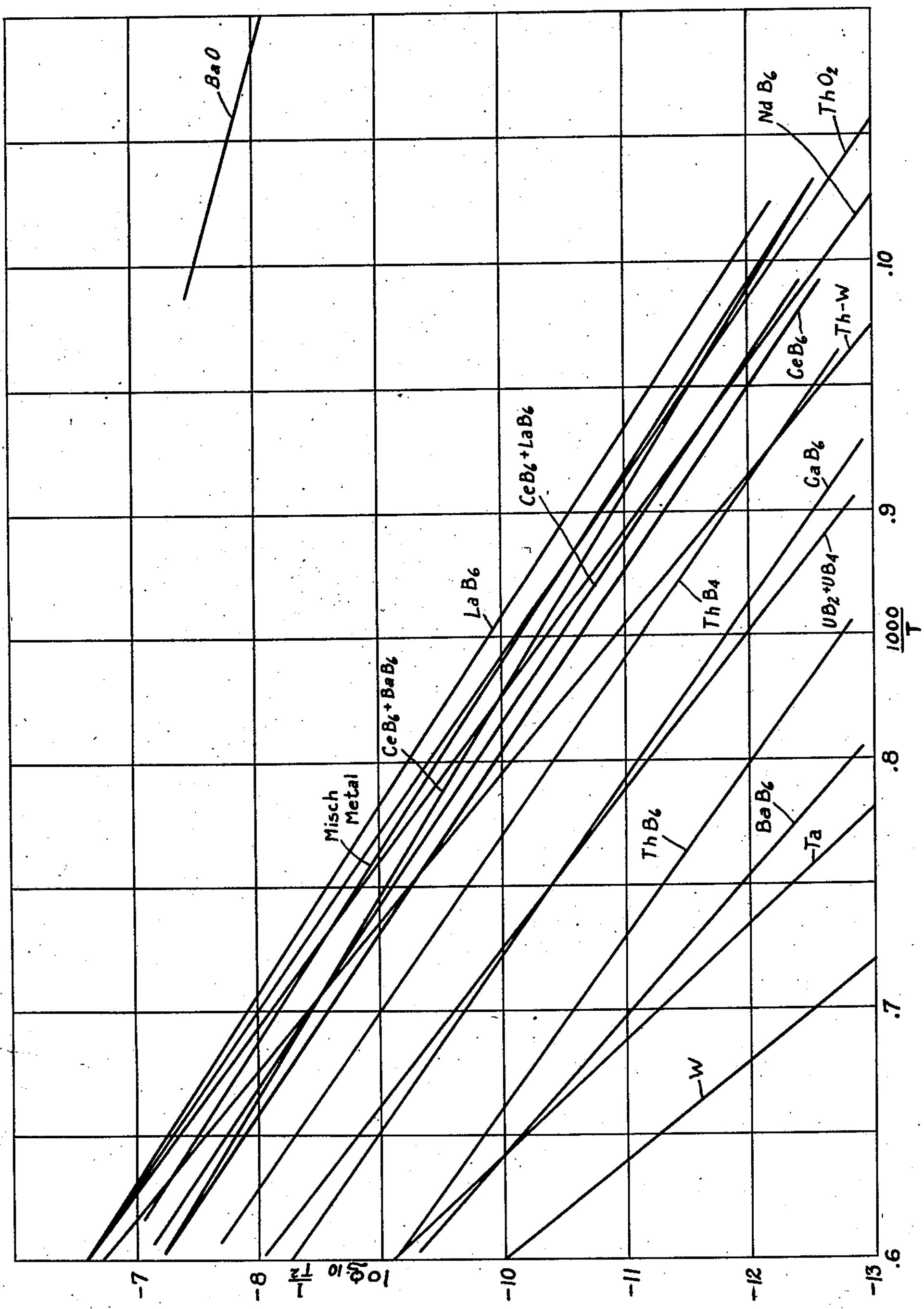
May 19, 1953 — J. M. LAFFERTY — 2,639,399

ELECTRON EMITTER

Filed March 31, 1950 — 2 Sheets-Sheet 1

Fig. 1.



Inventor:
James M. Lafferty,
by Merton D Morse
His Attorney.

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Fig. 2.

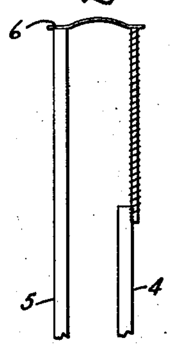


Fig. 3.

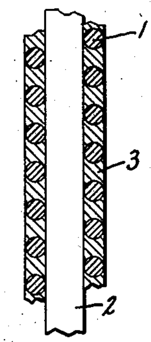


Fig. 4.

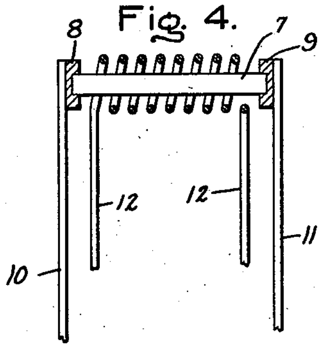


Fig. 5.

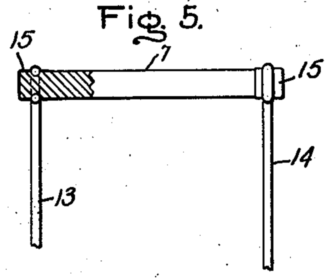
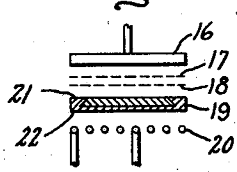


Fig. 6.



Inventor:
James M. Lafferty,
by Merton D. Morse
His Attorney.

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ELECTRON EMITTER

James M. Lafferty, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

Application March 31, 1950, Serial No. 153,212

8 Claims. (Cl. 313—345)

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My invention relates to improved electron emitters and particularly to metallic boride emitters.

It is generally recognized that known electron emitting materials, such as those commonly used in electric discharge devices for example, are subject to various disadvantages which limit their effectiveness as emitters or require special care in handling or storing or require special processing for rendering them effective emitters.

As a result of an intensive search for improved electron emitting materials, I have discovered that borides of certain metals provide emitters having very desirable properties which are in general superior to those of known emitters.

I have found that the rare earth metals form borides of the general formula MeB_6 where Me is any metal of the rare earth group and that these borides form the essential ingredient of emitters having superior properties. Certain of the alkaline earth metals, such as barium, calcium and strontium also form borides of this general formula and possess the desirable properties of the rare earth metal borides, although to a lesser degree. Thorium borides of the formula THB_4 and THB_6 and the uranium borides UB_4+UB_2 (a mixture of borides) also possess desirable characteristics as the emitters.

The borides of lanthanum, cerium, and neodymium have been used separately and work very satisfactorily. Since many of the rare earth metals, however, are not available individually and it is a matter of considerable commercial importance that mischmetal (which is a natural mixture of the rare earth metals) provides a very satisfactory metal boride emitter. It has also been found that a mixture of borides including one selected from the rare earth borides and one selected from the group consisting of the borides of barium, strontium, and calcium, particularly barium, is particularly advantageous.

The borides mentioned above are chemically and electrically stable, have high melting points, are generally metallic in character, and, therefore, have relatively good electrical conductivity. As a result of these qualities, electron emitters consisting essentially of these borides may be used in demountable systems which are frequently let down to the atmosphere without deterioration of the cathode material and no special care is required in storing. They are generally chemically stable so that they are not adversely affected by

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moisture, oxygen or even hydrochloric acid. They also have the desirable property that no activation is required to obtain emission and emission is uniform over the entire surface and remains substantially constant with time. Since the boride materials and their evaporation products are relatively good conductors, any contamination of other electrodes by deposition of the film of the evaporated material does not charge-up and as a result cause sparking between the parts of the tube in which they are employed, thus rendering cathodes of these materials suitable for high voltage applications. These materials also are refractory and have a low vapor pressure at relatively high operating temperatures. This quality, together with the relatively good electrical conductivity which permits thick coatings to be applied, provides emitters having very long life. As will be discussed in further detail, the materials also emit currents of relatively high density and may be operated at high temperatures. Cathodes employing these materials are also capable of either direct or indirect heating and may be easily fabricated since they may be applied as a spray or by dipping or painting. They may also be pressed and sintered to provide a solid emitter of the boride material.

In the accompanying drawing, Fig. 1 illustrates the characteristics of a number of emitters embodying the present invention; Fig. 2 illustrates a cathode embodying the invention; Fig. 3 is an enlarged partial elevational view in section of the cathode of Fig. 2; and Figs. 4, 5 and 6 illustrate modified cathode constructions also embodying the present invention.

A comparison of a number of borides of the present invention with some well-known emitters is shown in Fig. 1 of the drawing in which the logarithm to the base 10 of the ratio of current to absolute temperature squared is plotted as ordinates and the ratio of 1000 to absolute temperature is plotted as abscissae. These quantities are derived from data taken on emission current as a function of temperature and are chosen for the purpose of the plot since the resulting curves are significant with respect to Dushman's equation of emission. Dushman's equation is as follows:

$$J=AT^2Exp\frac{-Ewe10^7}{kT}$$

where

J=thermionic current density in amperes per cm.^{2}
A=a semi-empirical constant; its units are are amps./cm.^{2} degree Kelvin
T=temperature of cathode in degrees Kelvin
k=Boltzmann's universal gas constant: 1.37×10^{-16} erg per degree Kelvin
e=the electronic charge in coulombs
Ew=an empirical constant of the emitting surface, called its work functions measured in electron volts.

In Fig. 1, the slope of the various curves corresponds to the work function of the material and the intercept on the Y-axis corresponds to the logarithm of the constant A in Dushman's equation. It will be noted that emission current increases with increasing temperatures and that the materials may be employed for relatively high temperatures. The value of .7 for

$$\frac{1000}{T}$$

corresponds to an absolute temperature of 1428.5 degrees Kelvin.

The borides are relatively easy to produce and may to advantage be formed by reacting the metal with amorphous boron powder by heating in vacuum or in an atmosphere of hydrogen or inert gas such as helium or argon at a temperature of 1375° C. to 1850° C. depending upon the particular metal involved. The amorphous boron powder and the metal powder or metal filings are mixed together and pressed prior to the heating. The result of this operation is a sintered mass which may be pulverized in a ball mill and then made into a spray or paste by mixing with a suitable binder or carrier such amyl acetate or a cellulose binder. As an alternative, the powder may be pressed into a desired shape and sintered at a temperature of approximately 1375° C., or higher but below the melting points of the borides involved, to provide a solid boride body of suitable shape for use as an emitter.

In Figs. 2 and 3 of the drawing, I have shown a cathode construction employing a boride coating. An overwound tungsten wire 1 is formed into a helix over a core wire 2 and the outer surface of the assembly is coated with a boride 3 which may be applied as a paste of powdered boride and a suitable volatile carrier such as water or amyl acetate. After the paste has been applied, the assembly is heated in vacuum to a temperature in the neighborhood of 1600° C. to sinter and out-gas.

As shown in Fig. 2, the cathode may be supported from a pair of lead-in conductors 4 and 5, one end being connected directly to conductor 4 and the other end connected to conductor 5 by a resilient conductor 6. The cathode is heated by the passage of current through the supporting wire 1.

In Figs. 4 and 5, I have shown examples of a cathode structure employing a solid boride body 7 as a cathode. In Fig. 4, the cylindrical rod of boride 7 is formed as previously described and supported within terminal caps 8 and 9 which are pressed onto the ends of the boride rod. The terminals are connected with suitable support and lead-in wires 10 and 11 which may be sealed through the envelope of an electric discharge device in a manner well understood in the art. As shown in Fig. 4, the rod 7 is indirectly heated by a heater coil 12 surrounding the rod and supported by lead-in conductor 12. In Fig. 5, the boride rod 7 is arranged to be directly heated by passage of current through the rod. The rod is supported by lead-in conductors 13 and 14 which surround the end of the rod 7 and over which a suitable conductive coating 15 is applied to improve the contact between the lead-in conductors and the rod.

In Fig. 6, I have shown in modified form a cathode applied to a planar electrode type of device in which the electrodes are shown as an anode 16, a screen grid 17, a control grid 18, a cathode 19, and a heater element 20. As illustrated, the cathode is in the form of a disk having a rim 21 defining an open end recess on the side of the cathode facing the anode. This recess is filled with a body of boride material 22 which may be prepared by starting with the boride powder and a suitable carrier and pressing and sintering as previously described. In the operation of the device described in Fig. 6, the cathode may be heated by radiation from the heater element 20 and in addition by electron bombardment by keeping the heater element negative with respect to the potential of the cathode.

From the foregoing description, it is apparent that the boride emitters of the present invention may be used in any one of a number of ways to provide the essential component of commercial cathodes. These cathodes possess the many desirable qualities resulting from the properties of the boride as described in the earlier part of the specification.

While I have described and illustrated a particular embodiment of my invention, it will be apparent to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects, and I intend in the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A thermionic cathode including an emitter consisting essentially of at least one metal boride selected from the group consisting of the borides of calcium, barium, strontium, thorium, uranium and the rare earth metals and means supporting said emitter and providing a conductive connection therewith.

2. A thermionic cathode including an emitter comprising as the essential ingredient at least one metal boride selected from the group consisting of the borides of calcium, barium, strontium, thorium, uranium and the rare earth metals and means supporting said emitter and providing a conductive connection therewith.

3. A thermionic cathode including an emitter consisting essentially of at least one rare earth metal hexaboride and means supporting said emitter and providing a conductive connection therewith.

4. A thermionic cathode including an emitter consisting essentially of a mixture of barium hexaboride and at least one hexaboride selected from the hexaborides of the rare earth metals and means supporting said emitter and providing a conductive connection therewith.

5. A thermionic cathode including an electron emitter consisting essentially of mischmetal hexaboride means supporting said emitter and providing a conductive connection therewith.

6. A thermionic cathode including an electron

emitter consisting essentially of lanthanum hexaboride means supporting said emitter and providing a conductive connection therewith.

7. A thermionic cathode including an electron emitter consisting essentially of cerium hexaboride means supporting said emitter and providing a conductive connection therewith.

8. A cathode comprising a conductive support providing a heater and a coating comprising as the essential ingredient thereof at least one metal boride, the borides being selected from the group consisting of the borides of barium, strontium, calcium, thorium, uranium and the rare earth metals.

JAMES M. LAFFERTY.

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