April 4, 1967 J. M. LAFFERTY ETAL 3,312,856

RHENIUM SUPPORTED METALLIC BORIDE CATHODE EMITTERS

Filed March 26, 1963

Fig. 1.

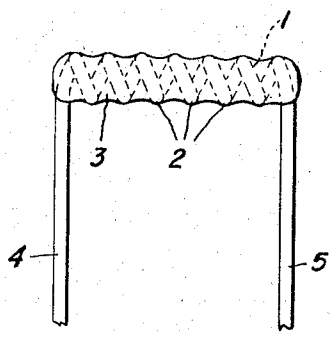


Fig. 2.

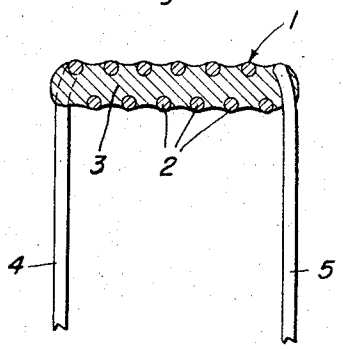


Fig. 3.

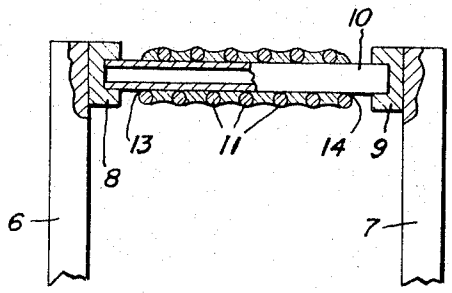


Fig. 4.

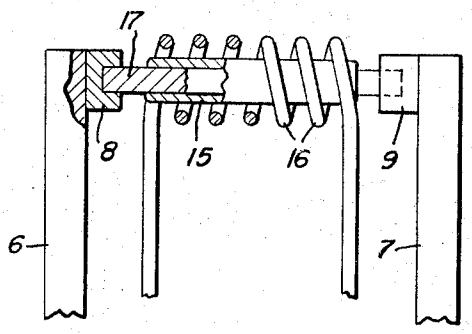
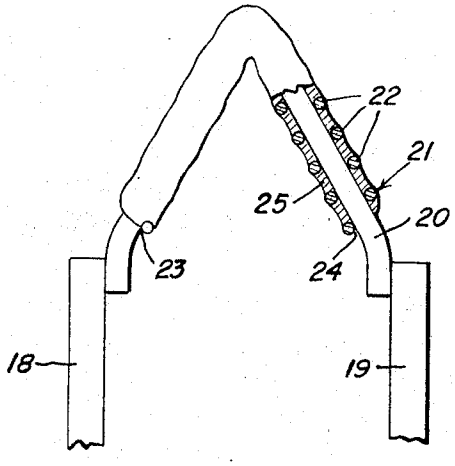


Fig. 5.



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RHENIUM SUPPORTED METALLIC BORIDE CATHODE EMITTERS

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7 Claims. (Cl. 313—346)

This invention relates generally to improved cathodes for electron discharge devices and more particularly pertains to such cathodes having an improved support for metallic boride emitters.

The borides of certain metals provide emiters having desirable properties which are in general superior to those of other known emitters. For example, emitters constituted of the borides of the alkaline earth metals, rare earth metals (of the group having atomic numbers 57 through 71), thorium and uranium are very desirable. This is clearly pointed out in U.S. Patent No. 2,639,399 to J. M. Lafferty.

As disclosed in the aforementioned patent, the properties of one of the rare earth metal borides, namely lanthanum hexaboride, are particularly desirable for electron emitters. For this reason, lanthanum hexaboride has achieved an especially high status in the realm of thermionic emissive materials. Misch metal hexaboride is a highly desirable material when economy is important because misch metal, an alloy of the rare earth metals, is readily available and relatively inexpensive.

It is an object of this invention to provide a cathode having an improved support for metallic boride emitters.

It is another object of this invention to provide a cathode having an improved support for lanthaum hexaboride or misch metal hexaboride emitters.

Briefly, the cathode of the present invention includes a support having a surface region consisting of rhenium which is in contact with and carries the thermionic emissive material. Preferably, the support takes the form of a loosely wound coil of wire consisting essentially of rhenium. The coil is filled with a metallic boride emitter material, such as lanthanum hexaboride, which is sintered. It has been discovered in a cathode of this description that the boron atoms do not diffuse into the rhenium base material at elevated temperatures. No reaction between the rhenium and lanthanum boride was observed.

The invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawings:

FIGURE 1 illustrates a cathode embodying the present invention;

FIGURE 2 is a cross-sectional view of the cathode of FIGURE 1;

FIGURE 3 is a cross-sectional view of an alternative cathode assembly embodying the present invention;

FIGURE 4 is a cross-sectional view of another alternative cathode assembly embodying the present invention; and

FIGURE 5 is a cross-sectional view of yet another alternative cathode assembly embodying the present invention.

It has been found that when certain metal borides are in contact with commonly used refractory metals such as tungsten, molybdenum, platinum, niobium or tantalum at high temperatures, boron diffuses into these metal lattices forming interstitial boron alloys which are very brittle. The metal of the boron compound is thereby released into the device and the supply of emissive material is reduced.

While the present invention pertains to supports for cathodes utilizing metal borides as emitters in general, the following description, for purposes of clarity and brevity, will be confined to cathodes utilizing lanthanum hexaboride as the emitter material since, as mentioned above, lanthanum hexaboride possesses particularly desirable properties which render this material one of the most commonly selected borides for thermionic electron emitters. These properties are clearly set forth in the above-mentioned Patent No. 2,639,399. It is to be understood that the present invention is not limited to cathodes utilizing lanthanum hexaboride and extends to other borides, for example, the economically desirable misch metal hexaboride.

As a result of an intensive search for an improved support for a cathode utilizing lanthanum hexaboride emissive material, we have discovered that rhenium possesses the sought-after physical and mechanical properties and can be utilized as the material for an effective support which is impervious to boron atoms. Thus, the deleterious effects of boron diffusion at high temperatures are avoided.

Rhenium is an element occurring in small amounts throughout the surface of the earth. In bulk form it resembles tungsten or rhodium and it is refractory metal having a melting point of 3100° C. Rhenium has a hexagonal crystal structure and its volatilization in vacuo is negligible at the operating temperature of the boride emitters. It can be worked mechanically and is available in the form of a bendable wire.

By way of more clearly pointing out the particular features of the cathode of the present invention, it should be noted that rhenium possesses thermionic emissive properties similar to those of tungsten. It is known that rhenium can be used as a thermionic emissive material, but, like tungsten, rhenium provides little electron emission at the usual temperature of operation of the more efficient thermionic electron emissive materials. Lanthanum hexaboride, for example, provides a copious supply of electrons at temperatures in the order of 1400° C. At this temperature, the electron emission from rhenium is negligible by comparison. The rhenium support utilized in the cathode of this invention is used as a base material to support the lanthanum hexaboride and takes no part in the electron emission properties of the cathode.

In FIGURES 1 and 2 there is shown a cathode constructed in accordance with the present invention. The support comprises a coil **1** having a plurality of turns **2** of wire consisting essentially of rhenium. The thermionic emitter is a coating **3** of lanthanum hexaboride which fills coil **1** and is supported thereby.

A cathode such as shown in FIGURES 1 and 2 was constructed by winding a 0.020" diameter rhenium wire about a 0.020" diameter mandrel, which was thereafter removed. As shown, coil **1** is loosely wound, that is say, there is a spacing or gap between turns **2**. In one specific example, the distance between turns was 0.020". Coating **3** may be applied by spraying, dipping or painting, but, a particularly effective method is to fill the voids inside and between turns **2** of coil **1** and thereafter sinter the lanthanum hexaboride to provide a complete encapsulation of coil **1**. Reference may be had to the aforementioned Patent No. 2,639,399 for a more detailed description of methods which may be used to provide the desired coating **3** on coil **1**.

Coil leads **4** and **5** provide means for supporting the cathode and means for supplying heating current thereto. In addition, one of leads **4** and **5** is utilized to provide electrical circuit connection to the cathode.

A cathode constructed as shown in FIGURES 1 and 2 and utilizing the above dimensions, which have been given by way of example, was used in an electron discharge

device. The cathode operated for 1000 hours at 1400° C. without dimunition of the emissive properties of coating **3**. Inspection thereafter under the microscope showed no diffusion or other reaction between the rhenium support and lanthanum boride emissive material.

FIGURE 3 shows an alternative embodiment of a cathode constructed in accordance with the present invention. The embodiment of FIGURE 3 provides a more rigid support than is normally obtainable by utilizing only coil leads, such as leads **4** and **5** in the embodiment of FIGURES 1 and 2.

The support of FIGURE 3 includes a pair of side members **6** and **7**, which are normally rigidly fastened to an assembly variously known as the stem, header or base of the electron discharge device. Members **6** and **7** are illustrated as having support caps **8** and **9** secured, as by welding, at the upper extremities thereof, respectively. Caps **8** and **9** provide means for securing a relatively large diameter rhenium tube **10** at opposite ends thereof adjacent members **6** and **7**. The cathode support is completed by a coil of relatively small diameter rhenium wire having a plurality of turns **11** wound about tube **10**. The extremities of the coil are secured, as by welding, to tube **10** at points **13** and **14**, but may be secured, alternatively, to members **6** and **7** or caps **8** and **9**. The heater circuit connection to tube **10** is provided through members **6** and **7** and caps **8** and **9** which are constructed of conductive material. A coating **12** of lanthanum boride is disposed about tube **10** and between turns **11** by any of the usual methods, such as filling and sintering in place. It may be seen that all of the surface regions of the support of FIGURE 3 which contact lanthanum hexaboride coating **12**, namely tube **10** and the coil wound thereon, consist essentially of rhenium. Thus, diffusion of boron atoms into any part of the support is avoided.

In the cathode of FIGURE 4, a lanthanum boride coating **15** is disposed about and carried by rhenium support wire **17**. In this embodiment, the heating coil, comprising turns **16**, is not in contact with coating **15**. Therefore, it is not necessary that the heating coil be constructed of rhenium wire, and the material may be any of the usual resistive refractory metals used for this purpose. Support members **6** and **7** and caps **8** and **9** should be conductive in this embodiment in order to provide electrical circuit connection to coating **15**, since the heating coil is not connected to the support, as in the embodiment of FIGURE 1.

FIGURE 5 illustrates a "hairpin" cathode constructed in accordance with the present invention. The cathode support comprises a pair of side members **18** and **19** carrying a rhenium wire **20**. Wire **20** is in the general form of an inverted V and secured, as by welding, to members **18** and **19**, respectively, at extremities thereof. A rhenium wire **21** of lesser diameter is disposed about wire **20** in a plurality of turns **22**, terminating in extremities **23** and **24** which are secured to wire **20**, as by welding thereto. Alternatively, extremities **23** and **24** may be secured to members **18** and **19**, respectively. In one particularly satisfactory support of this variety the diameter of wire **20** was double the diameter of wire **21** and the spacing between loosely wound turns **22** was equal to the diameter of wire **21**.

As in the embodiment of FIGURE 3, side members **18** and **19** of FIGURE 5 are electrically conductive and serve as part of the cathode circuit and heater circuit. It is not required that wire **21** provide any appreciable electric circuit path since the heating current flows predominantly through wire **20**. Wire **21** merely serves as a mechanical support for coating **25**.

By way of example, a "hairpin" cathode of the type shown in FIGURE 5 was constructed wherein wire **20**

was 10-mil-diameter rhenium wire and wire **21** was 5-mil-diameter rhenium wire with 5 mils betewen turns. Wire **21** was welded to wire **20** at opposite extremities of wire **20**, adjacent members **18** and **19**, respectively. The space between turns was filled with lanthanum hexaboride by painting with a paste of boride powder and amyl acetate. The cathode was sintered in argon for 5 minutes at 1600° C. The completed cathode supplied an emission current of 10^{-7} ampere at a surface temperature of only 675° C. The heating current supplied through members **18** and **19** was 1.8 amperes and heating power was 1.7 watts. No diffusion of boron into the rhenium support was observed when the cathode was later examined under a microscope.

While this invention has been described in connection with four specific cathode structures embodying the present invention, it is to be understood that the present invention is not limited thereto. Many variations and modifications of the specific cathodes disclosed will occur to those skilled in the art. In addition, other cathodes may be constructed utilizing a rhenium support for a metal boride thermionic emissive material. Therefore, it is intended by the following claims to include all such cathode structures as fall within the true spirit and scope of this invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A thermionic cathode comprising: a support, said support including a surface region consisting of rhenium; and a thermionic emissive material consisting of a metal boride, which does not diffuse into rhenium at elevated temperatures, in contact with said surface region and carried by said support.

2. A thermionic cathode comprising: a support, said support consisting essentially of rhenium; and a coating of thermionic material disposed on said support, said material 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.

3. The thermionic cathode of claim **2** wherein said metal boride is lanthanum hexaboride.

4. The thermionic cathode of claim **2** wherein said metal boride is misch metal hexaboride.

5. A thermionic cathode comprising: a support, said support including a loosely wound coil of wire consisting of rhenium; and a coating of thermionic emissive material disposed about said coil and supported thereby, said material consisting essentially of at least one metal hexaboride selected from the group consisting of the borides of calcium, barium, strontium, thorium, uranium and the rare earth metals.

6. The thermionic cathode of claim **5** wherein said metal hexaboride is lanthanum hexaboride.

7. The thermionic cathode of claim **5** wherein said metal hexaboride is misch metal hexaboride.

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