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Menelly

[11] **3,798,492**

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[54] **EMISSIVE ELECTRODE**

[75] Inventor: **Richard A. Menelly,** Danvers, Mass.

[73] Assignee: **International Telephone and Telegraph Corporation,** Nutley, N.J.

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 149,971, June 4, 1971, abandoned, and a continuation-in-part of Ser. No. 144,137, May 17, 1971, abandoned.

[52] **U.S. Cl.**..... **313/346 R,** 313/311, 313/349

[51] **Int. Cl.** **H01j 1/14,** H01j 19/06, H01k 1/04

[58] **Field of Search** ..... 313/311, 346, 349, 107.5, 313/346 DC

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Primary Examiner—Eli Lieberman
Assistant Examiner—Saxfield Chatmon, Jr.
Attorney, Agent, or Firm—John T. O'Halloran; Menotti J. Lombardi, Jr.; Edward Goldberg

[57] **ABSTRACT**

An emissive electrode of the type utilized in fluorescent lamps having a bulk density gradient structure and a method for making such an electrode. A powder of a metal having a high melting point and a low vapor pressure is mixed with an electron emissive material, compressed, and heated until an exothermic reaction occurs. The interior of the resultant fused material electrode has a high density relative to the surface thereof.

17 Claims, 6 Drawing Figures

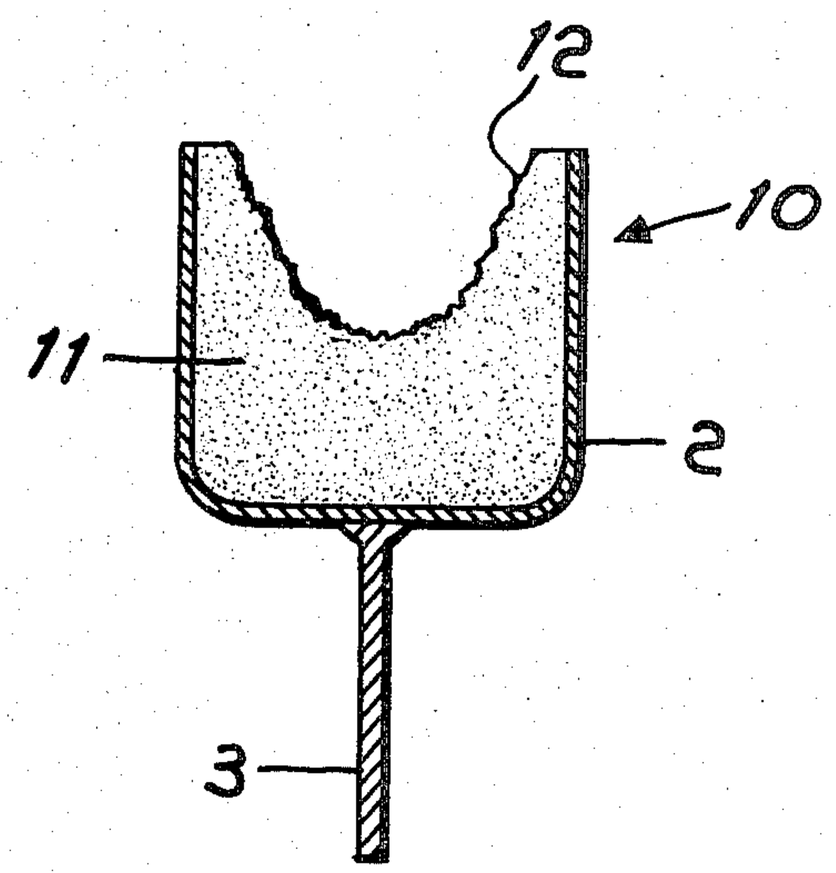


Fig. 1

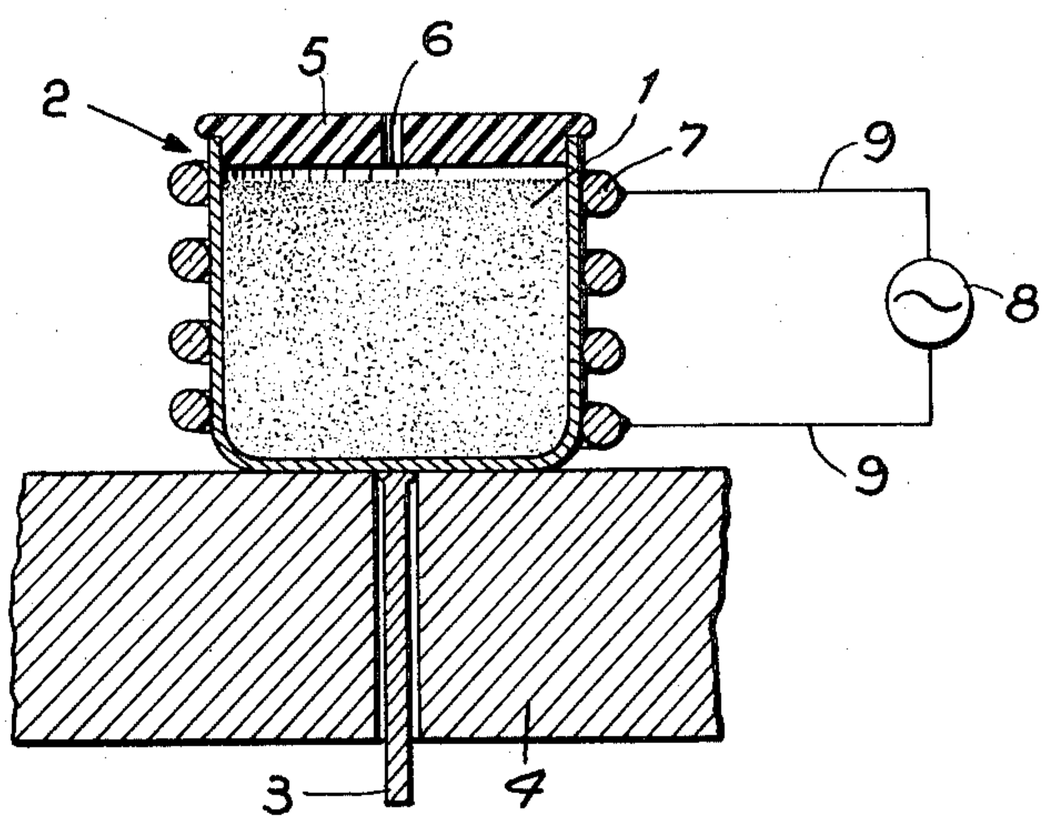
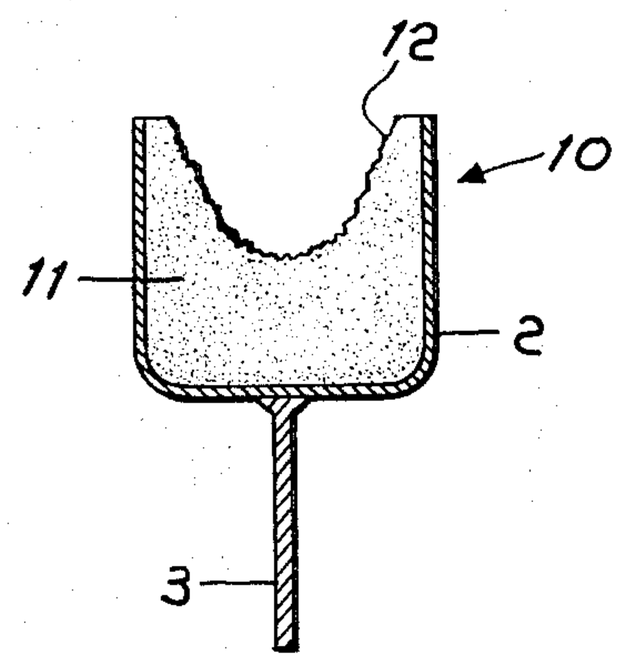


Fig. 2



INVENTOR
RICHARD A. MENELLY
BY Herbert L. Stern
ATTORNEY

Fig. 3

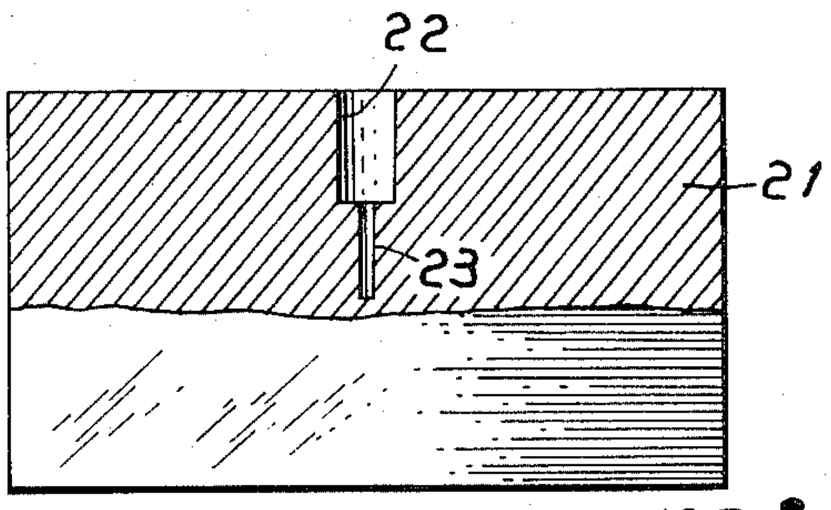


Fig. 6

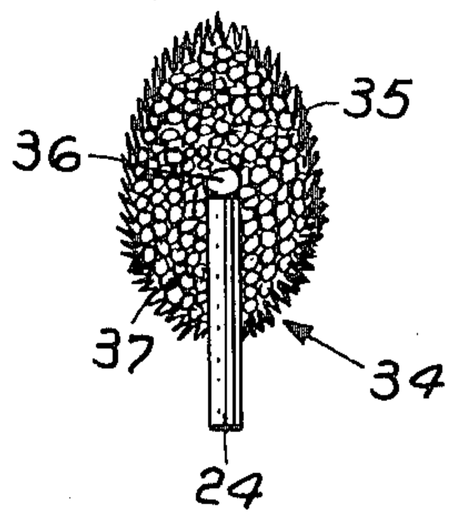
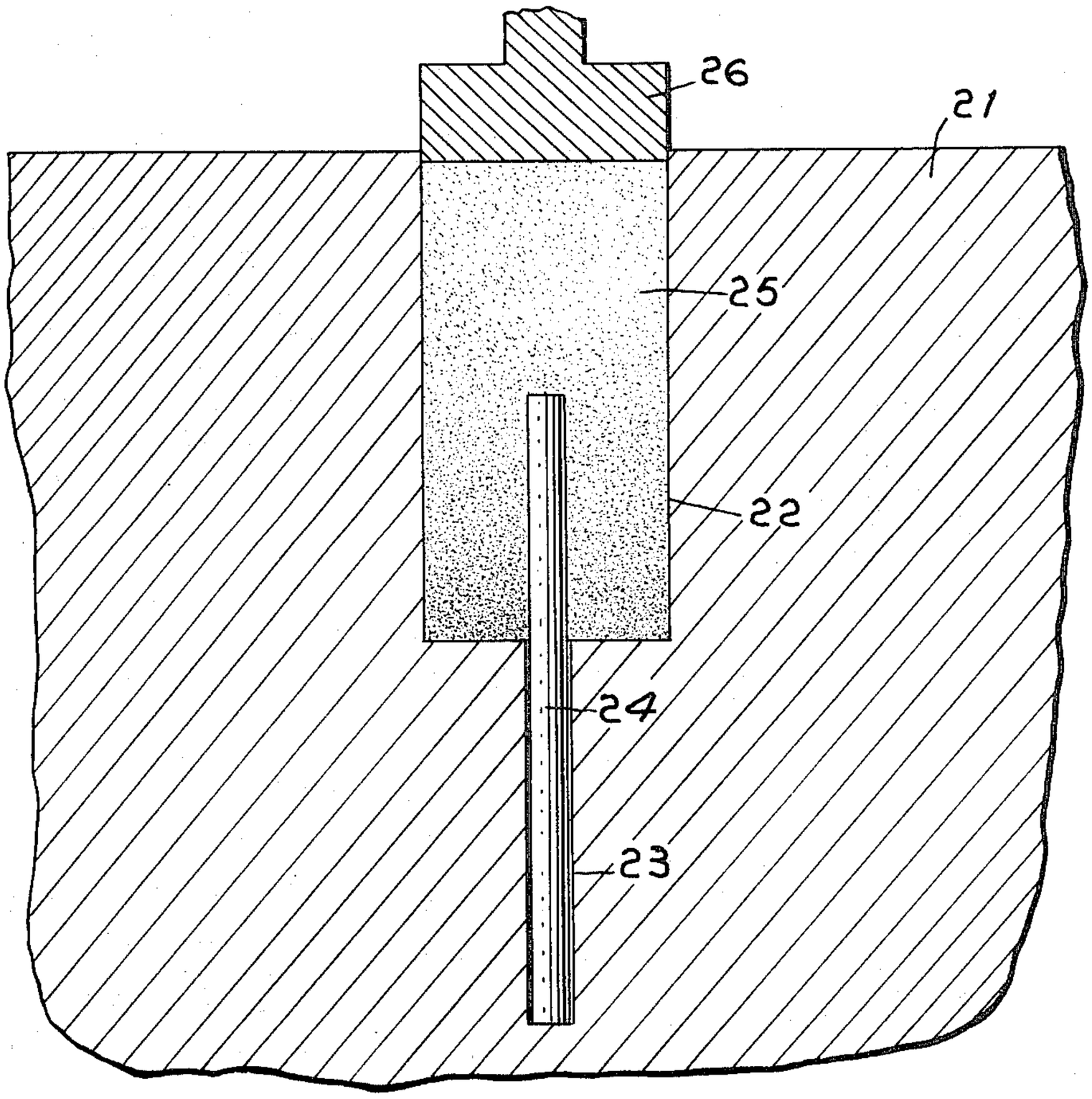


Fig. 4



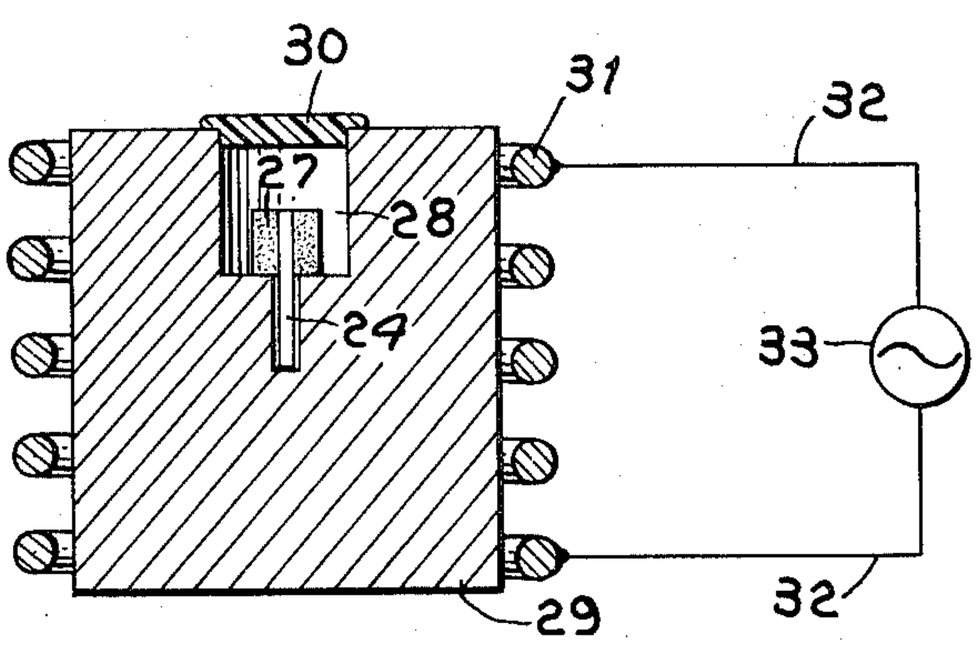


Fig. 5

INVENTOR
RICHARD A. MENELLY
BY Herbert L. Lerner
ATTORNEY

EMISSIVE ELECTRODE

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of my copending application, Ser. No. 149,971 entitled "Fused Cup Electrode Having a Bulk Density Gradient Structure," filed June 4, 1971 and Ser. No. 144,137, entitled "Fused Pellet Electrode Having a Bulk Density Gradient Structure," filed May 17, 1971 both now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to emissive electrodes of the cold cathode type and to a method of making such electrodes, and more particularly to such electrodes having a bulk density gradient 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.

The 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 material and when the 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. Although the instant invention relates to cathodes of the cold type, a brief, general discussion of both hot and cold cathodes is provided as an aid to understanding the invention.

Hot cathodes of the type well known in the art, which are 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, are normally made by painting, dipping or otherwise adhering a coprecipitated 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 is subsequently utilized as an emissive electrode in fluorescent lamps. This type of cathode is termed a hot cathode since it operates, in its thermionic emission mode, by the direct application of heat to the cathode body. Electrical energy, 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 a 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 to 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 filament 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, the 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.

In an attempt to lengthen electrode life beyond the aforementioned limit of 10 to 20,000 hours, the so-called cold cathode, as exemplified by the teachings of U.S. Pat. No. 2,677,623; No. 2,753,615, and No. 3,325,281 has been provided by the art. This type of cold cathode must be distinguished from another type of cold cathode which is here referred to as a "hybrid" cathode, and as a substitute for which the cold cathode was developed. A hybrid cathode is one which has a structure similar to that of the aforementioned hot cathode, that is, a qunatity of emissive material, approximately 6 to 7 milligrams, is coated onto a coiled tungsten filament substrate, as discussed above, but the filament leads are not connected across a source of electrical energy as was the case with regard to the hot cathode, and therefore the emissive material of the hybrid cathode is not raised to a temperature sufficient for thermionic emission in the same manner as that previously described with regard to a hot cathode. Rather, this hybrid cathode, which presently enjoys wide use in 8-foot instant-start fluorescent lamps, commonly referred to as a "Slimline" fluorescent lamp, is rendered electron emissive by ionic bombardment in the same manner as a cold cathode; this method of rendering a

cathode thermionically emissive to be more fully discussed below. The philosophy behind the development of the cold cathode is to provide a large quantity of electron emissive material, for example, 50 milligrams of alkaline earth material, within a container, it being understood that if more emissive material is available the life of the cathode will be greatly increased. These cathodes usually take the form of iron or nickel-plated iron cups which are filled with the aforementioned emissive material and they are termed cold cathodes because they, as well as the hybrid cathode discussed above, are not provided with a heating filament for direct cathode heating as are the hot cathodes. Rather, these cold cathodes, as is the case also with respect to the hybrid cathodes, are ignited, or driven into their thermionic emission mode, by the provision of a relatively high ignition voltage, approximately 500–550 volts in the case of the cold cathode and 400–450 volts in the case of the hybrid cathode, across the lamp electrodes. The ignition voltage ionizes the atmosphere in the fluorescent lamp, said atmosphere usually being a combination of an inert gas, such as argon, at a pressure of approximately 2.5 to 3 millimeters and mercury vapor at a pressure of approximately 9 microns. The ions thus provided impinge upon the cathode material with sufficient force to heat the cathode, thereby causing it to become electron emissive.

Although the cold cathode overcomes the basic problem existing with respect to both the hot and hybrid types of cathode, that is, a limited life span due to the limited quantity of emissive material available, nevertheless it has been found to be unsatisfactory in a number of other respects. Firstly, the ignition voltage of this type of cathode is, as above stated, approximately 500–550 volts as compared to the approximately 400–450 volts at which the hybrid cathode ignites and, thus, the cold cathode cannot be used as a substitute for the hybrid cathode in the existing fixtures designed for lamps utilizing hybrid cathodes since the circuitry associated with the lamps is not designed to provide voltage output levels sufficient to ignite such a cold cathode. Secondly, the glow to arc transition time of cold cathodes presently known in the art is approximately 1 to 2 seconds, this being the time required for the lamp to cross from its glow, or atmosphere utilization stage, to its arc, or conducting stage. During this glow to arc transition period the lamp is not yet conducting and a high field, known in the art as "cathode fall," exists in front of the cathode, causing high speed ions to impinge upon the emissive material and the aforementioned cup containing said emissive material. This is of course precisely the previously discussed process of ionic bombardment by which the cathode is heated to its thermionic emission mode. It is however desired that the glow to arc transition period be as brief as possible since during this period the high speed ions dislodge atoms from both the emissive material and the cup containing the material, this dislodging of atoms being termed "sputtering" in the fluorescent lamp art. Sputtering is undesirable since some of the dislodged atoms fall to the lamp envelope, causing a darkening of the envelope, termed "end-blackening," in the vicinity of the cathode. This end-blackening diminishes the light output from the lamp and further is cosmetically unesthetic. Additionally, sputtering has a deleterious effect on electrode life, since some of the atoms dislodged from the cup are deposited on the emissive material, thereby posioning the material and shortening the life of the electrode, thus defeating the very purpose for which the cold cathode was devised.

Thus it is seen that the presently known electron emissive cathodes utilized in fluorescent lamps are unsatisfactory in a number of respects. The hot and hybrid cathodes have a life span which is shorter than desirable while the cold cathode, which was designed to overcome this unsatisfactory feature of the hybrid cathode, is itself unsatisfactory in that higher ignition voltages are required for the cold cathode than for the hybrid cathode. Further, known cold cathodes have an extended glow to arc transition period during which undesirable sputtering occurs, this sputtering causing a shortening of electrode life and end-blackening of the lamp in which the electrode is utilized.

SUMMARY OF THE INVENTION

Therefore, the main object of this invention is to provide an improved electron emissive cold cathode having a relatively long life span.

It is a further object of this invention to provide such an emissive cathode of the cold cathode type which requires an ignition voltage comparable to that required by a hybrid cathode.

It is yet another object of this invention to provide such a cathode having a relatively short glow to arc transition period.

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

According to the present invention there is provided an electrode comprising a fused mixture of metal and an electron emissive material, said fused mixture having a bulk density gradient structure.

According to another aspect of this invention there is provided a method for making an electrode comprising the steps of forming a powder mixture comprising a metal and an electron emissive material, and firing said 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 mixture having a bulk density gradient structure is formed.

It is a feature of this invention that electrodes constructed according to the instant method are relatively air stable, that is, they 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 one hour after activation and they are thus suitable for batch activation processes.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates the apparatus utilized in constructing a first embodiment of the inventive electrode;

FIG. **2** illustrates said first embodiment of the inventive electrode;

FIG. **3** illustrates a mold utilized in constructing a second embodiment of the inventive electrode;

FIG. **4** is a detailed view of a cavity in the mold of FIG. **3** illustrating an intermediate step in the process of forming said second embodiment;

FIG. **5** illustrates a furnace utilized in the process of constructing said second embodiment; and

FIG. **6** illustrates said second embodiment of the inventive electrode.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The subject electrode, having a bulk density gradient structure, has been constructed in two distinct embodiments, one utilizing a cup for containing the emissive material and the other in pellet form having an electrode extending therefrom. Structure and methods of construction common to both will first be discussed and then the specific embodiments and their methods of construction will be described in greater detail.

In the construction of either embodiment a mixture of 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 provided below, a few grams of powdered tantalum, which is a refractory metal, approximately 99.8% pure, is mixed 67% by weight, with reagent grade barium peroxide powder, 33% 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 metal compositions, 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 lithuim, cesuim, 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 fused 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 fused electrode.

It is appropriate to note at this point that in forming the subject density gradient electrode it is necessary to control the rate of the 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 much of the material utilized in forming the electrode will splatter off, resulting in its being lost. If, on the other hand, the rate of reaction is too slow, the density gradient of the resultant 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. Further, if the rate of the exothermic reaction is too slow the resultant electrode will have a higher ignition voltage requirement than is otherwise obtainable since it will require more time to go through the glow to arc transition due to its more uniform surface and there will therefore not be as great an availability of protrusions from the electrode for starting the required arc.

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 have 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 cold 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 alkaline earth or alkali material 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 cold electrode. 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% by weight of a refractory metal powder and 33% by weight of an alkaline earth compound be used, it has been found through experimentation that ranges of mixtures of approximately 50% to 80% of metal powder by weight and approximately 20% to 50% 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, 1 hour.

Turning now to a description of the first embodiment of the inventive electrode, the mixed powder 1 illustrated in FIG. 1 is placed in an iron cup 2. In this example, the iron cup has a diameter of ¼'' and is approximately ¼'' in height. While the cup here is made of iron, other materials, such as nickel plated iron, tantalum, tungsten, and even molybdenum can be used in place thereof. Metal lead 3 has been attached to the center portion of the cup by, for example, spot welding and it may be of the same material as that used for the cup. In this example, approximately 150 to 250 milligrams of the mixed powder 1 is placed within the cup 2 and the material is now compressed, by, for example, a weighted steel plunger, with a pressure of 1,000–4,000 pounds per square inch. It is appropriate here to note that the pressure under which the material 1 is compressed is, while not critical, as evidenced by the fact that the suitable compression pressure may range between 1,000 and 4,000 pounds per square inch, important. As discussed above, the rate of exothermic reaction controls the density gradient of the completed electrode and it will be clear to those skilled in the art that the degree of compression to which the powder mixture is subjected will affect the rate of the aforementioned exothermic reaction. The cup is now placed on a suitable insulating support 4 which may be of any insulating material, such as a glass or ceramic, and which support is formed with a receptacle for lead 3. A cover 5 made of insulating material such as "transite" which is formed with a hole 6 for providing a vent path for the gaseous products of the exothermic reaction is placed over cup 2 and the cup and powder material 1 may now be heated to initiate the desired exo-

thermic 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 muffle furnace. It may also be provided by the structure illustrated, which includes an RF work coil **7** surrounding iron cup **2**, said coil **7** being connected to a source of electrical energy **8** by conductors **9**. To begin the exothermic reaction it is necessary to heat material **1** to a temperature of approximately 700° C to 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 cup. To provide the required heating, taking into account the impedance of the cup and the material which is to be heated, the source of electrical energy **8** here illustrated, is set to operate at a frequency of 450 kilohertz and to provide a current of approximately 165 milliamperes. Source **8** will remain energized until the exothermic reaction begins, said reaction being observable through hole **6** as a flash of light. Once the exothermic reaction begins source **8** can be de-energized since the exothermic reaction will continue until it self-extinguishes, the duration of the reaction being determined by the quantity of material **1** present within cup **2**. After the exothermic reaction has ended and the completed fused electrode has been cooled, it is available for standard processing and subsequent use in a fluorescent lamp.

Turning now to FIG. **2**, where there is illustrated the completed electrode **10**, it is seen that the electrode includes a fused mixture **11** having a top surface **12** which has a jagged, approximately concave contour. The configuration of surface **12** is due to both the partial venting of the gases caused by said exothermic reaction through hole **6** in cover **5** and to the back pressure from said gases in cup **2** due to the presence of cover **5** and the relatively small size, approximately 0.020 inches, of hole **6**, which prevents the complete venting of said gases. Fused mixture **11** has, as previously stated, a bulk density gradient structure, and by this is meant that, in the vincity of surface **12**, the mixture comprises particles which are 25 to 50 microns in magnitude and approximately 80% voids, while the interior of mixture **11**, the mixture becoming gradually more dense as the distance from surface **12** increases, comprises particles which have a magnitude in the order of tenths of microns and approximately 10% voids. Thus, the interior has a greater bulk density than the exterior surface.

The density gradient structure of the cathode makes it easier for electrons to travel through the cathode material to the surface thereof, thereby aiding in lowering the igntion voltage of the lamp in which it is utilized, said ignition voltage having been experimentally determined to be approximately 400–450 volts which is comparable to the ignition voltage of the hybrid cathode. The jagged protrusions extending from the surface of the electrode reduce the time duration of the glow to arc transition to less than one-half second, which is comparable to the glow to arc transition time required by hot and hybrid cathodes, thereby reducing sputtering. Additionally, it will be noted that a relatively large amount of alkaline earth material has been used in manufacturing the cathode and it will therefore have an extremely long life span relative to that of hot or hybrid cathodes.

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

Turning now to the second embodiment of the subject gradient density electrode, which is formed as a pellet without the use of the container utilized with the first embodiment discussed above, there is shown in FIG. **3** a mold **21** which may be advantageously utilized in the formation of said second embodiment. Mold **21** is formed with a cavity **22** therein, said cavity being one quarter of an inch in diameter and one quarter of an inch high and having a hole **23** extending from the bottom central portion thereof, said hole **23** having a diameter of 25 thousandths of an inch and extending downward from the bottom of cavity **22** for a distance of one quarter of an inch. Mold **21** may be made of any number of materials, for example, cast iron, machined steel, ceramic etc.

Referring now to FIG. **4**, which is a detailed view of that portion of mold **21** containing cavity **22** and hole **23**, there is illustrated a conducting metal electrode lead **24** which is positioned in hole **23**. Metal lead **24** has, in this example a diameter of twenty thousandths of an inch and a length of three-eighths of an inch, and it extends one-eighth of an inch into cavity **22**. The metal lead in this example is made of nickel wire although other suitable conducting materials may be used, for example, tungsten, tantalum and alloys thereof, and iron and nickel alloys.

As discussed above, with regard to embodiment **1**, a mixture of refractory metal powder or transitional metal powder and a source of electron emissive material are provided, the mixture being prepared in the same manner as previously discussed. In this example too, as was the case with respect to embodiment **1**, the mixture consists of 67% by weight of tantalum powder and 33% by weight of barium peroxide powder. Of course, as discussed above with regard to embodiment **1**, it is understood that various refractory or transitional metal powders and various alkali or alkaline earth materials may be utilized rather than the tantalum and barium peroxide of the example.

Cavity **22** is now filled with the aforementioned mixture of tantalum and barium peroxide, here indicated at **25**, and it is compressed with a pressure of 1,000 to 4,000 pounds per square inch in the same manner as was discussed with regard to embodiment **1**. Here a suitable piston **26** is illustrated as providing the aforementioned pressure, and it compresses powder mixture **25** to a volume approximately one half its original size, thus providing a pellet of compressed tantalum powder and barium peroxide powder one-eighth of an inch in diameter and approximately one-eighth of an inch in height, said pellet having a metal lead **24** extending therefrom.

Turning now to FIG. **5**, there is illustrated the compressed pellet here indicated at **27**, with lead **24** extending therefrom. The pellet is positioned within cavity **28**, which is one quarter inch in diameter and one quarter inch in height, of reaction chamber **29**, said reaction chamber being made of a conducting material to which the resultant fused cathode will not adhere, the chamber in this example being made of graphite. A solid cover **30** of the same material as chamber **29**, here graphite, is placed over cavity **28**, sealing it. An RF coil **31**, connected by leads **32** to an RF generator **33** sur-

rounds chamber 29 to provide the heat energy necessary to begin the desired exothermic reaction, in much the same manner as that illustrated in FIG. 1 with regard to embodiment 1 discussed above. Here too, as discussed with regard to embodiment 1, generator 33 is selected to provide sufficient energy to heat pellet 27 to a temperature between 700° C and 1,000° C, which is above the melting temperature of the barium peroxide material and which is the temperature at which the desired exothermic reaction commences. Further, as discussed previously with regard to FIG. 1, generator 33 operates at 450 kilohertz and the current through coil 31 is approximately 165 milliamperes.

After pellet 27 is heated to a temperature sufficient to initiate the desired exothermic reaction, said initiation being observable as a flash of light if a viewing window is provided in cover 30, generator 33 can be disconnected from the RF coil as was the case with regard to embodiment 1, and the exothermic reaction will continue until it self-extinguishes, the limiting factor in the duration of said reaction being the quantity of pellet material present. After the exothermic reaction has ended and the completed fused electrode has been cooled, it is available for standard processing and subsequent use in a fluorescent lamp.

Referring now to FIG. 6, there is illustrated a completed pellet type cold cathode having a bulk density gradient structure. Cathode 34 has an ellipsoidal configuration and is formed with a plurality of protrusions extending from the surface 35 thereof. A void 36 exists in the interior 37 of cathode 34 at the upper surface of lead 24 due to the outward explosion of the pellet material caused by the exothermic reaction. Cathode 34 has, as previously stated, a bulk density gradient structure, by which is meant, as previously discussed with regard to cathode 10, a structure comprising 80% voids and particle sizes of 25 to 50 microns at surface 35, and 10% voids and particle sizes in the range of tenths of microns in the region of interior 37. The structure of cathode 34 and its configuration are due to the shape of pellet 27, its size relative to that of cavity 28, the fact that no vent path was provided for the gases expunged from pellet 27 due to the exothermic reaction and, of course, the outwardly directed force provided by said reaction.

Cathode 34, as was the case with regard to cathode 10, discussed above, has a density gradient structure which makes it easier for electrons to travel through the cathode material to the surface thereof, thereby aiding in lowering the ignition voltage of the lamp in which the cathode is utilized, said ignition voltage having been experimentally determined to be approximately 400 to 450 volts which is comparable to the ignition voltage of the hybrid cathode. The jagged protrusions extending from the surface of the cathode function to reduce the time duration of the glow to arc transition to less than ½second, which is comparable to the glow to arc transition time required by hot and hybrid cathodes, thereby reducing the quantity of cathode material sputtered. Additionally, it will be noted that, as in the case of cathode 10, a relatively large amount of emissive material, here alkaline earth material, has been used in manufacturing cathode 34 and it will therefore have an extremely long life span relative to that of hot or hybrid cathodes.

It will thus be seen that there has been provided a second embodiment of a cold cathode suitable for use in fluorescent lamps which is superior to those cold or hybrid cathodes presently known in the art.

It has been found advantageous to utilize the embodiment of the invention exemplified by cathode 34 rather than that defined by cathode 10 in many fluorescent lamp applications because the former is subject to less sputtering than the latter, notwithstanding the fact that cathode 10 is itself subject to less sputtering than cold cathodes of the type presently known in the art. This is due to the fact that the emissive material of cathode 10 is maintained within a container which is not the case with regard to cathode 34, and thus no container atoms can be sputtered off cathode 34 during its glow to arc transition period. This results in the advantage that less end-blackening will occur in lamps utilizing cathode 34 than in lamps utilizing cathode 10 and, further, the lifetime of cathode 34 will be longer than that of cathode 10 since the emissive material of the former will not be poisoned by the deposition of container atoms thereon. On the other hand, it has been found preferable to use the embodiment defined by cathode 10 in applications where the lamp in which the cathode is to be utilized is subject to a great deal of vibration since the container structure of cathode 10 is structurally more sound than the structure of cathode 34.

It is here appropriate to note that both cathode structures disclosed have been discovered to be relatively air stable subsequent to their activation, that is, they will remain activated for a period of at least one 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 cathodes here described, while being greatly improved over the cathodes known in the prior art, for the reasons previously discussed, additionally are suitable for batch processing, thus providing an additional valuable advantage.

While the principles of the invention have been described in connection with specific structures, 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.

What is claimed:

1. An electrode comprising a fused mixture of metal and an electron emissive material, said fused mixture having a bulk density gradient structure wherein an interior portion has a greater bulk density than an exposed exterior surface.

2. An electrode, according to claim 1, wherein said metal is a refractory metal.

3. An electrode, according to claim 2, wherein said refractory metal is selected from a group consisting of tungsten, tantalum, molybdenum, thorium, titanium, zirconium and mixtures thereof.

4. An electrode, according to claim 1, wherein said electron emissive material is an alkaline earth material.

5. An electrode, according to claim 4, wherein said alkaline earth material is selected from a group consisting of oxides, peroxides and nitrates of barium and oxides, peroxides and nitrates of barium in combination with calcium oxide, strontium oxide and zirconium dioxide.

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

7. An electrode, according to claim 6, wherein said alkali material is selected from a group consisting of compounds of lithuim, cesium, potassium and sodium.

8. An electrode, according to claim 1, wherein said metal is a transition element metal.

9. An electrode, according to claim 8, wherein said transition element metal is selected from a group consisting of nickel and iron.

10. An electrode according to claim 1, wherein said fused mixture results from an exothermic reaction in a powder mixture comprising a powder of said metal and a powder of said electron emissive material.

11. An electrode, according to claim 10, wherein said metal powder comprises tantalum powder and said electron emissive material comprises barium peroxide powder,

said tantalum powder being between 60% and 70% by weight of said powder mixture and said barium peroxide powder being between 30% and 40% by weight of said powder mixture.

12. An electrode, according to claim 1, further comprising:

a conducting cup-shaped container retaining said fused mixture, one surface of said fused mixture being exposed; and

a conducting lead connected to said container.

13. An electrode, according to claim 12, wherein the exposed surface of said fused mixture has a low bulk density in relation to the remainder of said fused mixture and said exposed surface has a plurality of protrusions extending therefrom.

14. An electrode, according to claim 1, further comprising a conducting lead connected to and supporting said fused mixture.

15. An electrode, according to claim 14, wherein the exterior of said fused mixture has a low bulk density relative to the interior thereof and where the surface of said fused mixture has a plurality of protrusions extending therefrom.

16. An electrode as described in claim 1, wherein the fused mixture comprises particles on the exterior surface which are 25–50 microns in size and particles at the interior having a size of less than 1 micron.

17. An electrode as described in claim 1, wherein the exposed exterior surface has at least 70% voids and the interior portion comprises less than 20% voids.

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