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Broers

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[54] METHOD FOR FORMING SMALL DIAMETER TIPS ON SINTERED MATERIAL CATHODES

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[52] **U.S. Cl.**.....**29/25.18,** 29/25.17, 219/121 EM, 219/121 LM

[51] **Int. Cl.**.....**H01j 9/16, H01j 9/44**

[58] **Field of Search**.....29/25.1, 25.11, 25.17, 25.18; 219/121 EM, 121 LM; 313/336

[56] **References Cited**

UNITED STATES PATENTS

2,076,671	4/1937	Richter et al.	313/336
3,334,213	8/1967	Sauve et al.	219/121 EM
3,436,584	4/1969	Hughes et al.	313/336 X
3,532,923	10/1970	Vogel	313/336 X
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[57] **ABSTRACT**

There is disclosed a method for forming tips on normally sintered material electron-emitting cathodes. The method comprises melting the electron-emitting end of the cathode with an electron beam or other suitable narrow beam heating means, such as a laser, for example. This melting produces a dense fused mass at the end of the cathode. This fused mass can then be polished to a tip having a very small diameter such as substantially less than 5 microns.

4 Claims, 4 Drawing Figures

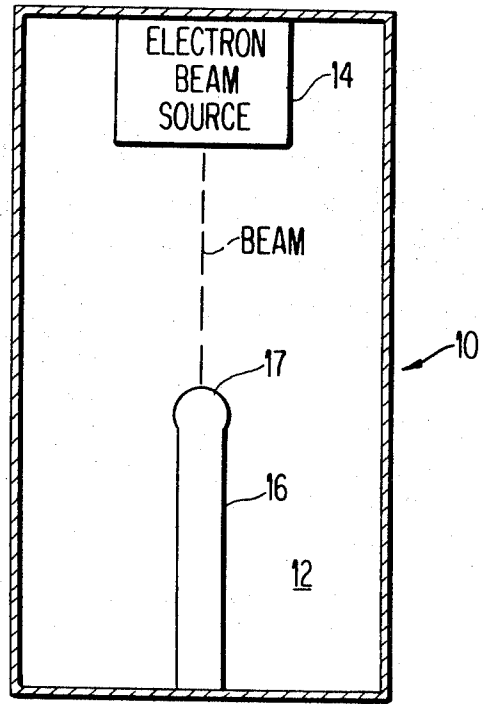


FIG. 1

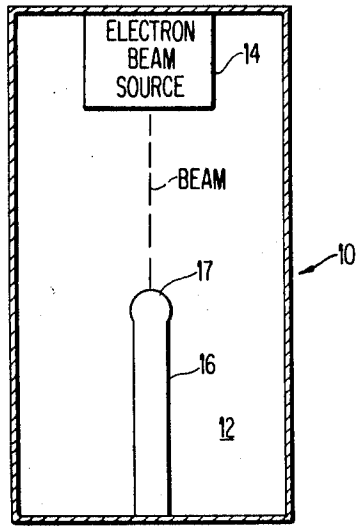
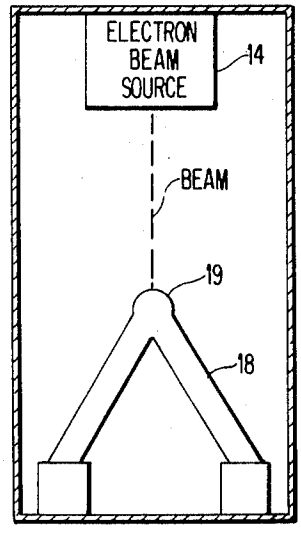


FIG. 2



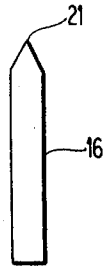


FIG. 3

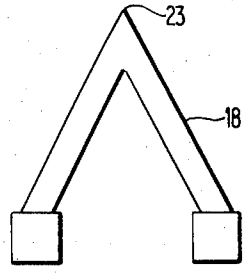


FIG. 4

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METHOD FOR FORMING SMALL DIAMETER TIPS ON SINTERED MATERIAL CATHODES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method for forming extremely small diameter tips on the ends of normally sintered material electron-emitting cathodes. More particularly, it relates to a method for forming extremely small diameter tips on sintered material lanthanum boride cathodes, such lanthanum borides being for example the Tetra, hexa and duodeca borides.

2. Description of the Prior Art

It is known that certain metallic borides, particularly those of the rare-earth metals, exhibit exceptionally good electron emission characteristics for use as cathodes to generate electron beams. Thus, for example, in U.S. Pat. No. 3,462,635 to A.N. Broers, there is disclosed the use of lanthanum hexaboride as an electron-emitting material to produce an electron beam.

The aforementioned Broers patent discloses that, if high brightness is to be obtained from a standard three-electrode gun, the geometry of the gun must be such that the field concentration at the electron source is high and that this is most easily obtained by using sharply pointed cathodes. Thus, when a lanthanum hexaboride cathode is employed in an electron beam apparatus, the maximum brightness that can be obtained from the gun is to a large extent determined by the sharpness of the tip that can be machined on the emitting portion of the cathode. In other words, the maximum brightness increases as the dimension of the cathode tip decreases.

In electron beam apparatus of the prior art in which lanthanum hexaboride cathodes were employed as the electron source material, the rods have been cut from sintered lanthanum hexaboride and the tips formed, e.g., by hand-polishing in a watch-marker's lathe or by suitable spark-machining processes. However, both of these processes suffer from the disadvantage that the sharpness of the tip is limited due to the powdery nature of the sintered material. As a result, the best tips that can be obtained for a lanthanum hexaboride sintered material have a radius of about 10 microns. The latter result is discussed in the publication entitled "-Some Experimental and Estimated Characteristics of the Lanthanum Hexaboride Rod Cathode Electron Gun," pages 273–276, Journal of Scientific Instruments, [Journal of Physics E.] 1969, Series 2, Volume 2.

Alternative methods for making the required rods from dense (e.g., arc-melted) lanthanum hexaboride rather than sintered material have not proven satisfactory heretofore because of the difficulty encountered in producing a crack-free rod or other structure. This latter difficulty is also discussed in the aforementioned Journal of Scientific Instruments article. In addition, various attempts have been made to zone-refine a sintered lanthanum hexaboride rod, but these attempts have failed due to the reluctance of the material to melt in a controlled manner.

Another alternative to employing sintered lanthanum hexaboride material is to use single crystal lanthanum hexaboride, which is both uniform and dense and permits a relatively small tip to be formed on the rod. However, it has not been possible to date to produce single crystals of lanthanum hexaboride, which are large enough for most practical cathodes. Even if this were possible, they would be relatively expensive and, therefore, undesirable from an economic viewpoint.

It is not possible to attach a small portion of high density lanthanum hexaboride to another material because of the extremely high chemical reactivity of the lanthanum hexaboride at the elevated temperatures required for electron emission.

A cathode emitter employing lanthanum hexaboride is disclosed in U.S. Pat. No. 3,312,856 to Lafferty et al. The Lafferty et al. patent discloses an improved cathode for an electron discharge device comprising lanthanum hexaboride as the emitter material supported by rhenium. The cathode is typically comprised of a coil of rhenium wire having a lanthanum hexaboride coating thereon which functions as the thermionic emitter. However, the cathode emitter disclosed by Lafferty et al is not suitable for use where high electron-emission densities (>1 amp/cm^2) are required such as is the case in most electron beam apparatus.

It is an important object of this invention to provide a method for forming extremely small diameter tips on sintered-material electron-emitting cathode structures.

It is another object of this invention to overcome the disadvantages of prior art cathodes detailed above and to provide a method for forming tips of extremely small dimensions on lanthanum hexaboride cathodes which will allow useful emission densities of up to 1,000A./cm^2 to be drawn therefrom.

SUMMARY OF THE INVENTION

Generally speaking, and in accordance with the invention, there is provided a method of forming a small diameter tip on a sintered material electron-emitting cathode comprising melting the end of the cathode from which electron emission is to be drawn by applying an electron beam to such end to melt it, whereby, when it resolidifies, it forms a fused mass, and subsequently, polishing the end of the fused mass to the desired small diameter tip.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings,

FIG. 1 is a schematic depiction of an apparatus suitable for use in carrying out the method of the invention, there being illustrated therein a sintered material rod-shaped cathode;

FIG. 2 is a schematic depiction of the apparatus shown in FIG. 1 wherein there is shown a hairpin-shaped cathode;

FIG. 3 shows the cathode of FIG. 1 after it has been machined; and

FIG. 4 shows the cathode of FIG. 2 after it has been machined.

DESCRIPTION OF A PREFERRED EMBODIMENT

The method of the present invention essentially comprises the use of an electron beam welder or other narrow beam heating means, such as a laser beam, to melt the end of a sintered-material electron-emitting cathode, which produces a fused mass thereof upon cooling. Examples of the material may be lanthanum tetraboride, lanthanum hexaboride and lanthanum duodecaboride.

Processes utilizing electron bombardment heating techniques for non-analogous uses are known. In this connection, U.S. Pat. No. 3,334,213 to Sauve et al., discloses a process for the hot machining of metals comprising heating a specimen by means of an energy beam and, subsequently, machining the hot portion of the specimen to a desired shape. The machining operation may comprise die-stamping, drop forging, hot bending or hot extrusion and other similar machining operations. The process disclosed in the Sauve et al patent is basically applicable to precious metals or other costly metals where it is desired to avoid oxidation of the specimen and in order to prevent loss by burning as a result of the machining operation.

Another metal-treating process employing an energy beam is that disclosed by U.S. Pat. No. 3,274,036 to Andrews et al. The latter patent describes an etching process wherein a thermoelectric element, which is to be bonded to a metallic substance, is first etched with concentrated nitric acid, subsequently bombarded by a concentrated emission of electrons, and thereafter subjected to a second etching using a concentrated nitric acid bath.

A similar etching process is disclosed by U.S. Pat. No. 2,989,385 to Glanola et al., wherein a smooth surface is obtained by removing the bombarded surface by an etching process.

With this invention, there is now provided a method for forming extremely small tips on sintered material lanthanum boride cathodes and other sintered-material electron-emitting cathodes to thereby provide emissive materials, which can be used to produce an extremely high electron brightness.

The method disclosed herein is for forming extremely small diameter tips on lanthanum hexaboride cathodes including the use of an electron beam welder or other high narrow beam energy source such as a laser to melt the end of the rod before forming the point. This produces a dense melted area at the end of the cathode from which the electron emission is to be drawn which, after being allowed to resolidify, is then polished to a fine tip, i.e., one having a diameter on the order of about 1 micron.

More specifically, the inventive method may be carried out as follows. A 1 millimeter diameter rod of sintered material such as lanthanum hexaboride is first cut into sections of about 1 inch long using a diamond wheel or a spark-machining process. The end of the rod is melted by the end-on bombardment of the end with an intense high powered electron or laser beam. The intensity of the electron beam is chosen to be sufficient to melt the end of the rod to which it is directed. For this purpose, a pulse of about 50–100 watts and one to two seconds duration has been found to be suitable.

In FIG. 1, there is shown an apparatus **10** for carrying out such melting. Apparatus **10** comprises an evacuated chamber **12** containing a rod **16** and a high energy narrow beam source **14**, such as an electron or a laser beam. In FIG. 1, there is shown a rod geometry which is being tip-melted, such tip being illustrated by the blob **17**.

FIG. 2 is the same as FIG. 1 with the difference that there is being tip-melted therein a hairpin-shaped cathode **18**, the blob on its end being designated by numeral **19**.

The approximate tip geometry desired may then be formed by a spark-machining process or any other suitable known method. Subsequently, the fine polishing of the resulting tip may be carried out by using any suitable means; such as various mechanical, chemical or electrochemical techniques.

FIG. 3 shows the rod **16** of FIG. 1 after its tip **21** has been machined down to the desired diameter, and FIG. 4 similarly shows the hairpin rod structure **18** of FIG. 2 with its tip **23** machined down to its final desired small diameter.

The structure of the tip thus formed is extremely dense as compared to the starting material of sintered-material cathode, which may only have a density of 80 percent of theoretical density of the cathode material. The melted tip has a density equal to the theoretical density.

A particular advantage of the invention is that it allows cathodes of any shape and size to be fabricated from sintered material structures, which can be readily and relatively cheaply obtained in large ingots. The critical emitting tip of the cathode is formed in the small melted region of the cathode thereby avoiding the problem of having to form the entire cathode from high density material.

In order to illustrate further the practice of the present invention, reference is made to the following example, which is merely illustrative and not intended to be limiting in any manner.

EXAMPLE

A conventional rod cathode for use in an electron beam generating apparatus was formed by hand polishing, in a watch-maker's (or by other suitable means). The rod was made from sintered lanthanum hexaboride and was one inch long and had a cross section of 1 millimeter. The resultant tip had a radius of about 10 microns. In addition, a lanthanum rod cathode was produced according to the process of the present invention as follows:

A 1 inch long sintered lanthanum hexaboride rod having a cross section of one millimeter was disposed in an electron beam welding apparatus. One end of the rod was subjected to an end-on electron beam bombardment of a power of 50–100 watts for a period of 1 to 2 seconds. The end, which was thus melted, was thereafter polished by first spark machining and then mechanical polishing with a 0.25 micron diamond lapping compound using a watch-maker's lathe. The resulting tip had a diameter of one micron.

Each of the above rod cathodes were operated in an electron gun of the type disclosed in U.S. Pat. No. 3,462,635 with a total cathode heating power of 80 watts. The electron beam brightness of the gun produced under these conditions is limited by space charge effects. The cathode produced with the new

technique which had the smaller tip radius had a larger electric field gradient at its surface. The effects of the space charge were therefore minimized. The electron beam brightness for the new cathode was measured to be 6×10^6A./cm^2 steradian compared with 7×10^5A./cm^2 steradian from the cathode produced by the old technique. The measurement was made at an electron beam accelerating potential of 25 kv.

The electron gun was used as the electron source on a high resolution scanning electron microscope. The electron optical portion of this microscope consists of the electron gun and a series of electromagnetic electron lenses, which are used to form an extremely fine electron beam (20A. in diameter). The brightness (β) of the electron gun was measured from the characteristics of this electron beam, i.e., its diameter (d), current (i) and convergence angle (α) from the following formula;

$$\beta \times (4i/\pi^2 d^2 d^2$$

The new cathode allows higher performance to be obtained from the microscope, i.e., approximately 8 times the current to be obtained in a beam of a given size, or a reduction in beam size of approximately 2 to 3 times for a given beam current. This is extremely important as the resolution of the microscope is determined by these beam characteristics. Similarly, the cathode can be used to improve the performance of any electron microscope or other related instrument, i.e., electron X-ray microanalyses or electron beam welders.

As can be seen from the above results, the method of this invention produced a lanthanum hexaboride rod cathode which had a substantially improved brightness as compared to the cathode produced by the conventional process. It is believed that the improved results are due to the finer tip of the lanthanum hexaboride rod.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

I claim:

1. The method of forming a small-diameter tip on a sintered-material electron-emitting cathode comprising melting an end of said cathode with a high-energy narrow beam whereby upon the cooling of said melted end, it resolidifies into a fused mass, and thereafter, polishing said resolidified end to a tip of a desired diameter.

2. The method of forming a tip on a lanthanum hexaboride cathode comprising melting an end of said lanthanum hexaboride cathode from which electron emission is to be drawn by treating said end with an electron energy beam, allowing the melted portion of said cathode to resolidify and thereafter polishing said resolidified end of said cathode to the desired diameter.

3. The method of forming a tip on a lanthanum hexaboride cathode as defined in claim 2, wherein said electron energy beam is directed axially toward the end of said lanthanum hexaboride cathode in order to melt it.

4. the method of forming a tip on a lanthanum hexaboride cathode as defined in claim 2, wherein said lanthanum hexaboride cathode comprises sintered lanthanum hexaboride.

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