "Inert Gas Arc Float Zone Refining." An electric arc melts a hot pressed-powder sample of LaB_6 or CeB_6 in inert gas. This allows the sample to assume the crystalline structure of a seed crystal. This further purifies the already 99.9% pure starting material and precisely controls the single crystal's composition. The result is single crystals with less than 30 ppmw (parts per million by weight) metal impurities. ■



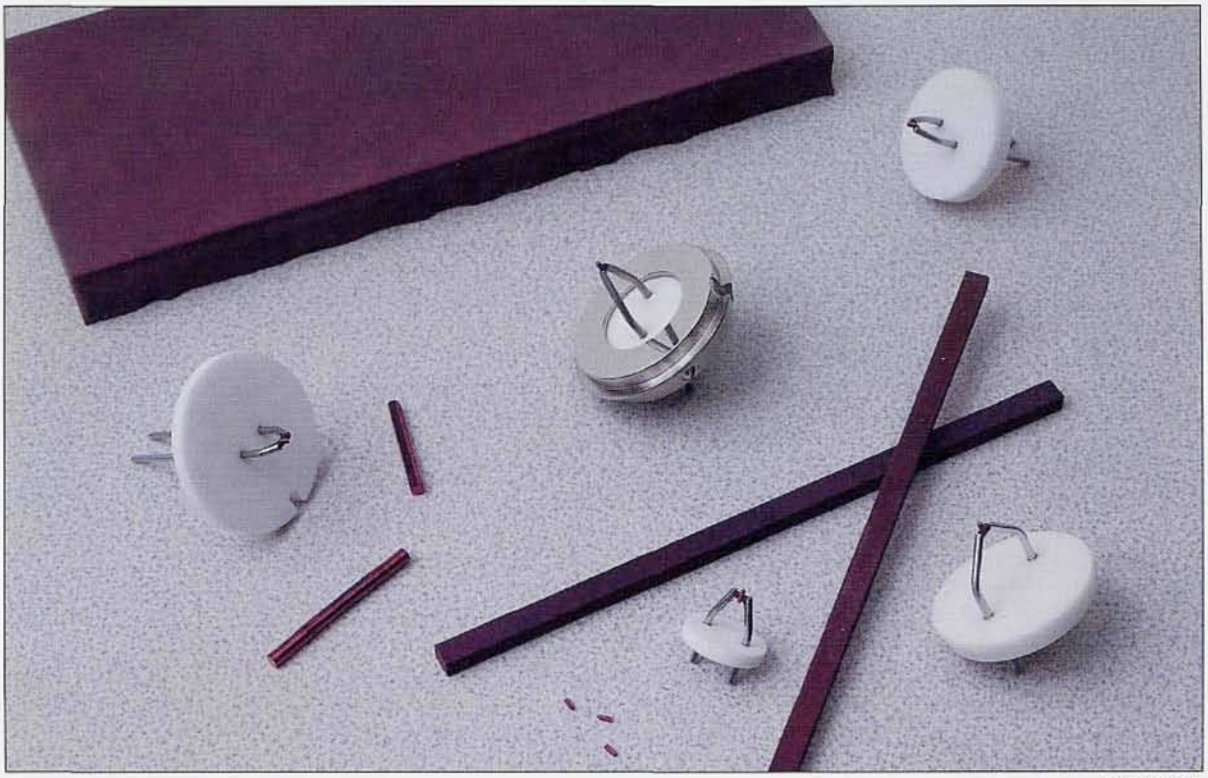
CeB_6 catholdes can provide up to 50% longer lifetimes than LaB_6 cathodes



The boron to lanthanum ratio greatly affects the work function and evaporation rate of LaB_6



Calculating the figure of merit determines the best compromise between high brightness and long lifetime



LaB6 Cathodes

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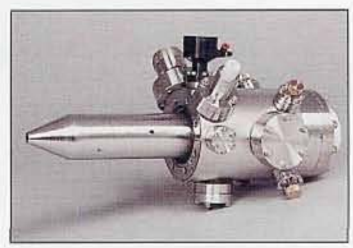

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