

[54] INTEGRAL EMISSIVE ELECTRODE

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[58] Field of Search..... 313/335, 341, 357, 313/267, 311, 346 R

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UNITED STATES PATENTS

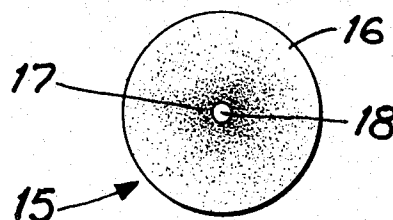
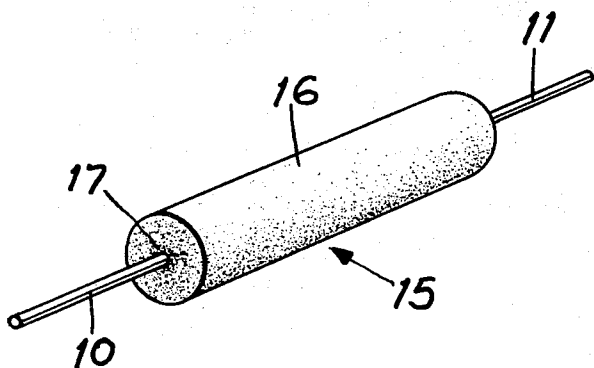
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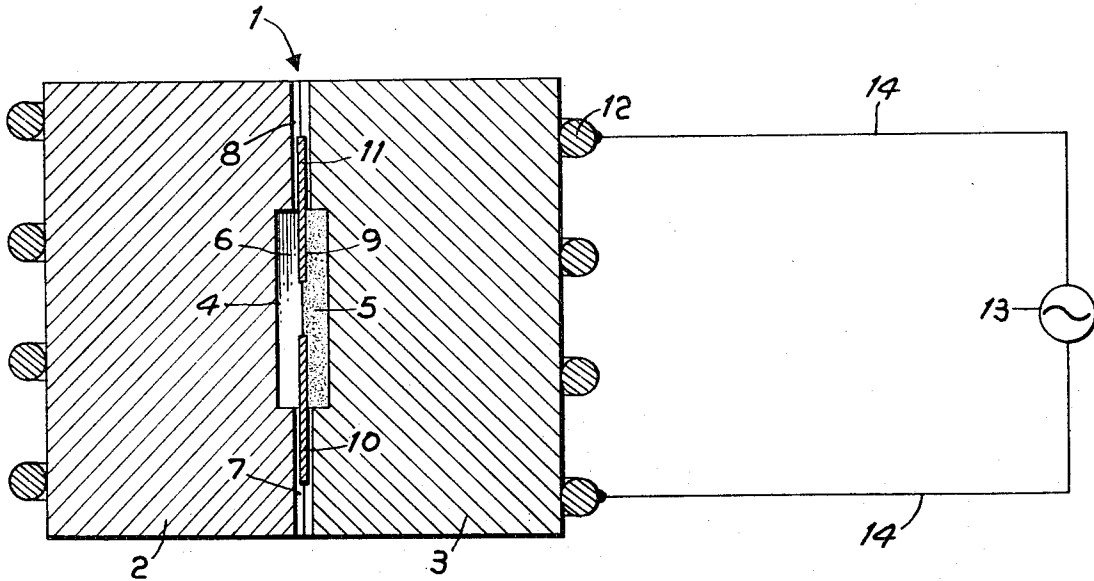
[57] ABSTRACT

An emissive electrode of the type utilized in fluorescent lamps and a method for making such an electrode. The electrode includes a fused cylindrical pellet and two metal leads, a portion of one of said leads extending within one end of said pellet and a portion of the other of said leads extending within the opposite end of the pellet. The pellet contains a fused mixture of electron emissive material and a metal having a high melting point and a low vapor pressure, and it has a bulk density gradient structure. The heat necessary to cause thermionic electron emission from said electrode is provided by current passing through the pellet structure separating said leads when a voltage is applied across said leads. The pellet is formed by mixing a powder of said metal with a powder of said electron emissive material, adhering said powder particles one to the other, and heating said mixed powder in a mold until an exothermic reaction occurs.

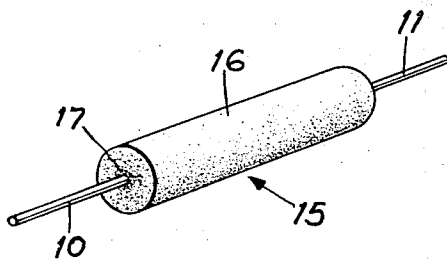
7 Claims, 3 Drawing Figures



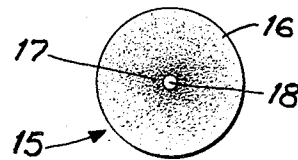
*Fig. 1*



*Fig. 2*



*Fig. 3*



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**INTEGRAL EMISSIVE ELECTRODE  
CROSS-REFERENCES TO RELATED  
APPLICATIONS**

This is a continuation-in-part of my, now abandoned application Ser. number 149,972, entitled INTEGRAL ARC DISCHARGE ELECTRODE, filed June 4, 1971.

**BACKGROUND OF THE INVENTION**

This invention relates to emissive fused pellet electrodes and to a method of making such electrodes, and more particularly to fused pellet electrodes having an integral structure.

Emissive electrodes are utilized in fluorescent lamps to supply free electrons, thereby enabling current flow in the fluorescent tube and may therefore be called cathodes.

Cathodes normally comprise one or more of the alkaline earth metals and compounds thereof, as these materials have relatively low work functions and are therefore able to supply free electrons without requiring the expenditure of great amounts of energy. The provision of said free electrons by the emissive alkaline earth material will of course consume the electrode and when the electrode material is depleted to the point where it can no longer supply sufficient electrons for lamp operation upon the application of standard fluorescent lamp voltages, the lamp will fail and will have to be discarded. It is therefore clear that it is advantageous to provide emissive electrodes incorporating the greatest amount of emissive material possible. The cathodes presently utilized in the art are normally one of two types, both of which are, for operation, heated to what is termed the "thermionic emission temperature" at which temperature they emit electrons. The first of these cathodes is heated to its emission temperature by a heated filament and is therefore termed, for the purposes of this specification, a "hot" cathode, while the other of said cathode types is heated to its emission temperature by ionic bombardment and is therefore termed, for the purposes of this specification, a "cold" cathode. The hot cathode, which is the type commonly utilized, for example in 40-watt fluorescent lamps of the "rapid start" type as well as in lamps of the "HO" and "VHO" type which are available in various wattage ratings, is the one here of interest, and it will now be briefly discussed.

Hot cathodes of the type well known in the art are normally made by painting, dipping or otherwise adhering a co-precipitated triple carbonate, usually comprising strontium carbonate, calcium carbonate and barium carbonate to a coil of tungsten wire. This cathode is subsequently activated to improve its electron emissive properties by methods well known to those skilled in the art and it is subsequently utilized as an emissive electrode in fluorescent lamps. This type of cathode is here termed a hot cathode since it operates, as stated above, in its thermionic emission mode, by the direct application of heat to the cathode body. Electrical energy, usually in the order of 3.6 volts, is provided by external circuitry associated with the lamp, more specifically the lamp ballast, to the low resistance coil of tungsten wire, said coil having an operating resistance of approximately 9 ohms. The voltage applied heats the tungsten coil and the heated coil directly heats the cathode material to a temperature sufficient to initiate electron emission. The hot cathode, although widely

utilized, has been found limited in that it has a life span in the range of 10,000-20,000 hours, this range depending primarily on lamp wattage rating. This limited life span is due to the fact that only a limited quantity of electron emissive alkaline earth material can be coated onto the aforementioned low resistance tungsten filament, and for the reasons discussed above cathode life is directly related to the quantity of electron emissive material which is available for use. Within the limits of present technology, only 6-7 milligrams of the electron emissive material can be coated onto such a tungsten filament utilized in, for example, the above-mentioned "rapid start" family of fluorescent lamps. Although numerous attempts have been made to provide a greater quantity of emissive material on the electrode filaments so as to extend lamp life, these attempts have always failed, since when additional emissive material has been painted, sprayed or otherwise adhered to the coiled filament it has flaked off, primarily for the following reasons. The emissive material which comprises, as stated above, alkaline earth carbonates, is adhered to the coil substrate by a temporary adhesive binder such as cellulose nitrate. This binder is removed by thermal decomposition and the cathode is subsequently heated to a sufficiently high temperature to decompose the carbonates to their respective oxides, this being the aforementioned activation process. The only binding force remaining after the removal of the cellulose nitrate and the subsequent activation of the cathode is the result of a weak sintering of the oxide particles, which now comprise the cathode, during said activation process. As the mass of the emissive material coated onto said coil substrate is increased, this binding force becomes insufficient to hold the particles together and to the coil substrate when the lamp in which the cathode is utilized is subjected to normal shock and vibration during manufacture and use.

**SUMMARY OF THE INVENTION**

Therefore the main object of this invention is to provide a hot cathode having a substantially longer life time than presently known hot cathodes.

It is a further object of this invention to provide such a cathode embodying substantially more emissive material than hot cathodes presently known in the art.

It is yet another object of this invention to provide such a cathode which does not require a coiled heating filament and in which the cathode heating current flows within the body of said cathode.

It is a still further object of this invention to provide a method of making such a cathode.

According to the present invention there is provided an emissive electrode comprising a fused body containing a fused mixture of electron emissive material and a metal, a first conducting lead embedded in said body and extending therefrom, and a second conducting lead embedded in said body and extending therefrom, said first and second leads being separated one from the other, said body having a bulk density gradient structure wherein the interior portion thereof has a high bulk density relative to the exterior portion thereof, and wherein the current provided for heating said electrode passes through said body separating said first and second conducting leads.

According to another aspect of the present invention there is provided a method of making an emissive electrode comprising the steps of placing a powder mixture

comprising a metal powder and a powder of electron emissive material in a mold, inserting first and second conducting leads into said mold, said leads being separated one from the other by said powder mixture and partially extending therefrom, and heating said powder mixture to a temperature above the melting point of said emissive material and until an exothermic reaction begins, said reaction continuing until self-extinguishing, whereupon a fused body having a bulk density gradient structure is formed.

It is a feature of this invention that the fused emissive electrode constructed according to the instant method is relatively air stable, that is, it may be exposed to reasonably dry air, by which is meant air containing less than 75 grains of water per pound of dry air for at least 1 hour after activation, and it is thus suitable for batch activation processes.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a mold utilized in constructing the inventive electrode;

FIG. 2 illustrates an example of the subject integral emissive electrode; and

FIG. 3 is a cross-sectional view of the subject electrode.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

An example of the method and apparatus utilized in constructing the subject integral emissive electrode will now be described.

In the construction of the instant electrode a mixture of a powder of a metal having a high melting point, over 1,400° C, and a low vapor pressure, such as a refractory metal or a transition element metal, hereafter referred to as a transitional metal, and a source of electron emissive material is prepared. In the specific example to be provided below, a few grams of powdered tantalum, which is a refractory metal, approximately 99.8 percent pure, is mixed 67 percent by weight, with reagent grade barium peroxide powder, 33 percent by weight. Of course, other refractory metal powders, such as tungsten, molybdenum, thorium, titanium, zirconium and mixtures thereof could be used instead of tantalum powder, while other electron emissive materials, for example, alkaline earth compositons such as oxides, peroxides, and nitrates of barium, and oxides, peroxides and nitrates of barium in combination with calcium oxide, strontium oxide and zirconium dioxide, or alkali metal compositions, such as compounds of lithium, cesium, sodium and potassium, could be used instead of barium peroxide. Mixtures of calcium, strontium and zirconium compounds are generally added to barium compounds in order to retard the emission of electrons from the finally formed integral electrode. However, it should also be noted that the increase in amounts of calcium, strontium and zirconium compounds will tend to increase the work function of the finally formed fused electrode.

It is appropriate here to note that in forming the subject fused electrode it is necessary to control the rate of exothermic reaction which is used to form the electrode, said reaction to be more fully discussed below, since if the rate of the reaction is too great the surface region thereof will be too dense, impeding the emission of electrons therefrom. If, on the other hand, the rate of reaction is too slow, the density gradient of the resul-

tant electrode will be too small, and the electrode structure will approach homogeneity. Such a homogeneous structure will result in a less efficient cathode than is otherwise obtainable.

At this time it is well to note that, although as stated above, different refractory metal powders, such as thorium or titanium may be utilized to form the instant fused electrode, these refractory metal powders having a greater exothermicity than, for example, tantalum. Thus, while an electron emissive material such as barium peroxide may here too be utilized in forming the subject cathode, it has been found advantageous to use a greater quantity by weight of, for example, zirconium powder and a lesser quantity of barium peroxide or other alkali or alkaline earth compound than would be used if the refractory metal powder was, for example, tantalum. A satisfactory reaction rate may also be obtained if it is desired to use the same quantity by weight of zirconium powder as of tantalum powder, if the less reactive oxide of barium or other alkaline earth metal is substituted for the more reactive peroxide of the alkaline earth metal. In the same manner it has been found that transitional metals, such as nickel and iron, which have a lower exothermicity than tantalum may also be utilized to form the subject hot cathode. This may be accomplished by either utilizing a greater portion of alkali or alkaline earth compound, such as barium peroxide, than would be used if a refractory metal were used rather than the transitional metal, or alternatively, the same result may be accomplished by keeping the ratio of the transitional metal constant and using a more reactive compound of alkali or alkaline earth metal than barium peroxide, such as for example barium nitrate. In general, although the above example specified that 67 percent by weight of a refractory metal powder and 33 percent by weight of an alkaline earth compound be used, it has been found through experimentation that ranges of mixtures of approximately 50 percent to 80 percent of metal powder by weight and approximately 20 percent to 50 percent alkaline earth compound by weight may be utilized to produce satisfactory reaction rates and therefore may be used to produce satisfactory fused electrodes.

Returning now to the example, the above-described mixture is prepared by rolling two parts by weight of tantalum powder and one part by weight of barium peroxide with flint pebbles in a standard porcelain jar mill, for a period of, for example, one hour.

Referring now to FIG. 1 there is shown a split mold 1 having sections 2 and 3 which are formed with troughs 4 and 5 respectively. Mold 1 has a cavity 6, comprising troughs 4 and 5, formed therein, said cavity being approximately one-eighth of an inch in diameter and five-eighths of an inch in height. Holes 7 and 8 extend between the end portions of cavity 6 and the bottom and top surfaces of the mold respectively, said holes each being approximately 0.025 inches in diameter. Mold 1 is constructed of a conducting material to which the fused integral emissive electrode which is to be constructed will not adhere, and it is fabricated, in this example, from graphite. Powder mixture 9, comprising approximately 150 milligrams of an emissive material and a metal, here barium peroxide and tantalum, is placed in trough 5 of cavity 6. After mixture 9 is placed in trough 5, a pressure of between 2 and 20 pounds per square inch is applied thereto by, for example, a weighted steel plunger, to compact the mixture.

It is possible to accomplish the same objective without applying said pressure by slightly wetting said powder mixture with a small amount of, for example, acetone, this wetting causing the mixture to compact. In the event that acetone is used to accomplish the desired compaction, the acetone will be evaporated from the mixture by exposure to air at room temperature prior to the occurrence of the exothermic reaction which is to be discussed below. Metal leads 10 and 11, which are to serve as electrode conducting leads, and which may be made of a suitable conducting material such as nickel, tantalum, iron and alloys thereof, are positioned in holes 7 and 8 respectively. The diameter of leads 10 and 11 is approximately twenty thousandths of an inch and the length of each is one-half inch. Each lead is positioned to extend approximately one-fourth of an inch into cavity 6, and the adjacent ends of said leads are therefore approximately one-eighth of an inch apart therein.

Mixture 9 may now be heated to initiate the desired exothermic reaction between the tantalum and the barium peroxide. The heat necessary to start said exothermic reaction may be provided in a number of ways, for example, by a muffled furnace. It may also be provided by the structure here illustrated which includes an RF work coil 12 surrounding mold 1, said coil 12 being connected to a source of electrical energy 13 by conductors 14. To begin the exothermic reaction it is necessary to heat mixture 9 to a temperature between 700° C and 1,000° C, said temperature being above the melting temperature of the barium peroxide powder and the temperature at which the exothermic reaction will begin within the mold. To provide the required heating, taking into account the impedance of the mold and the material which is to be heated, the source of electrical energy 13 is selected to operate at a frequency of 450 kilohertz and to provide a current of approximately 165 milliamperes. Source 13 will remain energized until the exothermic reaction begins, said reaction being observable if a viewing window is provided in mold 1, as a flash of light. The exothermic reaction which occurs causes material 9 in trough 5 to explode outwardly, filling trough 4 and embedding leads 10 and 11 in the body of the now formed fused electrode. The gases expunged from said powder mixture 9 by the exothermic reaction are vented through holes 7 and 8 which, as illustrated, extend through mold 1 and which are not completely sealed by leads 10 and 11 respectively, due to the fact that the diameter of said leads is 0.020 inches whereas the diameter of said holes is 0.025 inches. Once the exothermic reaction begins, source 13 can be de-energized since the exothermic reaction will continue until self-extinguishing, the duration of the reaction being determined by the quantity of the mixture present within mold 1. After the exothermic reaction is ended and the completed integral emissive electrode has been cooled, it is available for standard processing and subsequent use in a fluorescent lamp of the type having circuitry associated therewith for providing heating filament voltage.

Referring now to FIG. 2, there is illustrated the completed integral electrode having a bulk density gradient structure. Electrode or cathode 15 is a cylindrical shape and has a diameter of approximately one-eighth of an inch and a length of approximately five-eighths of an inch. Leads 10 and 11, which are, as previously stated, made of a conducting metal, are embedded in

the ends of cathode 15, as shown, and each extends outwardly from said cathode for a distance of approximately one-fourth of an inch. As previously stated, cathode 15 has a bulk density gradient structure by which is meant that in the region of surface 16 the electrode comprises particles 25 to 50 microns in size and 80 percent voids while the interior portion 17 of said fused electrode 15 comprises particle sizes in the order of tenths of microns and 10 percent voids.

Referring now to FIG. 3, there is shown a cross-sectional view of cathode 15 further illustrating the bulk density gradient structure of said cathode whereby it may be more readily seen that the cathode is less dense, that is, more porous, in the region of surface 16 than in interior region 17. Additionally, it is seen that cathode 15 is formed with a central void 18 due to the outward explosion of the emissive material and metal, here barium peroxide and tantalum, caused by the above-mentioned exothermic reaction.

The density gradient structure of cathode 15 makes it easier for electrons to travel through the cathode material to the surface thereof, this factor aiding in lowering the ignition voltage of the fluorescent lamp in which the cathode is utilized. The ignition voltage of the subject cathode has been experimentally determined to be approximately 195 volts, this being approximately the same voltage as that required by standard hot cathodes of the type commonly utilized, for example, in 40-watt fluorescent lamps of the "rapid start" type which, as above stated, comprise a coating of alkaline earth carbonates on a coiled tungsten filament. Further, cathode 15 contains approximately 150 milligrams of material, of which approximately 50 milligrams are electron emissive materials, here alkaline earth compounds. Comparing this quantity of emissive material to the approximately 6-7 milligrams of emissive material which comprise the aforementioned standard filament heated hot cathodes it is seen that the instant fused integral emissive cathode will have an extremely long life span relative to the life span enjoyed by said standard coil cathode.

As previously discussed, hot cathodes of the type known in the art are heated to their thermionic emission temperature by the connection of a heated filament voltage of approximately 3.6 volts across the coiled tungsten filament on which is coated the aforementioned co-precipitated triple carbonates. The resistance of the coiled tungsten filament, depending of course on its particular configuration and length, is normally approximately 9 ohms. The subject electrode does not, however, utilize such a heating filament. It has been discovered that the impedance across the subject integral electrode is approximately 6 ohms and thus, the aforementioned standard 3.6 volts may be applied across leads 10 and 11 and the cathode 15 will be heated to a temperature sufficient to initiate electron emission by current flow through the electrode itself, said current passing through all portions thereof. Cathode 15 thus functions in the same manner as the aforementioned hot cathodes known in the art and, since it does not utilize a heating filament, it may be termed "self-heating."

It will thus be seen that there has been provided a fused integral emissive cathode suitable for use in fluorescent lamps which is superior to those hot cathodes presently known in the art.

It is here appropriate to note that the subject cathode structure has been discovered to be relatively air stable subsequent to its activation, that is, it will remain activated for a period of at least 1 hour when maintained, after said activation, in reasonably dry air, by which is meant air containing less than 75 grains of water per pound of dry air. Thus, the cathode here described, while being greatly improved over the hot cathodes known in the art, for the reason previously discussed, additionally is suitable for batch processing, thus providing an additional valuable advantage.

While the principles of the invention have been described in connection with specific structure, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. A self-heating emissive electrode comprising: an electron emissive body containing a fused mixture of electron emissive material and a metal; said body having a bulk density gradient structure wherein the interior portion thereof has a high bulk density relative to the exterior portion thereof, and means providing an electrical current conductive path through said electron emissive body including first and second electrically conducting leads embedded in said body to be spaced from each other

so that electrical current flowing between said leads flows through and heats said body to cause said body to emit electrons therefrom;

whereby said bulk density gradient structure causes electrons to readily pass through said body to the exterior portion thereof to be emitted therefrom.

2. An emissive electrode, according to claim 1, wherein said body is cylindrical in shape and said leads extend from opposite ends thereof.

3. An emissive electrode, according to claim 1, wherein said metal comprises a refractory metal.

4. An emissive electrode, according to claim 1, wherein said metal comprises a transitional element metal.

5. An emissive electrode, according to claim 1, wherein said electron emissive material comprises an alkaline earth compound.

6. An emissive electrode, according to claim 1, wherein said electron emissive material comprises an alkali compound.

7. An emissive electrode, according to claim 1, wherein said metal comprises tantalum and said electron emissive material comprises barium peroxide, said tantalum being between 60 percent and 70 percent by weight of said mixture and said barium peroxide being between 30 percent and 40 percent by weight of said mixture.

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